Scilab Textbook Companion for Fluid Systems (fluid Machines) by Shiv Kumar[1]

Created by
Parmanand Mishra
B.Tech.
Mechanical Engineering
Maharaja Agrasen Institute of Technology
College Teacher
None
Cross-Checked by
None

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Book Description

Title: Fluid Systems (fluid Machines)

Author: Shiv Kumar

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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Chapter 2

Impact of Jet

Scilab code Exa 2.1 To Find the Force exerted by the Jet of water

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.1
    clc
    clear

//Given Data:-
       V=32;      //Velocity of the Jet, m/s
       d=5;       //Diameter of the Jet, cm

//Data Used:-
    rho=1000;      //Density of water, kg/m^3

//Computations:-
      d=d/100;       //cm
      a=(%pi/4)*d^2;       //cross-sectional area of Jet, m^2
      m=rho*a*V;          //Mass Flow Rate, kg/s
      F=m*V/1000;         //Force Exerted by the Jet on the flat plate, kN
//Result:-
```

```
printf("The Force exerted by the Jet on the plate=%.3f kN \n", F)      //The answer vary due to round off error
```

Scilab code Exa 2.2 To Determine a The Maximum force of the Jet on the plate b Com

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.2
     clc
    clear

//Given Data:-
        V=25;     //Velocity of the Jet, m/s
        theta=45;     //Inclination of the plate with Jet axis, degrees
        a=30;     //cross-sectional area of the Jet, cm^2

//Data Used:-
    rho=1000;     //Density of water, kg/m^3

//Computations:-
       a=a*10^-4;     //m^2
       //(a) Force normal to the plate is the maximum force of Jet on the plate Fn
       Fn=rho*a*V^2*sind(theta);     //N
       //(b) Components of the force Fn,
             Fx=Fn*sind(theta);      //N
             Fy=Fn*cosd(theta);      //N
       //(c) Ratio in which the discharge gets divided
          Q1_by_Q2=(1+cosd(theta))/(1-cosd(theta));
//Results:-
    printf("(a)The Maximum force of the Jet on the
```

```
plate, Fn=%.2f N \n", Fn)          //The answer vary due to round off error
printf("(b)Components of the Normal force, Fn are: \n\t")
printf("Fx=%.2f N    ,   Fy=%.2f N  \n", Fx, Fy)              //The answer vary due to round off error
printf("(C)The Ratio in which discharge gets divided, Q1/Q2=%.2f \n", Q1_by_Q2)          //The answer vary due to round off error
```

Scilab code Exa 2.3 `To Find the force exerted by the Jet of water in the direction`

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.3
     clc
    clear
//Given Data:-
        d=40;      //Diameter of the Jet, mm
        V=60;      //Velocity of the Jet, m/s
        AoD=125;      //Angle of Deflection, degrees

//Data Used:-
    rho=1000;      //Density of water, kg/m^3

//Computations:-
        d=d/1000;        //m
        a=(%pi/4)*d^2;       //cross-sectional area of Jet, m^2
        theta=180-AoD;       //degrees
        Fx=rho*a*V^2*(1+cosd(theta));      //N
//Results:-
    printf("The Force exerted by the Jet of water in the direction of Jet, Fx=%.2f N  \n",Fx)
```

```
        //The answer provided in the textbook
    is wrong.
```

Scilab code Exa 2.4 To Find the force exerted by the Jet on the plate in the Horiz

```

//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.4
     clc
    clear

//Given Data:-
        d=65;      //Diameter of the Jet, mm
        V=45;      //Velocity of the Jet, m/s
        theta_i=35;     //Entry angle with
           horizontal, degrees
        theta_o=25;     //Exit angle with horizontal
           , degrees

//Data Used:-
    rho=1000;      //Density of water, kg/m^3

//Computations:-
        d=d/1000;       //m
        a=(%pi/4)*d^2;       //cross-sectional area
           of Jet, m^2
        Fx=rho*a*V^2*(cosd(theta_i)+cosd(theta_o));
                //N
        Fy=rho*a*V^2*(sind(theta_i)-sind(theta_o));
                //N
//Results:-
    printf("Force exerted by Jet in horizontal
        direction, Fx=%.2f N \n", Fx)       //The
        answer provided in the textbook is wrong
```

```
    printf("Force exerted by Jet in vertial
       direction , Fy=%.3f N(Fy acts upward) or Fy=-
      %.3f N(Fy acts downward)  \n", Fy, Fy)
       //The answer vary due to round off error
```

Scilab code Exa 2.5 To Find the Angle through which the plate will swing

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.5
     clc
    clear

//Given Data:-
        d=30;     //Diameter of the Jet, mm
        V=15;     //Velocity of the Jet, m/s
        W=245.25;     //Weight of plate, N

//Data Used:-
    rho=1000;     //Density of water, kg/m^3

//Computations:-
        d=d/1000;       //m
        a=(%pi/4)*d^2;      //cross-sectional area
           of Jet, m^2
        theta=asind(rho*a*V^2/W);      //degrees
//Results:-
    printf("The Angle through which the plate will
       swing, theta=%.2f degrees \n", theta)
       //The answer vary due to round off error
```

Scilab code Exa 2.6 To a Find the force applied at lower edge of plate to keep it

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.6
     clc
    clear
//Given Data:-
       M=13.5;      //Mass of plate, kg
       d=16;       //Diameter of the Jet, mm
       V=20;       //Velocity of the Jet, m/s
       L=300;      //Length of Edge of plate, mm

//Data Used:-
    rho=1000;      //Density of water, kg/m^3
    g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
       d=d/1000;          //m
       L=L/1000;         //m
       W=M*g;            //Weight of Plate, N
       a=(%pi/4)*d^2;   //cross sectional area of Jet, m^2
   //(a)
       Fx=rho*a*V^2;    //Force exerted by Jet normal to plate, N
   //Taking Moment at 'A',
       P=Fx*(L/2)/L;       //N
   //(b)
       theta=asind(rho*a*V^2/W);       //Angle of Swing, degrees
//Results:-
    printf("(a)Horizontal force applied at Lower edge of plate to keep it vertical, P=%.3f N\n", P)        //The answer vary due to round off error
    printf("(b)Angle of swing, theta=%.2f degrees", theta)       //The answer vary due to round off error
```

Scilab code Exa 2.7 To a Find the horizontal force applied at centre of gravity to

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.7

     clc
     clear

//Given Data:-
        W=55.50;    //Weight of plate, N
        V=8;      //Velocity of the Jet, m/s
        d=22;      //Diameter of the Jet, mm
        AG=125;      //Distance between centre of
           gravity of plate from hinge, mm
        AC=150;      //Distance between axis of Jet
           and hinge, mm
        theta=35;     //Deflection, degrees

//Data Used:-
     rho=1000;      //Density of water, kg/m^3

//Computations:-
        d=d/1000;        //m
        AC=AC/1000;      //m
        AG=AG/1000;       //m
        a=(%pi/4)*d^2;   //cross sectional area of
           Jet, m^2
        Fx=rho*a*V^2;     //N
    //Taking moment about hinge point 'A',
        P=Fx*AC/AG;      //N
        Fn=(W*AG*sind(theta)+P*AG*cosd(theta))/(AC/
           cosd(theta));    //N
        V1=sqrt(Fn/(rho*a*cosd(theta)));      //
```

```
Absolute Velocity of Jet, m/s
    velocity_increase=V1-V;      //Velocity Increase of the Jet, m/s

//Results:-
    printf("(a)Horizontal force applied at centre of gravity to maintain the plate in vertical position, P=%.3f N \n", P)      //The answer vary due to round off error
    printf("(b)Increase in velocity of Jet=%.3f m/s ", velocity_increase)      //The answer vary due to round off error
```

Scilab code Exa 2.8 To Find a the Force exerted by the Jet on the plate b Work don

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.8
     clc
    clear

//Given Data:-
        d=75;     //Diameter of the Jet, mm
        V=14;     //Velocity of the Jet, m/s
        u=5;     //Velocity of plate, m/s

//Data Used:-
    rho=1000;     //Density of water, kg/m^3

//Computations:-
        d=d/1000;       //m
        a=(%pi/4)*d^2;  //cross sectional area of Jet, m^2
        F=rho*a*(V-u)^2;    //N
        W=F*u;           //J/s
```

```
        KE=(1/2)*rho*a*V^3;      //N-m/s
        eta=W/KE*100;       //In percentage

//Results:-
     printf("(a)The Force exerted by the Jet on the plate, F=%.2f N  \n", F)       //The answer vary due to round off error
     printf("(b)Work done by the Jet on the plate per second=%.1f N-m/s or J/s  \n", W)      //The answer vary due to round off error
     printf("(c)Efficiency of Jet, eta=%.2f percent", eta)      //The answer vary due to round off error
```

Scilab code Exa 2.9 To Find a Force exerted on the plate in the direction of Jet b

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.9
      clc
     clear

//Given Data:-
        d=65;       //Diameter of the Jet, mm
        V=20;       //Velocity of the Jet, m/s
        u=8;        //Velocity of curved vane, m/s
        AoD=160;      //Angle of Deflection, degrees

//Data Used:-
     rho=1000;      //Density of water, kg/m^3

//Computations:-
        d=d/1000;         //m
        a=(%pi/4)*d^2;       //cross-sectional area of Jet, m^2
```

```
        theta=180-AoD;      //degrees
        Fx=rho*a*(V-u)^2*(1+cosd(theta));      //N
        P=Fx*u/1000;        //Power of Jet, KW
        KE=(1/2)*rho*a*V^3;      //Kinetic energy of
           Jet per second, N-m/s(W)
        eta=P*1000/KE*100;      //In percentage

//Results:-
     printf("(a)The Force exerted on plate in
        direction of Jet, Fx=%.2f N \n", Fx)
        //The answer vary due to round off error
     printf("(b)Power of Jet=%.3f KW \n", P)
        //The answer vary due to round off error
     printf("(c)Efficiency of Jet, eta=%.2f percent"
        , eta)
```

Scilab code Exa 2.10 To Calculate the magnitude and direction of the Resultant For

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.10
      clc
     clear
//Given Data:-
        V1=40;      //Velocity of the Jet at Inlet, m
           /s
        V2=32;      //Velocity of the Jet at Outlet,
           m/s
        theta=65;     //Angle of Deflection from
           original direction, degrees
        m=0.9;         //Mass flow rate, kg/s

//Computations:-
        Fx=m*(V1-V2*cosd(theta));       //N    (
           Answer in textbook is wrong)
```

```
        Fy=m*V2*sind(theta);      //N
        F_R=sqrt(Fx^2+Fy^2);      //Resultant Force, N
        phi=atand(Fy/Fx);      //Angle made by resultant with X-axis, degrees

//Results:-
    printf("Resultant Force, F_R=%.2f N at an angle, phi=%.2f Degrees to X-axis", F_R, phi)        //The answer provided in the textbook is wrong
```

Scilab code Exa 2.11 a `To Determine the components of force acting on Vane in dire`

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.11
     clc
    clear
//Given Data:-
  //(a)
        V=60;     //Velocity of the Jet, m/s
        theta=30;     //Angle of Outlet, degrees
  //(b)
        u=25;      //Velocity of vane, m/s


//Data Used:-
    g=9.81;     //Acceleration due to gravity, m/s^2

//Computations:-
  //(a)
        Fx=(V/g)*(1+cosd(theta));       //Force exerted by Unit weight of water in
```

```
direction of Jet, N/N of Water
Fy=V*sind(theta)/g;  //Force exerted by Unit weight of water in direction perpendicular to direction of Jet, N/N of Water
F_R=sqrt(Fx^2+Fy^2);    //Resultant for per unit weight of water, N/N of Water
phi=atand(Fy/Fx);            //Angle made by resultant with X-axis, degrees

//Results(a):-
printf("(a)\nForce exerted by Unit weight of water in direction of Jet, Fx=%.2f N/N of Water  \n", Fx)
printf("Force exerted by Unit weight of water in direction perpendicular to direction of Jet, Fy=%.2f N/N of water  \n", Fy)      //The answer vary due to round off error
printf("Resulatant Force, F_R=%.2f N/N of Water at angle, phi=%.2f degrees \n\n", F_R, phi)    //The answer vary due to round off error
//(b)
Fx=(V-u)*(1+cosd(theta))/g;       //Force exerted by Unit weight of water in direction of Jet, N/N of Water
Fy=(V-u)*sind(theta)/g;       //Force exerted by Unit weight of water in direction perpendicular to direction of Jet, N/N of Water
F_R=sqrt(Fx^2+Fy^2);          //Resultant force per unit weight of water, N/N of Water
phi=atand(Fy/Fx);             //Angle made by resultant with X-axis, degrees
W=Fx*u;              //N-m/s/N of Water
P=Fx*u/1000;         //Power developed per unit weight of water, KW/N of Water
```

```
//Result(b)
    printf("(b)\nForce exerted by Unit weight of water in direction of Jet, Fx=%.2f N/N of Water \n", Fx)      //The answer vary due to round off error
    printf("Force exerted by Unit weight of water in direction perpendicular to direction of Jet, Fy=%.2f N/N of water \n", Fy)
    printf("Resulatant Force, F_R=%.2f N/N of Water at angle, phi=%.2f degrees \n\n", F_R, phi)      //The answer vary due to round off error
    printf("Work done per unit weight of water=%.2f N-m/s/N of Water \n", W)      //The answer vary due to round off error
    printf("Power developed per unit weight of water=%.4f KW/N of Water", P)      //The answer vary due to round off error
```

Scilab code Exa 2.12 To Find a Vane angles b Work done per second per unit weight

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.12
     clc
    clear
//Given Data:-
        Vi=22;      //Absolute velocity of Jet at Inlet of Vane, m/s
        u=11;      //Velocity of Vane, m/s
        ui=u;
        uo=u;
        alpha_i=25;       //Angle made by Jet at Inlet, degrees
        alpha_1=135;      //Angle made by Jet at
```

```
            leaving , degrees
        alpha_o=180-alpha_1;        //degrees

//Data Used:-
    g=9.81;        //Acceleration due to gravity, m/
        s^2

//Computations:-
    //(a)
        Vwi=Vi*cosd(alpha_i);       //m/s
        Vfi=Vi*sind(alpha_i);        //m/s
        Vrwi=Vwi-ui;        //m/s
        beta_i=atand(Vfi/Vrwi);          //degrees
        Vri=Vfi/sind(beta_i);           //m/s
        Vro=Vri;
        beta_o=alpha_o-asind(uo*sind(180-alpha_o)/
            Vro);        //degrees
        Vwo=Vro*cosd(beta_o)-uo;          //degrees
    //(b)
        W=(Vwi+Vwo)*u/g;        //N-m/N

//Results:-
    printf("(a)Vane angle at Inlet, beta_i=%.2f
        degrees \n", beta_i)      //The answer vary
         due to round off error
    printf("    Vane angle at Outlet, beta_o=%.2f
        degrees \n", beta_o)      //The answer vary
         due to round off error
    printf("(b)Work done per second per unit weight
         of water striking the vane per second=%.2f
        N-m/N", W)       //The answer vary due to
        round off error
```

Scilab code Exa 2.13 `To Find the maximum value of work done and Efficiency`

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.13
    clc
    clear

//Given Data:-
        d=25;       //Diameter of the Jet, mm
        V=27;      //Velocity of the Jet, m/s
        AoD=140;        //Angle of Deflection, degrees

//Data Used:-
    rho=1000;      //Density of water, kg/m^3

//Computations:-
        d=d/1000;       //m
        a=(%pi/4)*d^2;       //cross-sectional area of Jet, m^2
        m=rho*a*V;          //Mass Flow Rate, kg/s
    //For condition of Maximum work done,
        u=V/3;         //Velocity of Vane, m/s
        theta=180-AoD;          //degrees
    //(a)Maximum work done/second
        W=rho*a*(V-u)^2*(1+cosd(theta))*u/1000;         //kJ/s
    //(b)Efficiency of the Jet,
        KE=(1/2)*rho*a*V^3;         //kinetic energy supplied by jet per second, J
        eta=W*1000/KE*100;          //In percentage

//Result:-
    printf("(a)Maximum work done/sec=%.3f kJ/s \n", W)       //The answer vary due to round off error
    printf("(b)Effeciency of the Jet, eta=%.2f percent \n", eta)       //The answer vary due to round off error
```

Scilab code Exa 2.14 To Determine the Vane Angle at Inlet and Outlet

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.14
      clc
     clear
//Given Data:-
        Vi=50;      //Absolute velocity of Jet at
           inlet , m/s
        u=25;        //velocity of vane , m/s
        ui=u;
        uo=u;
        alpha_i=32;      //Angle made by Vi at
           inlet , degrees
        alpha_l=90;      //Angle made by Vi at
           outlet , degrees
        alpha_o=180-alpha_l;     //degrees

//Computations:-
       Vfi=Vi*sind(alpha_i);     //m/s
       Vwi=Vi*cosd(alpha_i);    //m/s
       Vwi=Vwi-ui;       //m/s
       beta_i=atand(Vfi/Vwi);          //degrees
       Vri=Vfi/sind(beta_i);     //m/s
       Vro=Vri;
       beta_o=acosd(uo/Vro);      //degrees

//Result:-
     printf("Vane Angle at Inlet , beta_i=%.2f
        degrees \n", beta_i)
     printf("Vane angle at outlet , beta_o=%.2f
        degrees \n", beta_o)      //The answer vary
        due to round off error
```

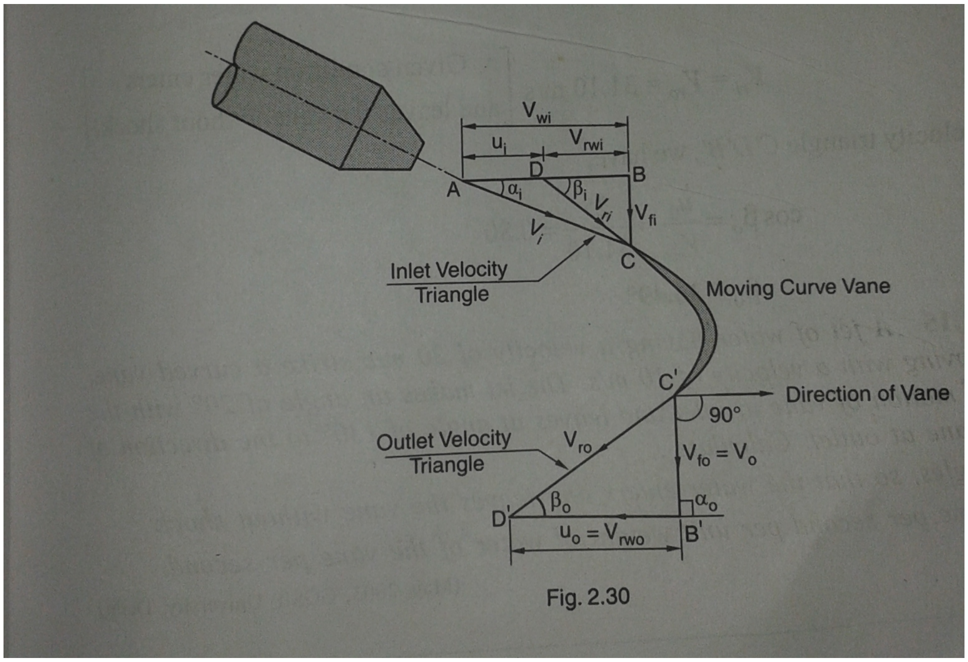

Figure 2.1: To Determine the Vane Angle at Inlet and Outlet

Scilab code Exa 2.15 To Find a Vane angles b Work done per second per unit weight

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.15
      clc
     clear

//Given Data:-
        Vi=20;      //Absolute velocity of Jet at
           Inlet of Vane, m/s
        u=10;      //Velocity of Vane, m/s
```

```
        ui=u;
        uo=u;
        alpha_i=20;      //Angle made by Jet at Inlet, degrees
        alpha_l=130;     //Angle made by Jet at leaving, degrees
        alpha_o=180-alpha_l;         //degrees

//Data Used:-
      g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
   //(a)
        Vwi=Vi*cosd(alpha_i);        //m/s
        Vfi=Vi*sind(alpha_i);         //m/s
        Vrwi=Vwi-ui;         //m/s
        beta_i=atand(Vfi/Vrwi);           //degrees
        Vri=Vfi/sind(beta_i);            //m/s
        Vro=Vri;
        beta_o=alpha_o-asind(uo*sind(180-alpha_o)/Vro);         //degrees
        Vwo=Vro*cosd(beta_o)-uo;          //degrees
   //(b)
        W=(Vwi+Vwo)*u/g;        //N-m/N

//Results:-
     printf("(a)Vane angle at Inlet, beta_i=%.2f degrees  \n", beta_i)
     printf("    Vane angle at Outlet, beta_o=%.2f degrees  \n\n", beta_o)       //The answer vary due to round off error
     printf("(b)Work done per second per unit weight of water striking the vane per second=%.2f N-m/N", W)       //The answer vary due to round off error
```

Scilab code Exa 2.16 a To Find the angles of Jet at Inlet and outlet of vane b To

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.16
     clc
    clear

//Given Data:-
        Vi=18;     //velocity of Jet at Inlet of, m/s
        u=6;     //Velocity of Vane, m/s
        ui=u;
        uo=u;
        AoD=110;       //Angle of deflection of the Jet, degrees

//Data Used:-
    g=9.81;     //Acceleration due to gravity, m/s^2

//Computations:-
    beta_i=(180-AoD)/2;
    beta_o=beta_i;

  //(a)
        alpha_i=beta_i-asind(ui*sind(180-beta_i)/Vi);       //degrees
        Vwi=Vi*cosd(alpha_i);       //m/s
        Vfi=Vi*sind(alpha_i);        //m/s
        Vri=Vfi/sind(beta_i);           //m/s
        Vro=Vri;
        Vfo=Vro*sind(beta_o);       //m/s
        Vrwo=Vro*cosd(beta_o);       //m/s
```

```
        Vwo=Vrwo-uo;            //m/s
        alpha_o=atand(Vfo/Vwo);          //degrees
    //(b)
        alpha_o_dash=180-alpha_o;        //degrees
    //(c)
        W=(Vwi+Vwo)*u/g;          //N-m/N
//Results:-
     printf("(a)Angle of Jet at Inlet of Vane, alpha_i=%.2f Degrees  \n", alpha_i)       //The answer vary due to round off error
     printf("    Angle at Outlet of Vane, alpha_o=%.2f Degrees  \n", alpha_o)       //The answer vary due to round off error
     printf("(b)Angle made by leaving Jet to the direction of motion of Vane, alpha_o_dash=%.2f Degrees  \n", alpha_o_dash)       //The answer vary due to round off error
     printf("(c)Work done per second per unit weight of water striking the vane per second=%.2f N-m/N", W)       //The answer vary due to round off error
```

Scilab code Exa 2.17 To Find a The force exerted by the Jet on the vane in the dir

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.17
      clc
     clear
//Given Data:-
        d=60;      //Diameter of Jet, mm
        Vi=22;        //Absolute Velocity of Jet at Inlet, m/s
        u=11;         //Velocity of vane, m/s
        ui=u;
```

```
        uo=u;
        alpha_i=0;    //degrees
        alpha_l=65;   //degrees
        alpha_o=180-alpha_l;      //degrees

//Data Used:-
     rho=1000;      //Density of water, kg/m^3

//Computations:-

       d=d/1000;       //m
       a=(%pi/4)*d^2;       //cross-sectional area of
           Jet, m^2
       Vwi=Vi;       //m/s
       Vri=Vi-ui;     //m/s
       Vro=Vri;
       beta_o=alpha_o-asind(uo*sind(alpha_l)/Vro);
                //degrees
       Vwo=uo-Vro*cosd(beta_o);      //m/s
   //(a)The Force exerted by Jet on Vane in
      direction of motion, Fx
       Fx=rho*a*Vri*(Vwi-Vwo);      //N
   //(b)Power developed by vane,
       P=Fx*u/1000;          //kW
   //(c)Efficiency of Vane,
       eta=2*Fx*u/(rho*a*Vi^3)*100;         //in
          Percentage

//Results:-
     printf("(a)The Force exerted by Jet on Vane in
        direction of motion, Fx=%.2f  N  \n", Fx)
            //The answer vary due to round off
        error
     printf("(b)Power developed by vane=%.3f kW  \n"
        , P)       //The answer vary due to round off
         error
     printf("(c)Efficiency of vane, eta=%.2f percent
          \n", eta)       //The answer vary due to
```

```
round off error
```

Scilab code Exa 2.18 To Determine i The angle of Jet at Inlet of Vane ii The absol

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.18
      clc
     clear

//Given Data:-
        Vi=18;       //velocity of Jet at Inlet of, m/
           s
        u=6;      //Velocity of Vane, m/s
        ui=u;
        uo=u;
        AoD=120;         //Angle of deflection of the
           Jet, degrees

//Data Used:-
     g=9.81;           //Acceleration due to gravity,
         m/s^2

//Computations:-
        beta_i=(180-AoD)/2;          //degrees
        beta_o=beta_i;
   //(i)
        alpha_i=beta_i-asind(ui*sind(180-beta_i)/Vi)
           ;          //degrees
   //(ii)
        Vrwi=Vi*cosd(alpha_i)-ui;        //m/s
        Vfi=Vi*sind(alpha_i);        //m/s
        Vri=Vfi/sind(beta_i);            //m/s
        Vro=Vri;
        Vfo=Vro*sind(beta_o);        //m/s
```

```
        Vwo=Vro*cosd(beta_o)-uo;        //m/s
        alpha_o=atand(Vfo/Vwo);         //degrees
        Vo=Vfo/sind(alpha_o);       //m/s
    //(iii)
        W=(Vi*cosd(alpha_i)+Vwo)*u/g;          //N-m/N
//Results(a):-
    printf("(i)Angle of Jet at Inlet, alpha_i=%.2f Degrees \n", alpha_i)
    printf("(ii)Absolute velocity of Jet at Outlet, Vo=%.2f m/s with angle alpha_o=%.2f Degrees \n", Vo,alpha_o)       //The answer vary due to round off error
    printf("(iii)Work done per N of Water=%.2f N-m/N", W)       //The answer vary due to round off error
```

Scilab code Exa 2.19 To Find a Force exerted by the Jet on the plate in the direct

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.19
     clc
    clear

//Given Data:-
        d=40;       //Diameter of the Jet, mm
        V=24;       //Velocity of the Jet, m/s

//Data Used:-
    rho=1000;       //Density of water, kg/m^3

//Computations:-
        d=d/1000;          //m
        a=(%pi/4)*d^2;         //cross-sectional area of Jet, m^2
```

```
    //CaseI - Jet strikes normal to a fixed plate
      //(a)
         Fx=rho*a*V^2;        //N
      //(b)Work done, W
         W=0;      //As there is no motion of flat plate
      //(c)
         eta=0;          //Hydraulic efficiency is zero

//Result I:-
     printf("Case I:  \n\t")
     printf("(a)Force exerted by Jet on the Plate in direction of Jet, Fx=%.2f N  \n\t", Fx)     //The answer vary due to round off error
     printf("(b)Work done by Jet per second=%.2f N \n\t", W)       //The answer vary due to round off error
     printf("(c)Hydraulic efficiency of the Jet, eta_H=%.2f percent \n\n", eta)       //The answer vary due to round off error
  //Case II - Jet strikes the moving plate
          u=10;          //Velocity of moving flat plate, m/s
    //(a)
          Fx=rho*a*(V-u)^2;          //N
    //(b)
          W=Fx*u;        //N-m/s
    //(c)
          eta=2*W/(rho*a*V^3)*100;         //In percentage
  //Result II
     printf("Case II: \n\t")
     printf("(a)Force exerted by Jet on the Plate in direction of Jet, Fx=%.2f N  \n\t", Fx)     //The answer vary due to round off error
```

```
    printf("(b)Work done by Jet per second=%.2f N \n\t", W)      //The answer vary due to round off error
    printf("(c)Hydraulic efficiency of the Jet, eta_H=%.2f percent \n\n", eta)      //The answer vary due to round off error
  //Case III - Jet strikes a series of flat moving plate
      u=10;          //velocity of flat plate, m/s
    //(a)
      Fx=rho*a*V*(V-u);           //N
    //((b)
      W=Fx*u;            //N-m/s
    //(c)
      eta=W*2/(rho*a*V^3)*100;         //In percentage
  //Result III

    printf("Case III: \n\t")
    printf("(a)Force exerted by Jet on the Plate in direction of Jet, Fx=%.3f N  \n\t", Fx)       //The answer vary due to round off error
    printf("(b)Work done by Jet per second=%.2f N \n\t", W)      //The answer vary due to round off error
    printf("(c)Hydraulic efficiency of the Jet, eta_H=%.2f percent \n\n", eta)      //The answer vary due to round off error
```

Scilab code Exa 2.20 To Find a Force exerted on a series of curved plate in direct

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
```

```
//Example 2.20
  clc
 clear

//Given Data:-
    d=40;      //Diameter of the Jet, mm
    V=35;      //Absolute Velocity of the Jet, m/s
    u=18;       //Velocity of the curved plate, m/s
    AoD=165;            //Angle of deflection of the Jet, degrees

//Data Used:-
 rho=1000;       //Density of water, kg/m^3


//Computations:-
    d=d/1000;        //m
    a=(%pi/4)*d^2;       //cross-sectional area of Jet, m^2
    theta=180-AoD;       //degrees
  //(a)
    Fx=rho*a*V*(V-u)*(1+cosd(theta));       //N
  //(b)Work done by Jet per second, W
     W=Fx*u;             //N-m/s
  //(c)
     eta=W*2/(rho*a*V^3)*100;         //In percentage

//Results:-
 printf("(a)Force exerted on the series of curved plates in direction of Jet, Fx=%.2f N \n", Fx)     //The answer vary due to round off error
 printf("(b)Work done by Jet per second=%.2f N-m/s \n", W)      //The answer vary due to round off error
```

```
      printf("(c)Efficiency of the Jet, eta=%.2f percent", eta)      //The answer vary due to round off error
```

Scilab code Exa 2.21 To Find a The work done per unit weight of water b Efficiency

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.21
       clc
      clear
//Given Data:-
         Vi=30;      //velocity of Jet at Inlet of, m/s
         u=15;      //Velocity of Vane, m/s
         ui=u;
         uo=u;
         alpha_i=32;        //Angle of Jet at Inlet, degrees
         alpha=125;           //Angle made by Jet at Outlet with direction fo motion of Vanes, degrees
         alpha_o=180-alpha;       //degrees

//Data Used:-
      g=9.81;           //Acceleration due to gravity, m/s^2
      rho=1000;      //Density of water, kg/m^3

//Computations:-
         Vwi=Vi*cosd(alpha_i);        //m/s
         Vfi=Vi*sind(alpha_i);         //m/s
         Vrwi=Vwi-ui;        //m/s
         beta_i=atand(Vfi/Vrwi);        //degrees
         Vri=Vfi/sind(beta_i);            //m/s
```

```
        Vro=Vri;
        beta_o=alpha_o-asind(uo*sind(180-alpha_o)/
            Vro);       //degrees

        Vrwo=Vri*cosd(beta_o);          //m/s
        Vwo=Vrwo-uo;            //m/s

    //(a)
        W=(Vwi+Vwo)*u/g;            //N-m/N   (Answer in
            textbook is wrong due to wrong value of
            Vwi used)
    //(b)Work done by Jet per second, W
        eta=2*(Vwi+Vwo)*u/(Vi^2)*100;           //In
            percentage

//Results:-
     printf("(a)Work done per unit weight of water=%
        .2f N-m/N  \n", W)          //The answer
        provided in the textbook is wrong
     printf("(b)Efficiency of the vane, eta=%.2f
        percent", eta)          //The answer provided
        in the textbook is wrong
```

Scilab code Exa 2.22 To Determine a Vane Angles at entrance and exit b Work done o

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.22
      clc
     clear
//Given Data:-
        Vi=32;      //velocity of Jet at Inlet, m/s
        u=16;      //Velocity of Vane, m/s
```

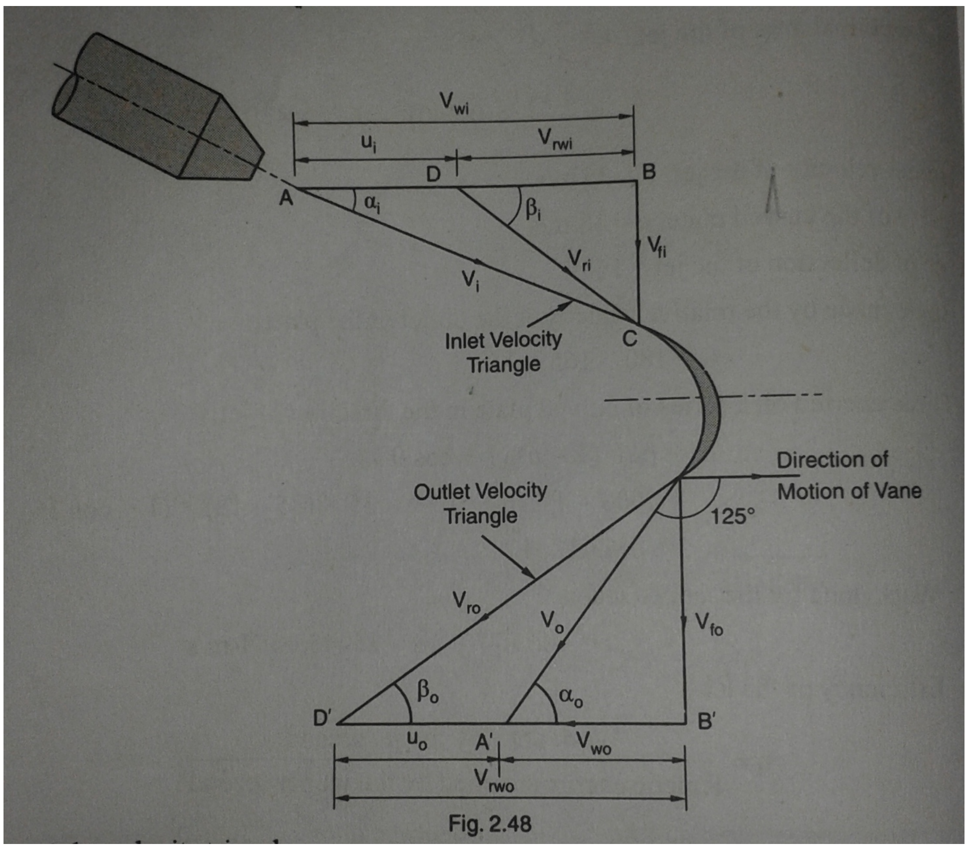

Figure 2.2: To Find a The work done per unit weight of water b Efficiency of the Vane

```
        ui=u;
        uo=u;
        alpha_i=22;        //Angle of Jet at Inlet, degrees
        K=0.92;            //Co-efficient of Vane

//Data Used:-
    g=9.81;            //Acceleration due to gravity, m/s^2

//Computations:-
        Vwi=Vi*cosd(alpha_i);        //m/s
        Vfi=Vi*sind(alpha_i);         //m/s
        Vrwi=Vwi-ui;        //m/s
   //(a)
        beta_i=atand(Vfi/Vrwi);        //degrees
        Vri=Vfi/sind(beta_i);             //m/s
        Vro=K*Vri;      //m/s
        beta_o=acosd(uo/Vro);         //degrees
    //(b)
        Vwo=0;             //m/s(as alpha_o=90 degrees)
        W=(Vwi+Vwo)*u/g;          //N-m/N
    //(c)
        eta=2*Vwi*u/Vi^2*100;         //In percentage

//Results:-
    printf("(a)Vane angle at Entrance, beta_i=%.2f degrees \n", beta_i)       //The answer vary due to round off error
    printf("    Vane angle at exit, beta_o=%.2f degrees \n", beta_o)       //The answer vary due to round off error
    printf("(b)Work done on vanes per unit weight of water=%.2f N-m/N \n", W)
    printf("(c)Efficiency of the system, eta=%.2f percent", eta)       //The answer vary due to round off error
```

Scilab code Exa 2.23 To Find a Speed of the wheel b Work done per unit weight of w

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.23
      clc
     clear
//Given Data:-
        Vi=65;     //Absolut velocity of Jet at Inlet, m/s
        Ri=400;      //Inner radius of wheel, mm
        Ro=800;       //outer radius of wheel, mm
        alpha_i=24;        //degrees
        Vfo=12;      //Flow velocity at outlet, m/s
        beta_i=40;        //blade angle at Inlet, degrees
        beta_o=30;        //Blade angle at outlet, degrees

//Data Used:-
     g=9.81;          //Acceleration due to gravity, m/s^2

//Computations:-
        Ri=Ri/1000;       //m
        Di=2*Ri;        //m
        Ro=Ro/1000;       //m
        Do=2*Ro;          //m
        Vfi=Vi*sind(alpha_i);        //m/s
        Vwi=Vi*cosd(alpha_i);       //m/s
        Vrwi=Vfi/tand(beta_i);      //m/s
   //(a)
        ui=Vwi-Vrwi;      //m/s
        N=ui*60/(%pi*Do);       //rpm
```

```
        omega=2*%pi*N/60;          //rad/s
        uo=%pi*Di*N/60;            //m/s
        Vro=Vfo/sind(beta_o);          //m/s
        Vrwo=Vro*cosd(beta_o);         //m/s
        Vwo=Vrwo-uo;               //m/s
    //(b)
        W=(Vwi*ui+Vwo*uo)/g;           //Work done per unit weight of water, N-m/N
    //(c)
        eta=(Vwi*ui+Vwo*uo)*2/Vi^2*100;          //In percentage

//Results:-
     printf("(a)For the speed of wheel:  \n\t")
     printf("N=%.2f rpm  \n\t", N)       //The answer vary due to round off error
     printf("Angular velocity, omega=%.2f rad/s  \n\t", omega)       //The answer vary due to round off error
     printf("Peripheral velocity of wheel at outlet, uo=%.2f m/s  \n\t", uo)
     printf("Vwo=%.2f m/s  \n\n", Vwo)       //The answer vary due to round off error
     printf("(b)Work done per unit weight of water=%.2f N-m/N  \n", W)       //The answer vary due to round off error
     printf("(c)Efficiency of the system, eta=%.2f percent", eta)       //The answer vary due to round off error
```

Scilab code Exa 2.24 To Find a Blade angles at entry and exit b Velocity of water

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.24
```

```
    clc
   clear

//Given Data:-
       Do=1.5;     //Diameter of rotor at inlet of
          vane, m
       Di=1;       //Diameter of rotor at outlet of
           vane, m
       N=400;       //Speed of the rotor, rpm
       Vi=15;       //m/s
       alpha_i=12;       //Nozzle angle at inlet,
          degrees
       Vo=5;       //m/s
       VFo=Vo;
//Data Used:-
    g=9.81;          //Acceleration due to gravity,
        m/s^2

//Computations:-
       ui=%pi*Do*N/60;           //m/s
       uo=%pi*Di*N/60;           //m/s
       Vfi=Vi*sind(alpha_i);       //m/s
       Vfo=Vo;     //m/s
       Vwi=Vi*cosd(alpha_i);        //m/s
   //(a)
       Vrwi=ui-Vwi;            //m/s
       beta_i=180-atand(Vfi/Vrwi);         //Blade
          angle at inlet, degrees
       beta_o=atand(Vfo/uo);           //Blade angle
           at outlet, degrees
    //(b)
       Vro=uo/cosd(beta_o);           //m/s
    //(c)
       W=Vwi*ui/g;         //N-m/N

//Results:-
    printf("(a)Blade angle at entry and exit are:
       \n\t")
```

```
printf("beta_i=%.2f degrees \t beta_o=%.2f degrees \n\n", beta_i,beta_o)      //The answer vary due to round off error
printf("(b)Velocity of water relative to Vanes at exit, Vro=%.2f m/s \n", Vro)      //The answer vary due to round off error
printf("(c)Work done per second per unit weight of water strikes on Vane per second=%.2f N-m/N", W)      //The answer vary due to round off error
```

Scilab code Exa 2.25 `To Find a Vane angles at inlet and outlet b Work done per sec`

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.25
    clc
    clear

//Given Data:-
        Vi=32;        //Absolute velocity of Jet at inlet, m/s
        N=250;        //Speed of the wheel, rpm
        alpha_i=20;       //angle of Jet at inlet, degrees
        Vo=6;        //Absolute velocity of Jet at outlet, m/s
        alpha=132;       //Angle made by Jet at outlet with tangent to wheel, degrees
        alpha_o=180-alpha;        //degrees
        Do=1.2;      //outer Diameter of wheel, m
        Di=0.75;     //Inner diameter of wheel, m

//Data Used:-
    g=9.81;          //Acceleration due to gravity,
```

```
            m/s^2

//Computations:-
        ui=%pi*Do*N/60;            //m/s
        uo=%pi*Di*N/60;            //m/s
   //(a)
        Vfi=Vi*sind(alpha_i);        //m/s
        Vwi=Vi*cosd(alpha_i);         //m/s
        Vrwi=Vwi-ui;              //m/s
        Vwo=Vo*cosd(alpha_o);          //m/s
        Vrwo=uo+Vwo;     //m/s
        Vfo=Vo*sind(alpha_o);       //m/s
        beta_i=atand(Vfi/Vrwi);           //degrees
        beta_o=atand(Vfo/Vrwo);            //degrees
    //(b)
        W=(Vwi*ui+Vwo*uo)/g;          //N-m/N
    //(c)
        eta=2*(Vwi*ui+Vwo*uo)/Vi^2*100;         //in
           percentage

//Results:-
     printf("(a)Vane angle at Inlet, beta_i=%.2f
        degrees \n", beta_i)       //The answer vary
         due to round off error
     printf("    Vane angle at Outlet, beta_o=%.2f
        degrees \n", beta_o)       //The answer vary
         due to round off error
     printf("(b)Work done per second per unit weight
         of water strikes on vane per second=%.2f N-
       m/N \n", W)       //The answer vary due to
        round off error
     printf("(c)Efficiency of the wheel, eta=%.2f
        percent",eta)       //The answer vary due to
        round off error
```

Scilab code Exa 2.26 To Find the force exerted by the Jet of water on the statione

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.26
      clc
     clear

//Given Data:-
        H=4;          //Head of water in tank, m
        d=150;         //Diameter of orfice, mm
        Cv=0.96;

//Data Used:-
        rho=1000;       //Density of water, kg/m^3
        g=9.81;        //Acceleration due to gravity,
           m/s^2


//Computations:-
        d=d/1000;      //m
        a=(%pi/4)*d^2;         //cross-sectional are
            of orifice, m^2
        V=Cv*sqrt(2*g*H);        //Velocity of Jet,
           m/s
        F=rho*a*V^2;          //Force exerted on
           tank, N

//Results:-
     printf("The force exerted on the tank=%.2f n",
        F)      //The answer vary due to round off
        error
```

Scilab code Exa 2.27 To Find a Propelling force on the tank b Work done by the pro

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.27
     clc
    clear

//Given Data:-
        H=3.8;          //Head of water in tank, m
        d=200;         //Diameter of orfice, mm
        Cv=0.97;
        u=2;            //Velocity of tank, m/s

//Data Used:-
        rho=1000;       //Density of water, kg/m^3
        g=9.81;         //Acceleration due to gravity, m/s^2

//Computations:-
        d=d/1000;       //m
        a=(%pi/4)*d^2;          //cross-sectional are of orifice, m^2
        V=Cv*sqrt(2*g*H);          //Velocity of Jet, m/s
   //(a)
        F=rho*a*(V+u)*V;            //N
   //(b)
        W=F*u;              //N-m/s
   //(c)
        eta=2*V*u/(V+u)^2*100;            //in Percentage

//Results:-
    printf("(a)Propelling Force on tank, F=%.2f N \n", F)         //The answer provided in the textbook is wrong
    printf("(b)Work done by propelling force per second=%.2f N-m/s  \n", W)          //The answer provided in the textbook is wrong
```

```
    printf("(c)Efficiency of propulsion, eta=%.2f
      percent", eta)      //The answer vary due to
       round off error
```

Scilab code Exa 2.28 To Determine a Propelling force on the boat b Power required

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.28
     clc
    clear

//Given Data:-
        V=20;          //Absolute Velocity of Jet of
           Water, m/s
        a=0.02;        //Cross-sectional area of Jet,
            m^2
        u=30;           //Speed of boat, km/hr

//Data Used:-
        rho=1000;       //Density of water, kg/m^3

//Computations:-
        u=u*1000/3600;          //m/s
   //(a)
        Fx=rho*a*(V+u)*V;           //N
   //(b)
        P=Fx*u/1000;        //kW
   //(c)
        eta=2*V*u/(V+u)^2*100;           //in
           Percentage

//Results:-
    printf("(a)Propelling Force on the boat, Fx=%.f
          N \n", Fx)       //The answer vary due to
```

```
round off error
printf("(b)power required to drive the pump=%.2f kW \n", P)    //The answer vary due to round off error
printf("(c)Efficiency of the Jet propulsion, eta=%.2f percent", eta)    //The answer vary due to round off error
```

Scilab code Exa 2.29 To Find a Propelling force on the boat b Power required to dr

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.29
 clc
clear

//Given Data:-
    V=20;           //Absolute Velocity of Jet of Water, m/s
    a=0.18;         //Cross-sectional area of Jet, m^2
    u=30;           //Speed of boat, km/hr

//Data Used:-
    rho=1000;       //Density of water, kg/m^3

//Computations:-
    u=u*1000/3600;          //m/s
  //(a)
    Fx=rho*a*(V+u)*V/1000;          //kN
  //(b)
    P=Fx*u;         //kW
  //(c)
    eta=2*V*u/(V+u)^2*100;          //in Percentage
```

```
//Results:-
    printf("(a)Propelling Force on the boat, Fx=%.4f kN \n", Fx)
    printf("(b)power required to drive the pump=%.2f kW  \n", P)
    printf("(c)Efficiency of the Jet propulsion, eta=%.2f percent", eta)
```

Scilab code Exa 2.30 To Find the propelling Force and Efficiency of propulsion

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.30
    clc
    clear

//Given Data:-
        V=40;          //Absolute Velocity of Jet, m/s
        a=0.04;          //Cross-sectional area of Jet, m^2
        u=40;            //Speed of boat, km/hr

//Data Used:-
        rho=1000;        //Density of water, kg/m^3

//Computations:-
        u=u*1000/3600;           //m/s
        F=rho*a*(V+u)*V;            //N
        eta=2*u/(V+2*u)*100;            //in Percentage

//Results:-
    printf("(a)Propelling Force, F=%.f N \n", F)        //The answer vary due to round off error
```

```
	printf("(b)Efficiency of propulsion, eta=%.2f
	   percent", eta)
```

Scilab code Exa 2.31 To Find i The volume of water drawn by the pump per second ii

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.31
//To Find (i)The volume of water drawn by the pump
   per second (ii)The Efficiency of Jet propulsion.
	clc
	clear

//Given Data:-
	F=5890;		//Total resistance offered to
	   motion, N
	a=424;		//Total area of Jet, cm^2
	u=6;		//Speed of boat, m/s

//Data Used:-
	rho=1000;	//Density of water, kg/m^3

//Computaions:-
	a=a/10000;	//m^2
    //For solving Quadratic in V
		A=rho*a;
		B=rho*a*u;
		C=-F;
	 V=(-B+sqrt(B^2-4*C*A))/(2*A);		//m/
	    s
	//(i)
	 Q=a*(V+u);			//m^3/s
	//(ii)
	 eta=2*V*u/(V+u)^2*100;			//In
	    percentage
```

```

//Results:-
    printf("(i)The Volume of water drawn by the pump per second=%.4f m^3/s  \n", Q)    //The answer vary due to round off error
    printf("(ii)The Efficiency of Jet propulsion, eta=%.2f percent", eta)    //The answer vary due to round off error
```

Scilab code Exa 2.32 `To Find the propelling Force and Efficiency of Propulsion`

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.32
     clc
    clear

//Given Data:-
        V=18;       //Absolute Velocity of the Jet, m/s
        a=0.04;       //cross-sectional area of Jet, m^2
        u=28;          //Speed of the ship, km/hr

//Data Used:-
        rho=1000;       //Density of water, kg/m^3

//Computations:-
        u=u*1000/3600;          //m/s
    //(a)
        F=rho*V*a*(V+u);               //N
    //(b)
        eta=2*u/(V+2*u)*100;           //In percentage

//Results:-
```

```
printf("(a)Propelling Force, F=%.f N \n", F)
printf("(b)The Efficiency of propulsion, eta=%.2f percent \n", eta)        //The answer vary due to round off error
```

Scilab code Exa 2.33 To Find a Propelling Force and b Overall Efficiency

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.33
 clc
clear

//Given Data:-
        a=0.72;            //Total cross-sectional area of Jets, m^2
        Vr=12;           //Velocity through the Jet relative to ship, m/s
        u=6;              //Speed of ship, m/s
        eta_E=85/100;          //Efficiency of I.C. engine
        eta_P=70/100;          //Efficiency of Centrifugal Pump
        Pipe_Loss_per=8;          //Percentage of pipe losses (of the kinetic energy of Jet per sec)

//Data Used:-
        rho=1000;       //Density of water, kg/m^3

//Computations:-
        Pipe_Loss=(Pipe_Loss_per/100)*(rho*a*Vr^3/2);              //Pipe Losses, N-m/s
        V=Vr-u;           //Absolute Velocity of the Jet, m/s
```

```
    //(a)
        F=rho*V*a*(V+u);            //N
    //(b)
        W=F*u;          //Work done by Jet per second, N-m/s
        OE_P=rho*a*Vr^3/2+Pipe_Loss;            //Output energy of pump per sec, N-m/s
        IP_P=OE_P/eta_P;            //Input Energy of pump per sec, N-m/s
        OE_E=IP_P;          //Output of Engine is equal to Input to the pump
        IE_E=OE_E/eta_E;            //Input Energy of Engine per sec, N-m/s
        eta_o=W/IE_E*100;           //Overall Efficiency in percentage

//Results:-
    printf("(a)Propelling Force=%.f N  \n", F)
    printf("(b)Overall Efficiency, eta_o=%.2f percent", eta_o)      //The answer vary due to round off error
```

Scilab code Exa 2.34 To Find a The volume of water drawn by the pump per second b

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.34
     clc
    clear

//Given Data:-
        F=100800;       //Total resistance offered to motion, N
        a=0.8;      //Total area of Jet, m^2
        u=5;            //Speed of boat, m/s
```

```

//Data Used:-
        rho=1000;       //Density of water, kg/m^3

//Computations:-
    //For solving Quadratic in V
            A=rho*a;
            B=rho*a*u;
            C=-F;
         V=(-B+sqrt(B^2-4*C*A))/(2*A);          //m/
            s
     //(a)
         Q=a*(V+u);               //m^3/s
     //(b)
         eta=2*V*u/(V+u)^2*100;          //In
            percentage

//Results:-
     printf("(a)The Volume of water drawn by the
        pump per second=%.1f m^3/s  \n", Q)
     printf("(b)The Efficiency of Jet propulsion,
        eta=%.2f percent", eta)      //The answer
        vary due to round off error
```

Scilab code Exa 2.35 i To Find a Resistance to the motion of ship b Propulsion wor

```
//Fluid system - By - Shiv Kumar
//Chapter 2 - Impact of Jet
//Example 2.35
      clc
     clear

//Given Data:-
        Vr=14;      //Relative Velocity of ship, m/s
        a=0.025;       //cross-sectional area of Jet
```

```
            , m^2
        u=32;             //Speed of ship , km/hr
        eta_P=80/100;          //Efficiency of pump
        h_f=2.5;          //Frictional Losses , m of water

//Data Used:-
        rho=1000;        //Density of water , kg/m^3
        g=9.81;          //Acceleration due to gravity , m/s^2

//Computations:-
        u=u*1000/3600;          //m/s
    //(i)
     //(a)
        V=Vr-u;       //m/s
        F=rho*V*a*(V+u);              //N
     //(b)
        W=F*u;            //N-m/s, Value in textbook is wrong due to incorrect value of u ia used.
     //(ii)
        E=rho*a*Vr*((Vr^2-u^2)/2+g*h_f);
                        //Actual energy supplied to water per second, N-m/s
        OE_P=E;            //Output fluid energy per second of pump
     //(a)
        P=OE_P/eta_P;          //Power required to drive the pump, W
     //(b)
        eta_o=W/P*100;          //In percentage

//Results:-
      printf("(i) (a)Resistance to the motion of ship, F=%.f N \n", F)          //The answer provided in the textbook is wrong
      printf("    (b)Propulsive work per second=%.2f
```

```
    N-m/s  \n\n", W)         //The answer
    provided in the textbook is wrong
printf("(ii) (a)Power required to drive the
    pump=%.2f W  \n", P)         //The answer
    provided in the textbook is wrong
printf("      (b)Overall Efficiency of
    propulsion, eta_o=%.2f percent", eta_o)
        //The answer vary due to round off
    error
```

Chapter 4

Pelton Turbine Impulse Turbine

Scilab code Exa 4.1 To Determine a Diameter of turbine b The number of Jets requir

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.1
     clc
    clear

//Given Data:-
        P=735.75;      //Power Developed, kW
        H=200;         //Head, m
        N=800;          //Speed, rpm
        eta_O=86/100;      //Overall Efficiency
        d_by_D=1/10;       //Ratio of Jet diameter to
            turbine diameter (d/D)
        Cv=0.98;          //Co-efficienct of velocity
        Ku=0.45;       //Speed ratio

//Data Used:-
    rho=1000;      //Density of water, kg/m^3
    g=9.81;         //Acceleration due to gravity, m
```

```
/s^2

//Computations:-
        Q=P*1000/(rho*g*H*eta_O);          //Net discharge , m^3/s
   //(a)Diameter of Turbine , D
        D=60*Ku*sqrt(2*g*H)/(%pi*N);        //m
        d=D*d_by_D;                        //m
   //(b)The no. of Jets required
        q=(%pi/4)*d^2*Cv*sqrt(2*g*H);           //Discharge of a single Jet , m^3/s
        n=round(Q/q);                     //No. of Jets
   //(c)Diameter of Jet , d
        d=d_by_D*D;                       //m

//Results:-
     printf("(a)Diameter of Turbine , D=%.4f m \n", D)    //The answer vary due to round off error
     printf("(b)The number of Jets required , n=%.f \n", n)
     printf("(c)Diameter of Jet , d=%.4f m \n", d)
```

Scilab code Exa 4.2 To Find a The power given by water to runner and b The hydraul

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.2
      clc
     clear

//Given Data:-
        u=12;      //Speed of bucket , m/s
        ui=u;
        uo=u;
```

```
        Q=650;          //Discharge, liters/s
        H=40;             //Head of water, m
        AoD=162;              //Angle of Deflection, degrees
        Cv=0.98;            //Co-efficient of Velocity

//Data Used:-
    rho=1000;       //Density of water, kg/m^3
    g=9.81;          //Acceleration due to gravity, m/s^2

//Computations:-
        Q=Q/1000;           //m^3/s
        beta_O=180-AoD;            //Blade angle a outlet, degrees
        Vi=Cv*sqrt(2*g*H);            //Velocity of Jet, m/s
        Vwi=Vi;
        Vri=Vi-ui;              //m/s
        Vro=Vri;
        Vrwo=Vro*cosd(beta_O);            //m/s
        Vwo=Vrwo-uo;                //m/s
   //(a)Power given by water to runner, P
        P=rho*Q*(Vwi+Vwo)*u/1000;            //kW
   //(b)The hydraulic efficiency, eta_H
        eta_H=2*(Vwi+Vwo)*u/Vi^2*100;            //In percentage

//Results:-
    printf("(a)The Power given by water to the runner=%.3f kW  \n", P)      //The answer vary due to round off error
    printf("(b)The Hydraulic Efficiency of Turbine, eta_H=%.2f percent \n", eta_H)      //The answer vary due to round off error
```

Scilab code Exa 4.3 To Find a The power given by water to runner b Hydraulic effie

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.3
      clc
     clear

//Given Data:-
        H=30;             //Effective Head, m
        AoD=165;             //Jet Deflection Angle, degrees
        Cv=0.98;            //Co-efficient of Velocity
        Ku=0.45;            //Speed ratio
        d=22;             //Diameter of Jet, mm
    //As  relative velocity at outlet is 0.98 times relative velocity at inlet,
       Vro_by_Vri=0.98;        // Vro/Vri

//Data Used:-
     rho=1000;       //Density of water, kg/m^3
     g=9.81;          //Acceleration due to gravity, m/s^2

//Computations:-
        d=d/1000;           //m
        beta_O=180-AoD;           //degrees
        Vi=Cv*sqrt(2*g*H);           //Absolut Velocity of Jet, m/s
        Vwi=Vi;
        u=Ku*sqrt(2*g*H);           //peripheral velocity of runner, m/s
        ui=u;
        uo=u;
```

```
        Vri=Vi-ui;          //m/s
        Vro=Vro_by_Vri*Vri;         //m/s
        Vrwo=Vro*cosd(beta_O);            //m/s
        Vwo=Vrwo-uo;                //m/s

    //(a)Power given by water to runner, P
        Q=(%pi/4)*d^2*Vi;            //m^3/s
        P=rho*Q*(Vwi+Vwo)*u/1000;              //kW

    //(b)The hydraulic efficiency, eta_H
        eta_H=2*(Vwi+Vwo)*u/Vi^2*100;             //In
           percentage

//Results:-
      printf("(a)The Power given by water to the
         runner=%.3f kW  \n", P)      //The answer
         vary due to round off error
      printf("(b)The Hydraulic Efficiency, eta_H=%.2f
          percent \n", eta_H)       //The answer vary
         due to round off error
```

Scilab code Exa 4.4 To Determine the specific speed of the Turbine

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.4
       clc
      clear

//Given Data:-
        Cv=0.97;
        Ku=0.46;
        K=0.98;
        m=10.2;
        beta_o=10;          //Bucket angle at exit,
```

```
          degrees
        eta_m=90.5/100;           //Mechanical Efficiency

//Data Used:-
    rho=1000;      //Density of water, kg/m^3
    g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
        Vi_by_rootH=Cv*sqrt(2*g);         //Vi/sqrt(H)
        Vwi_by_rootH=Vi_by_rootH;
        ui_by_rootH=Ku*sqrt(2*g);          //ui/sqrt(H)
        Vri_by_rootH=Vi_by_rootH-ui_by_rootH;               //Vi/sqrt(H)
        Vro_by_rootH=K*Vri_by_rootH;           //Vro/sqrt(H)
        Vrwo_by_rootH=Vro_by_rootH*cosd(beta_o);         //Vrwo/sqrt(H)
        Vwo_by_rootH=Vrwo_by_rootH-ui_by_rootH;          //Vwo/sqrt(H)
        Q_by_d2_rootH=(%pi/4)*Vi_by_rootH;          //Q/(d^2*sqrt(H))
   //Pr=Power developed by runner
        Pr_by_d2_H3_2=rho*Q_by_d2_rootH*(Vwi_by_rootH+Vwo_by_rootH)*ui_by_rootH;          //Pr/(d^2*H^(3/2)), P in W
   //P=Shaft Power
        P_by_d2_H3_2=eta_m*Pr_by_d2_H3_2/1000;          //P/(d^2*H^(3/2)), P in kW
        N_d_by_rootH=ui_by_rootH*60/(%pi*m);          //N*d/sqrt(h), N in rpm
        Ns=N_d_by_rootH*sqrt(P_by_d2_H3_2);          //Specific Speed in SI Units

//Results:-
```

```
    printf("The Specific Speed of the Turbine, Ns=%
        .f  (SI Units)", Ns)
```

Scilab code Exa 4.5 To Find the Overall Efficiency of the Turbine

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.5
     clc
    clear

//Given Data:-
        n=2;            //Number of Jets
        P=15450;            //Shaft Power, kW
        d=200;              //Diameter of each Jet, mm
        H=400;               //Net Head, m
        Cv=1;

//Data Used:-
    rho=1000;       //Density of water, kg/m^3
    g=9.81;          //Acceleration due to gravity, m
        /s^2

//Computations:-
        P=P*1000;           //W
        d=d/1000;             //m
        Vi=Cv*sqrt(2*g*H);           //Absolute
           Velocity of Jet at Inlet, m/s
        q=(%pi/4)*d^2*Vi;           //Discharge
           through each Jet, m^3/s
        Q=n*q;                //Net Discharge
        eta_O=P/(rho*Q*g*H)*100;            //Overall
           Efficiency, in percentage

//Results:-
```

```
      printf("The Overall Efficiency of the Turbine,
         eta_o=%.2f percent", eta_O)      //The
         answer vary due to round off error
```

Scilab code Exa 4.6 To Find i Resultant force on the bucket ii Shaft Power iii Ove

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.6
       clc
      clear
//Given Data:-
         N=300;            //Speed of runner, rpm
         H=510;          //Head, m
         d=200;           //Diameter of the Jet, mm
         AoD=165;          //Angle of Jet(Deflection
            inside bucket), degrees
         Vel_per=15;            //Percentage by which
            velocity is reduced due to friction
         Loss_per=3;          //Percentage of
            mechanical Losses (of power Supplied)

//Data Used:-
      rho=1000;      //Density of water, kg/m^3
      g=9.81;         //Acceleration due to gravity, m
         /s^2
      Cv=0.98;       //Co-efficient of Velocity
      Ku=0.46;       //Speed ratio

//Computations:-
         d=d/1000;            //m
         beta_O=180-AoD;        //degrees
         Vro_by_Vri=1-Vel_per/100;           //Vro/Vri
         Vi=Cv*sqrt(2*g*H);                //m/s
         Vwi=Vi;
```

```
        u=Ku*sqrt(2*g*H);          //m/s
        uo=u;
        ui=u;
        Vri=Vi-ui;          //m/s
        Vro=Vri*Vro_by_Vri;          //m/s
        Vrwo=Vro*cosd(beta_O);          //m/s
        Vwo=uo-Vrwo;          //m/s
        Q=(%pi/4)*d^2*Vi;          //Discharge, m^3/s
    //(i) Resultant Force on bucket, F
        F=rho*Q*(Vwi-Vwo)/1000;          //kN

   //Result (i):-
      printf("(i) Resultant Force on bucket, F=%.3f kN  \n", F)      //The answer vary due to round off error

    //(ii) Shaft Power, P
        Pr=F*u;          //power developed by runner, kW
        P=Pr-(Loss_per/100)*Pr;          //kW

   //Result (ii)
      printf("(ii)Shaft Power, P=%.3f kW \n", P)          //The answer given in the textbook is wrong (due to round off error in F)
   //OR
        eta_m=1-Loss_per/100;      //Mechanical Efficiency
        P=eta_m*Pr;          //kW

   //(iii) Overall Efficiency, eta_O
        eta_O=P*1000/(rho*Q*g*H)*100;          //In percentage
   //Result (iii)
      printf("(iii)Overall efficiency, eta_O=%.2f percent", eta_O)
```

Scilab code Exa 4.7 `To Determine the power given by the water to the runner and Hy`

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.7
      clc
     clear

//Given Data:-
        H_G=500;          //Gross Head, m
        h_f=(1/3)*H_G;          //Head lost in friction in penstock, m
        Q=2;            //Discharge, m^3/s
        AoD=165;            //Angle of Deflection of Jet, degrees
        Ku=0.45;          //Speed ratio
        Cv=1;

//Data Used:-
     rho=1000;      //Density of water, kg/m^3
     g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
        H=H_G-h_f;          //Working Head, m
        Vi=Cv*sqrt(2*g*H);        //m/s
        Vwi=Vi;
        u=Ku*sqrt(2*g*H);           //m/s
        ui=u;
        uo=u;
        Vri=Vi-u;     //m/s
        Vro=Vri;
        beta_o=180-AoD;            //degrees
        Vrwo=Vro*cosd(beta_o);       //m/s
```

```
        Vwo=Vrwo-uo;            //m/s
        P=rho*Q*(Vwi+Vwo)*u/1000;        //power given by water to runner, kW
        eta_H=2*(Vwi+Vwo)*u/Vi^2*100;          //Hydraulic efficiency, In percentage

//Results:-
     printf("Power given by water to the runner=%.2f kW  \n", P)       //The answer vary due to round off error
     printf("Hydraulic efficiency, eta_H=%.2f percent", eta_H)     //The answer vary due to round off error
```

Scilab code Exa 4.8 To Determine the Flow Rate and Shaft Power developed by the Tu

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.8
      clc
     clear

//Given Data:-
        Cv=0.97;           //Co-efficient of Velocity
        H_l=400;          //Head at lake, m
        d=80;        //Diameter of Jet, mm
        D_pipe=0.6;        //Diameter of pipe, m
        l=4;         //Length of pipe, m
        f_dash=0.032;           //Friction factor
        AoD=165;         //Angle of Deflection, degrees
        beta_o=180-AoD;         //degrees
  // As bucket runs at 0.48 Jet speed
        u_by_Vi=0.48;          //u/Vi
        Vel_per=15;         //percentage by which
```

```
velocity is reduced
        eta_m=90/100;          //Mechanical Efficiency

//Data Used:-
    rho=1000;       //Density of water, kg/m^3
    g=9.81;         //Acceleration due to gravity, m/s^2

//Computations:-
        d=d/1000;           //m
        l=l*1000;           //m
        Vro_by_Vri=1-Vel_per/100;         //Vro/Vri
    //using continuity equation,
        V_by_Vi=(d/D_pipe)^2;         //V/Vi
        Vi=sqrt((2*g*H_l)/(1/Cv^2+f_dash*l*V_by_Vi^2/D_pipe));        //m/s
        Vwi=Vi;
        u=Vi*u_by_Vi;        //m/s
        ui=u;
        uo=u;
        Vri=Vi-ui;        //m/s
        Vro=Vri*Vro_by_Vri;            //m/s
        Vrwo=Vro*cosd(beta_o);          //m/s
    //(i) Flow Rate, Q
        Q=(%pi/4)*d^2*Vi;                  //m^3/s
    //(ii) Shaft Power, P
        Vwo=uo-Vrwo;        //m/s
        Pr=rho*Q*(Vwi-Vwo)*u/1000;       //Power developed by the runner, kW
        P=eta_m*Pr;           //kW

//Results:-
    printf("Flow Rate, Q=%.4f m^3/s  \n", Q)    //The answer vary due to round off error
    printf("Shaft power, P=%.2f kW", P)       //The answer vary due to round off error
```

Scilab code Exa 4.9 To Find i Diameter of the Turbine and ii Diameter of the Jet

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.9
     clc
    clear

//Given Data:-
        P=3000;             //Power developed, kW
        H=300;            //Head, m
        N=375;            //Speed, rpm
        eta_O=83/100;          //Overall efficiency
        Ku=0.46;        //Speed ratio
        Cv=0.98;          //Co-efficient of Velocity

//Data Used:-
    rho=1000;       //Density of water, kg/m^3
    g=9.81;          //Acceleration due to gravity, m/s^2

//Computations:-
   //(i) Diameter of Turbine, D
        D=60*Ku*sqrt(2*g*H)/(%pi*N);            //m
   //(ii) Diameter of Jet, d
        Q=P*1000/(rho*g*H*eta_O);             //m^3/s
        Vi=Cv*sqrt(2*g*H);          //m/s
        d=(Q/((%pi/4)*Vi))^(1/2);          //m

//Results:-
    printf("(i) Diameter of the Turbine, D=%.2f  m \n", D)       //The answer vary due to round off error
    printf("(ii) Diameter of the Jet, d=%.4f m", d)
```

```
            //The answer vary due to round off
        error
```

Scilab code Exa 4.10 To Determine i Water power available at the inlet of turbine

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.10
      clc
     clear

//Given Data:-
        N=300;          //Speed of runner, rpm
        H=510;           //Head, m
        d=200;            //Diameter of the Jet, mm
        AoD=165;        //Angle of Deflection,
           degrees
        Vel_per=15;        //percentage by which
           velocity is reduced

//Data Used:-
     rho=1000;     //Density of water, kg/m^3
     g=9.81;        //Acceleration due to gravity, m
        /s^2
     Cv=0.98;
     Ku=0.46;

//Computations:-
     d=d/1000;              //m
     beta_O=180-AoD;               //degrees
     Vro_by_Vri=1-Vel_per/100;              //Vro/Vri
     Vi=Cv*sqrt(2*g*H);                //m/s
     Vwi=Vi;
     ui=Ku*sqrt(2*g*H);               //m/s
     uo=ui;
```

```
    u=ui;
    Vri=Vi-ui;           //m/s
    Vro=Vri*Vro_by_Vri;         //m/s
    Vrwo=Vro*cosd(beta_O);         //m/s
    Vwo=uo-Vrwo;           //m/s

  //(i) Water power available at inlet of turbine, P
    Q=(%pi/4)*d^2*Vi;             //m^3.s
    P=(1/2)*rho*Q*Vi^2/1000;          //kW
  //(ii)Resultant force on the bucket, F
    F=rho*Q*(Vwi-Vwo)/1000;            //kN
  //(iii)Overall Efficiency, eta_o
    eta_H=F*u/P;                //Hydraulic
       efficiency
   //Assume,
    eta_V=100/100;            //Volumetric efficiency
        is 100%
    eta_m=98/100           //Mechanical Efficiency
       is 98%

    eta_O=eta_V*eta_H*eta_m*100;           //In
       percentage

//Results:-
    printf("(i)Water power available at inlet of
       turbine=%.2f kW \n", P)        //The answer
        provided in the Textbook is wrong
    printf("(ii)Resultant force on the bucket, F=%
       .3f kN \n", F)      //The answer vary due to
        round off error
    printf("(iii)Overall efficiency, eta_O=%.2f
       percent", eta_O)      //The answer vary due
       to round off error
```

Scilab code Exa 4.11 To Find a Water power b The Force on the bucket in the direct

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.11

    clc
    clear

//Given Data:-
       N=300;          //Speed of runner, rpm
       H=500;           //Head, m
       d=200;            //Diameter of the Jet, mm
       AoD=165;        //Angle of Deflection, degrees
       Vel_per=15;       //percentage by which velocity is reduced
       Cv=0.98;        //Co-efficient of Velocity
       Ku=0.46;        //Speed ratio
     Loss_per=3;      //Percentage of Mechanical losses

//Data Used:-
    rho=1000;      //Density of water, kg/m^3
    g=9.81;         //Acceleration due to gravity, m/s^2


//Computations:-
    d=d/1000;               //m
    beta_O=180-AoD;             //degrees
    Vro_by_Vri=1-Vel_per/100;            //Vro/Vri
    K=Vro_by_Vri;
    Vi=Cv*sqrt(2*g*H);              //m/s
    Vwi=Vi;
    ui=Ku*sqrt(2*g*H);             //m/s
    uo=ui;
    u=ui;
    Vri=Vi-ui;          //m/s
    Vro=K*Vri;         //m/s
```

```
    Vrwo=Vro*cosd(beta_O);         //m/s
    Vwo=uo-Vrwo;           //m/s

   //(a) Water power, WP
    Q=(%pi/4)*d^2*Vi;            //m^3.s
    WP=rho*Q*g*H/1000;        //kW

  //(b)The Force on the bucket in the direction of
     Jet, F
    F=rho*Q*(Vwi-Vwo)/1000;           //kN

   //(c)Shaft Power, SP
     Pr=F*u;     //Power developed by the Runner, W
     SP=Pr-Loss_per/100*Pr;      //kW

  //(d)Overall Efficiency, eta_o
    eta_o=SP/WP*100;          //In percentage

//Results:-
    printf("(a) Water power, WP=%.2f  kW  \n",WP)
       //The answer provided in the Textbook is
       wrong
    printf("(b)The Force on the bucket in the
       direction of Jet=%.3f kN  \n", F)     //The
       answer vary due to round off error
    printf("(c)Shaft Power, SP=%.3f kW\n",SP)   //
       The answer provided in the Textbook is wrong
    printf("(d)Overall efficiency, eta_o=%.2f
       percent", eta_o)       //The answer vary due
        to round off error
```

Scilab code Exa 4.12 To Find a Efficiency of the Runner b The Diameter of each Jet

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
```

```
//Example 4.12

       clc
        clear

//Given Data:-
       n=2;            //Number of Jets
       P=5000;           //Shaft Power, HP
       N=375;           //Speed of Shaft, rpm
       Hth=200;        //Theoretical Head at Base of
          Nozzle, m
       eta_p=90/100;          //Efficiency of Power
          Transmission
       D=1.65;            //Diameter of the Runner, m
       Vel_per=10;           //Percentage by which
          velocity is decreased
       Deflection=165;            //Jet Deflection,
          degrees
        eta_o=90/100;             //Overall Efficiency
       Cv=0.98;


//Data Used:-
         rho=1000;             //Density of water, kg/m
            ^3
          g=9.81;               //Acceleration due to
             gravity, m/s^2

//Computations:-
           P=P*736;        //W
           Hact=eta_p*Hth;          //Actual Head
              available at base of Nozzle, m
           Vro_by_Vri=1-Vel_per/100;            //Vro/
              Vri
           beta_o=180-Deflection;          //degrees

            u=%pi*D*N/60;           //Velocity of
               Runner, m/s
```

```
            ui=u;
            uo=u;
           Vi=Cv*sqrt(2*g*Hact);          //m/s
           Vwi=Vi;
           Vri=Vi-u;       //m/s
          Vro=Vri*Vro_by_Vri;      //m/s
          Vrwo=Vro*cosd(beta_o);       //m/s
          Vwo=uo-Vrwo;         //m/s

      //(a)Efficiency of Runner, eta_H
                eta_H=2*(Vwi-Vwo)*u/Vi^2*100;            //In Perecentage

     //(b)Diameter of each jet, d
          Q=P/(rho*g*Hact*eta_o);          //Discharge, m^3/s
          d=sqrt(Q/((%pi/4)*n*Vi));       //Diameter of each Jet, m

//Results:-
      printf("(a)Efficiency of the Runner, eta_H=%.2f Percent\n",eta_H)       //The answer vary due to round off error
      printf("(b)Diameter of each Jet , d=%.3f m\n",d)
```

Scilab code Exa 4.13 To Find a Diameter of the Jet b Diameter of the Runner c Widt

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.13

      clc
       clear

```

```
//Given Data:-
      H=62;           //Effective Head, m
      N=225;          //Speed of Runner, rpm
      P=133.15;          //Shaft Power, HP
      Ku=0.45;            //Speed  Ratio
      eta_o=86/100;            //Overall Efficiency
      Cv=0.98;


//Data Used:-
        rho=1000;            //Density of water, kg/m
           ^3
         g=9.81;              //Acceleration due to
            gravity, m/s^2

//Computations:-
        P=P*736;            //W

        Vi=Cv*sqrt(2*g*H);          //m/s
        u=Ku*sqrt(2*g*H);         //m/s
        ui=u;
        uo=u;
        Q=P/(rho*g*H*eta_o);        //m^3/s

         d=sqrt(Q/((%pi/4)*Vi))*1000;        //
            Diameter of Jet, mm
         D=60*u/(%pi*N);             //Diameter of
            Runner, m
    //As per designing range, b=3*d to 4*d
         b=3.5*d;            //Width of Buckets, mm
   //As per designing range, b=0.8*d to 1.2*d
          T=1.2*d;            //Depth of Buckets, mm
         Z=round(0.5*D/(d/1000)+15);         //Number
             of Buckets

//Results:-
         printf(" (a)Diameter of Jet, d=%.2f mm \n",
            d)        //The answer vary due to round
```

```
off error
        printf(" (b) Diameter of Runner, D=%.3f m \n",D)
        printf(" (c) Width of Buckets, b=%.2f mm \n",b)       //The answer vary due to round off error
        printf(" (d) Depth of Buckets, T=%.2f mm \n",T)       //The answer vary due to round off error
        printf(" (e) Number of Buckets , Z=%.f  \n",Z)
```

Scilab code Exa 4.14 To Find a Diameter of the Jet b Diameter of the Runner c Powe

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.14

      clc
       clear

//Given Data:-
      H=452;      //Net Head, m
      m=12;         //Jet Ratio (D/d)
      Ku=0.46;       //Speed Ratio
      AoD=165;      //Angle of Jet Deflection, degrees
      Cv=0.98;        //Co-efficient of Velocity
      Loss_f=15;       //Percentage of Friction Loss of Buckets
      eta_o=86/100;            //Overall Efficiency
      P_G=10200;          //Power developed by Generator, HP
      eta_G=95/100;          //Generator  Efficiency

```

```
//Data Used:-
        rho=1000;          //Density of water, kg/m^3
         g=9.81;           //Acceleration due to gravity, m/s^2

//Computations:-
          P_G=P_G*736;        //W
          Vro_by_Vri=1-Loss_f/100;          //Vro/Vri
          beta_o=180-AoD;       //degrees

           u=Ku*sqrt(2*g*H);         //Velocity of Runner, m/s
           ui=u;
           uo=u;
          Vi=Cv*sqrt(2*g*H);         //m/s
          Vwi=Vi;
          Vri=Vi-ui;      //m/s
         Vro=Vri*Vro_by_Vri;      //m/s
         Vrwo=Vro*cosd(beta_o);       //m/s
         Vwo=uo-Vrwo;         //m/s

         P=P_G/eta_G;        //Shaft Power, W
         Q=P/(rho*g*H*eta_o);          //Discharge, m^3/s

    //(a)
         d=sqrt(Q/((%pi/4)*Vi));       //Diameter of Jet, m

    //(b)
          D=m*d;        //Diameter of Runner, m

     //(c)
        Pr=rho*Q*(Vwi-Vwo)*u/1000;       // Power developed by Runner, kW
```

```
    //(d)
        eta_m=P/(Pr*1000)*100;          //Mechanical Efficiency in Percentage


//Results:-
    printf("(a) Diameter of the Jet, d=%.3f m\n",d)
    printf(" (b)Diameter of the Runner, D=%.3f m\n",D)         //The answer vary due to round off error
    printf(" (c)Power Developed by the Runner=%.3f kW\n",Pr)          //The answer provided in the textbook is wrong
    printf(" (d)Mechanical Efficiency , eta_m=%.2f Percent\n",eta_m)        //The answer vary due to round off error
```

Scilab code Exa 4.15 To Find a Power lost in Nozzle b Power lost due to Hydraulic

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.15

    clc
     clear

//Given Data:-
    H=120;      //Head, m
    d=74;         //Diameter of Jet, mm
    Q=200;        //Discharge,  litres/s
    P=202.766;          //Shaft Power, kW
    P_mr=3.2;        //Power lost in mechanical resistance,  kW
```

```


//Data Used:-
        rho=1000;          //Density of water, kg/m^3
         g=9.81;            //Acceleration due to gravity, m/s^2

//Computations:-
              Q=Q/1000;          //m^3/s
              d=d/1000;        //m
             P=P*1000;       //W
             P_mr=P_mr*1000;       //W

            Vi=Q/((%pi/4)*d^2);        //m/s
            P_n=(rho*Q*g*H-rho*Q*Vi^2/2)/1000;          //Power lost in Nozzle, kW
            P_hr=(rho*Q*g*H-(P+P_n*1000+P_mr))/1000;          //Power lost due to hydraulic resistance in Runner, kW


//Results:-
     printf("(a) Power lost in Nozzle=%.3f kW\n",P_n)        //The answer vary due to round off error
     printf(" (b)Power lost due to Hydraulic Resistance in Runner =%.2f kW\n",P_hr)        //The answer vary due to round off error
```

Scilab code Exa 4.16 To Find a The Power available at the base of Nozzle b Overall

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
```

```
//Example 4.16

      clc
       clear

//Given Data:-
       P=4900;          //Shaft Power, kW
      P_mr=100;         //Power absorbed in mechanical resistance, kW
      eta_H=92/100;          //Hydraulic Efficiency
      P_n=415;           //Power lost in Nozzle, kW


 //Computations:-
           P_rd=P+P_mr;            //Power Devrloped by Runner, kW
           P_rs=P_rd/eta_H;         //Power Supplied to Runner, kW
           P_an=P_n+P_rs;          //Power Available at base of Nozzle, kW
           eta_o=P/P_an*100;          //Overall Efficiency in Percentage

//Results:-
        printf("(a)Power Available at the Base of Nozzle=%.3f kW\n",P_an)          //The answer vary due to round off error
        printf("(b)Overall Efficiency, eta_o=%.2f Percent\n",eta_o)
```

Scilab code Exa 4.17 `To Find a Power developed by the runner b Hydraulic efficienc`

```
//Fluid system - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.17
```

```
    clc
    clear

//Given Data:-
        H_G=510;            //Gross Head, m
        h_f=(1/3)*H_G;          //Head lost in friction in penstock, m
        d=170;          //Diameter of Jet, mm
        AoD=165;            //Angle of Deflection of Jet, degrees
        Ku=0.45;            //Speed ratio
        Cv=0.98;        //Co-efficient of Velocity

//Data Used:-
    rho=1000;       //Density of water, kg/m^3
    g=9.81;         //Acceleration due to gravity, m/s^2

//Computations:-
        H=H_G-h_f;          //Effective Head, m
        Vi=Cv*sqrt(2*g*H);          //m/s
        Vwi=Vi;
        u=Ku*sqrt(2*g*H);           //m/s
        ui=u;
        uo=u;
        Vri=Vi-u;       //m/s
        Vro=Vri;
        beta_o=180-AoD;             //degrees
        Vrwo=Vro*cosd(beta_o);          //m/s
        Vwo=Vrwo-uo;            //m/s
        Q=(%pi/4)*(d/1000)^2*Vi;            //Discharge, m^3/s
        P=rho*Q*(Vwi+Vwo)*u/1000;           //Power developed by runner, kW
        eta_H=2*(Vwi+Vwo)*u/Vi^2*100;               //Hydraulic efficiency, In percentage

```

```
//Results:-
    printf("(a)Power developed by the runner=%.3f kW  \n",P) //The answer provided in the Textbook is wrong
    printf("(b)Hydraulic efficiency, eta_H=%.2f percent", eta_H)       //The answer vary due to round off error
```

Scilab code Exa 4.18 To Find a Speed of runner in rpm b Diameter of each Jets c Me

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.18

     clc
      clear

//Given Data:-
      Ns=15;          //Specific Speed
     P=1200;         //Shaft Power, kW
     Ht=500;      //Total Head at reservoir, m
     Loss_per=5;       //Percentage of Head loss in Pipe friction
     Cv=0.98;         //Co-efficient of Velocity
     Ku=0.45;         //Speed Ratio
    eta_o=85/100;       //Overall Efficiency
     n=2;        //Number of Jets

//Data Used:-
       rho=1000;          //Density of water, kg/m^3
        g=9.81;             //Acceleration due to gravity, m/s^2

//Computations:-
```

```
            H=Ht-Loss_per/100*Ht;           //Effective Head, m

        //(a)Speed of Runner, N
                N=Ns*H^(5/4)/sqrt(P/n);         //rpm

       //(b)Diameter od each Jet, d
            Q=P*1000/(rho*g*H*eta_o);           //Net Discharge, m^3/s
             q=Q/n;                  //Net Discharge per Jet, m^3/s
             Vi=Cv*sqrt(2*g*H);          //m/s
            d=sqrt(q/((%pi/4)*Vi));           //m

        //(c)Mean Diameter of Bucket Circle, D
           D=Ku*60*sqrt(2*g*H)/(%pi*N);           //m

       //(d)Number of Buckets in the Runner, Z
             Z=round(0.5*D/d+15);

//Results:-
          printf(" (a)Speed of the Runner, N=%.f rpm\n",N)
          printf(" (b)Diameter od each Jet, d =%.3f m\n",d)
          printf(" (c)Mean Diameter of Bucket Circle, D =%.3f m\n",D)
          printf(" (d)Number of Buckets on the Runner, Z =%.f \n",Z)
```

Scilab code Exa 4.19 To Find a Shaft Power b Diameter of the Jet c Diameter of the

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.19
```

```
clc
 clear

//Given Data:-
      Q=2.5;              //Total Discharge, m^3/s
      Hr=300;           //Head from reservoir to base
         of nozzle, m
      n=6;          //Total number of Jets
      L=1200;       //Lenght of Pipe, m
      eta_p=92/100;           //Efficiency of Power
         Transmission
      eta_o=86/100;         //Overall Efficiency
      Cv=0.97;          //Co-efficient of Velocity
      f=0.0025;       //Darcy Co-efficient of
         Friction


//Data Used:-
        rho=1000;            //Density of water, kg/m
           ^3
         g=9.81;              //Acceleration due to
            gravity, m/s^2

//Computations:-
            h_f=(1-eta_p)*Hr;        //m
            H=Hr-h_f;              //Effective Head, m
            Vi=Cv*sqrt(2*g*H);            //Velocity
               of Jet, m/s

       //(a)Shaft Power, P
             P=rho*Q*g*H*eta_o/1000;           //kW

       //(b)Diameter of the Jet, d
          q=Q/n;         //Discharge per Jet, m^3/s
          d=sqrt(q/((%pi/4)*Vi));          //m

      //(c)Diameter of the Pipe, D_pipe
```

```
            D_pipe=(64*f*L*Q^2/(h_f*2*g*%pi^2))^(1/5)*1000;        //mm

//Results:-
        printf(" (a)Shaft Power, P=%.3f kW\n",P)
        printf(" (b)Diameter of the Jet, d=%.4f m\n",d)
        printf(" (c)Diameter of the Pipe, D_pipe=%.2f mm\n",D_pipe)        //The answer vary due to round off error
```

Scilab code Exa 4.20 `To Find a Diameter of the the Nozzle b Speed Ratio c Specific`

```
//Fluid Systems - By - Shiv Kumar
//Chapter 4 - Pelton Turbine (Impulse Turbine)
//Example 4.20

      clc
       clear

//Given Data:-
      D=1.6;          //Mean Diameter of Bucket Circle, m
      P=3200;          //Power Developed, kW
      n=2;          //Number of Wheels
      H=300;          //Effective Head, m
      N=410;          //Speed, rpm
      eta_o=0.89;         //Overall Efficiency
      Cv=0.98;          //Co-efficient of Velocity


//Data Used:-
        rho=1000;            //Density of water, kg/m^3
         g=9.81;             //Acceleration due to
```

```
              gravity , m/s^2

//Computations:-
        Q=P*1000/(rho*g*H*eta_o);                //Discharge , m^3/s

      //(a)Diameter of the Nozzle , d
              Vi=Cv*sqrt(2*g*H);         //m/s
               d=sqrt(Q/((%pi/4)*Vi))*1000;        //mm

     //(b)Speed Ratio , Ku
              u=%pi*D*N/60;            //m/s
              Ku=u/sqrt(2*g*H);

     //(c)Specific Speed , Ns
          Ns=N*sqrt(P/n)/(H^(5/4));         // In SI Units


//Results:-
        printf(" (a)Diameter of the Nozzle , d=%.2f mm\n",d)        //The answer vary due to round off error
        printf(" (b)Speed Ratio , Ku =%.3f \n",Ku)        //The answer vary due to round off error
        printf(" (c)Specific Speed , Ns =%.f (SI Units)\n",Ns)
```

Chapter 5

Francis Turbine

Scilab code Exa 5.1 To Find a Discharge passing through the Runner and b Width of

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.1
//To Find (a)Discharge passing through the Runner
   and (b) Width of Runner at Outlet

     clc
     clear

//Given Data:-
    Do=0.8;         //External Diameter of the Runner
       , m
    Di=0.4;          //Internal Diameter of the
       Runner, m
    Vfi=1.4;        //Velocity of Flow at Inlet, m/s
    Vfo=Vfi;       //Velocity of Flow at Outlet, m/s
    bo=210;     //Width of Runner at Inlet, mm

//Computations:-
        Q=%pi*Do*(bo/1000)*Vfi;          //Discharge
           passing through the Runner, m^3/s
```

```
      bi=Do*bo/Di;          //Width of Runner at Outlet, mm

//Results
  printf("(a)Discharge passing through the Runner, Q=%.4f m^3/s\n",Q)        //The Answer Vary due to  Round off Error
  printf("(b)Width of Runner at Outlet, bi=%.f mm",bi)
```

Scilab code Exa 5.2 To Find a Discharge b Power Developed and c Hydraulic Efficien

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.2
//To Find  (a)Discharge   (b) Power Developed  and  (c)Hydraulic Efficiency

    clc
    clear

//Given Data:-
    Do=1.2;         //Diameter of Runner at Inlet, m
    Ao=0.4;         //Area of Flow at Inlet, m^2
    N=500;         //Speed of Runner, rpm
    H=135;         //Head, m
    alpha_i=20;         //Guide Vane Angle at Inlet, degrees
    beta_i=65;           //Vane angle at Inlet, degrees

//Data Required:-
      rho=1000;        //Density of Water, Kg/m^3
      g=9.81;            //Acceleration due to gravity, m/s^2
```

```


//Computations:-
        ui=%pi*Do*N/60;      //m/s
        Vri=ui*sind(alpha_i)/sind(beta_i-alpha_i);
            //m/s
        Vfi=Vri*sind(beta_i);         //m/s
        Vwi=Vfi/tand(alpha_i);        //m/s

    //(a)Discharge, Q
            Q=Ao*Vfi;         //m^3/s

    //(b)Power develpoed by Runner
            P=rho*Q*Vwi*ui/1000;         //kW

    //(c)Hydraulic Efficiency, eta_H
            eta_H=Vwi*ui*100/(g*H);         //
               Percentage


//Results:-

printf(" (a)Discharge, Q=%.3f m^3/s\n ",Q)      //The
    Answer Vary due to Round off Error
printf(" (b)Power develpoed by Runner=%.3f kW\n ",P)
         //The Answer provided in the Textbook is
   Wrong
printf(" (c)Hydraulic Efficiency, eta_H =%.2f
   Percent\n ",eta_H)         //The Answer Vary due
   to Round off Error
```

Scilab code Exa 5.3 To Find a The Absolute Velocity of Water at Inlet of Runner b

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
```

```
//Example 5.3
//To Find  (a)The Absolute Velocity of Water at Inlet of Runner   (b)The Velocity of Whirl at Inlet    (c) The Relative Velocity at Inlet
        //(d) The Runner Blade Angles    (e)Width of Runner at Outlet   (f)Weight of Water flowing through the Runner per second
        //(g)Head at Inlet of the Turbine   (h)Power developed    (i) Hydraulic Efficiency of the Turbine

     clc
     clear

//Given Data:-
    Do=1;           // External Diameter of Runner, m
    Di=0.5;         //Internal Diameter of Runner, m
    N=200;        //Speed of Turbine, rpm
    bo=225;      //Width of Runner at Inlet, mm


     Vfi=2.15;    //Velocity of flow at Inlet, m/s
   // As Velocity of Flow is constant through the Runner,
        Vfo=Vfi;    //Velocity of flow at Outlet, m/s
        Vo=Vfo;
      alpha_i=11;        //Guide Blades Angle at Inlet, degrees
   //As Discharge at Outlet of the Turbine is Radial,
     alpha_o=90;          //Guide Blades angle at Outlet, degrees
     Vwo=0;


//Data Required:-
```

```
      rho=1000;       //Density of Water, Kg/m^3
      g=9.81;          //Acceleration due to gravity, m/s^2


//Computations:-
        ui=%pi*Do*N/60;     //m/s

    // (a)The Absolute Velocity of Water at Inlet of Runner,
            Vi=Vfi/sind(alpha_i);          //m/s

    //(b)The Velocity of Whirl at Inlet,
           Vwi=Vfi/tand(alpha_i);       //m/s


    // (c) The Relative Velocity at Inlet,
           Vri=sqrt(Vfi^2+(Vwi-ui)^2);          //m/s

    // (d) The Runner Blade Angles,   beta_i, beta_o
             beta_i=asind(Vfi/Vri);     //Runner Blade Angle at Inlet, degrees
             uo=%pi*Di*N/60;     //m/s
             beta_o=atand(Vfo/uo);         //Runner Blade Angle at Outlet, degrees

     // (e)Width of Runner at Outlet , bi
              bi=Do*bo/Di;        //mm

    // (f)Weight of Water flowing through the Runner per second, W
              W=rho*g*%pi*Do*(bo/1000)*Vfi/1000;          //kN/s

    //(g)Head at Inlet of the Turbine, H
             H=Vwi*ui/g+Vo^2/(2*g);     //m

```

```
    // (h)Power developed by the Runner,
            Q=%pi*Do*(bo/1000)*Vfi;        //m^3/s
             P=rho*Q*Vwi*ui/1000;        //kW
    //(i)Hydraulic Efficiency , eta_H
               eta_H=Vwi*ui*100/(g*H);        //In Percentage

//Results:-
      printf("(a)The Absolute Velocity of Water at Inlet of Runner, Vi=%.3f m/s\n",Vi)  //The Answer Vary due to Round off Error
      printf(" (b)The Velocity of Whirl at Inlet, Vwi=%.2f m/s\n",Vwi)
      printf(" (c) The Relative Velocity at Inlet, Vri=%.2f m/s\n",Vri)
      printf(" (d) The Runner Blade Angles are:- \n      beta_i =%.2f Degrees    and      beta_o =%.2f Degrees\n",beta_i,beta_o)        //The Answer Vary due to Round off Error
      printf(" (e)Width of Runner at Outlet , bi =%.f mm\n",bi)
      printf(" (f)Weight of Water flowing through the Runner per second, W =%.2f kN/s\n",W)        //The Answer Vary due to Round off Error
      printf(" (g)Head at Inlet of the Turbine, H =%.3f m\n",H)        //The Answer Vary due to Round off Error
      printf(" (h)Power developed by the Runner =%.3f kW\n",P)        //The Answer Vary due to Round off Error
      printf(" (i)Hydraulic Efficiency , eta_H =%.2f Percent\n",eta_H)        //The Answer Vary due to Round off Error
```

Scilab code Exa 5.4 To Find a Diameter and Width at Inlet ant Outlet b Runner Vane

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.4
//To Find  (a)Diameter and Width at Inlet ant Outlet      (b)Runner Vane Angles at Inlet and Outlet     (c)Guide Blade Angles

    clc
    clear

//Given Data:-
        H=70;       //Net Head, m
        N=700;      //Speed, rpm
        P=330;      //Shaft Power, kW
        eta_o=85/100;        //Overall Efficiency
        eta_H=92/100;       //Hydraulic Efficiency
        Kf=0.22;              //Flow Ratio
        bo_by_Do=0.1;        //Breadth Ratio
        t_per=6;        //Percentage of Circumferential Area occupied by the Thickness of Vanes
        Kt=1-t_per/100;         //Vane Thickness Factor
      //As Outer Diameter= 2 times the Inner Diameter,
             Do_by_Di=2;        //Do/Di


//Data Required:-
    rho=1000;         //Density of Water, Kg/m^3
    g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
        Vfi=Kf*sqrt(2*g*H);      //m/s
         Vfo=Vfi;
```

```
Q=P*1000/(rho*g*H*eta_o);          //m^3/s

//(a)Diameter and Width at Inlet ant Outlet,
    Do,bo, Di and bi.
            Do=sqrt(Q/(Kt*%pi*bo_by_Do*Vfi));
                //m
            Di=Do/Do_by_Di;          //m
            bo=Do*bo_by_Do*1000;         //mm
            bi=Do*bo/Di;           //mm

        ui=%pi*Do*N/60;        //m/s
        uo=%pi*Di*N/60;      //m/s
        Vwi=eta_H*g*H/ui;      //m/s

// (b)Runner Vane Angles at Inlet and Outlet,
    beta_i,beta_o
            beta_i=atand(Vfi/(Vwi-ui));        //
                Runner Vane Angle at Inlet,
                degrees
            beta_o=atand(Vfo/uo);        //Runner
                Vane Angle at Outlet, degrees

//(c)Guide Vane Angle, alpha_i
            alpha_i=atand(Vfi/Vwi);        //
                degrees
        //As flow is radial at outlet,
            alpha_o=90;       //degrees

//Results:-
printf(" (a)Diameter and Width at Inlet and
    Outlet are: \n\t")
    printf("Do=%.3f m       bo=%.1f mm\n          Di=
        %.3f m       bi=%.1f mm\n",Do,bo,Di,bi)
                //The Answer Vary due to Round off
        Error
printf(" (b)Runner Vane Angles at Inlet and
    Outlet are:-   \n          beta_i=%.2f Degrees    ,
        beta_o =%.2f Degrees \n",beta_i,beta_o)
```

```
            //The Answer Vary due to Round off Error
    printf(" (c)Guide Vane Angles, \n       alpha_i=%.2f Degrees   ,  alpha_o=%.f Degrees\n ",alpha_i,alpha_o)        //The Answer Vary due to Round off Error
```

Scilab code Exa 5.5 To Determine a Guide Blade Angle b Runner Vane Angles at Inlet

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.5
//To Determine  (a) Guide Blade Angle    (b)Runner Vane Angles at Inlet and Outlet    (c) Diameter of Runner at Inlet and Outlet        (d) Width of Wheel at Inlet.

    clc
    clear

//Given Data:-
        H=70;       //Net Head, m
        N=600;     //Speed, rpm
        P=367.875;     //Shaft Power, kW
        eta_o=85/100;        //Overall Efficiency
        eta_H=95/100;       //Hydraulic Efficiency
        Kf=0.25;               //Flow Ratio
        bo_by_Do=0.1;        //Breadth Ratio
        t_per=10;        //Percentage of Circumferential Area occupied by the Thickness of Vanes
        Kt=1-t_per/100;         //Vane Thickness Factor
     //As Outer Diameter= 2 times the Inner Diameter,
```

```
                Do_by_Di=2;       //Do/Di


//Data Required:-
     rho=1000;        //Density of Water, Kg/m^3
     g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
        Vfi=Kf*sqrt(2*g*H);      //m/s
         Vfo=Vfi;
        Q=P*1000/(rho*g*H*eta_o);          //m^3/s

                Do=sqrt(Q/(Kt*%pi*bo_by_Do*Vfi));        //m
                Di=Do/Do_by_Di;          //m
                bo=Do*bo_by_Do*1000;         //mm
                bi=Do*bo/Di;            //mm

            ui=%pi*Do*N/60;       //m/s
            uo=%pi*Di*N/60;     //m/s
            Vwi=eta_H*g*H/ui;     //m/s

    //(a)Guide Vane Angle, alpha_i
               alpha_i=atand(Vfi/Vwi);        //degrees

    // (b)Runner Vane Angles at Inlet and Outlet, beta_i,beta_o
                beta_i=atand(Vfi/(Vwi-ui));        //Runner Vane Angle at Inlet, degrees
                beta_o=atand(Vfo/uo);        //Runner Vane Angle at Outlet, degrees


      //(c)Diameter of Runner at Inlet ant Outlet, Do and Di .
```

```
                           //Calculated Above

      // (d) Width of Wheel at Inlet , bi.
                       //Calculated Above

 //Results:-
    printf(" (a)Guide Vane Angle ,   alpha_i=%.2 f
       Degrees\n ",alpha_i)           //The Answer
       Vary due to Round off Error

    printf(" (b)Runner Vane Angles at Inlet and
       Outlet are:-  \n        beta_i=%.2 f Degrees   ,
          beta_o =%.2 f Degrees \n",beta_i,beta_o)
              //The Answer Vary due to Round off
       Error

    printf(" (c)Diameter of Runner at Inlet and
       Outlet are: \n           Do=%.4 f m            Di
       =%.4 f m \n",Do,Di)          //The Answer(Do)
       Vary due to Round off Error
    printf(" (d) Width of Wheel at Inlet , bo=%.2 f mm
       \n",bo )          //The Answer Vary due to
       Round off Error
```

Scilab code Exa 5.6 To Find a Guide Blade Angles b Blade Angle at Inlet c Power De

```
//Fluid Systems - By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.6
//To Find   (a) Guide Blade Angles    (b) Blade
   Angle at Inlet     (c) Power Developed

      clc
      clear

```

```
//Given Data:-
            Q=300;      //Discharge, litres/s
            Di=0.36;     //Diameter of Runner at Outlet, m
            Dp=Di;        //Diameter of Outlet Pipe, m
            H=36;         //Head,  m
            ui=21;        // Velocity of Wheel at Inlet, m/s

//Data Required:-
        rho=1000;      //Density of water, Kg/m^3
        g=9.81;           //Acceleration due to gravity, m/s^2

//Computations:-
        Vfo=(Q/1000)/((%pi/4)*Di^2);       //m/s
        Vo=Vfo;
        Vfi=Vfo;
    //By Energy Balance Equation,
         Vwi=(g*H-Vo^2/2)/ui;        //m/s

    // (a) Guide Blade Angles,      alpha_i, alpha_o
            alpha_i=atand(Vfi/Vwi);      //degrees
        //As Discharge is Radial,
             alpha_o=90;           //degrees

    // (b) Blade Angle at Inlet, beta_i
             beta_i=180-atand(Vfi/(ui-Vwi));        //degrees

   // (c) Power Developed by Runner
             P=rho*(Q/1000)*Vwi*ui/1000;        //kW

//Results:-
      printf(" (a) Guide Blade Angles are: \n          alpha_i=%.2f Degrees,      alpha_o=%.f Degrees\n",alpha_i, alpha_o )
```

```
printf(" (b) Blade Angle at Inlet, beta_i=%.2f Degrees\n",beta_i)
printf(" (c) Power Developed by Runner, P =%.2f kW\n",P)          //The Answer Vary due to Round off Error
```

Scilab code Exa 5.7 To Determine a The Diameter of Wheel b The Quantity of Water S

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.7
//To Determine  (a) The Diameter of Wheel   (b) The Quantity of Water Supplied    (c) The Guide Blade Angle at Inlet       (d) The Runner Vane Angles at Inlet and Exit.

    clc
    clear

//Given Data:-
        P=368;       //Shaft Power, kW
        H=71;         //Head, m
        N=748;       //Speed, rpm
        bo_by_Do=0.1;          //Breadth Ratio
        Kf=0.15;                //Flow Ratio
        eta_H=95/100;         //Hydraulic Efficiency
        eta_m=85/100;       //Mechanical Efficiency
        eta_v=100/100;      //Volumetric Efficiency (Assumed to be 100%)

    //As Inner Diameter is Half the  Outer Diameter,
            Di_by_Do=1/2;         //Di/Do


```

```
//Data Required:-
     rho=1000;          //Density of Water, Kg/m^3
     g=9.81;         //Acceleration due to gravity, m/
        s^2

//Computations:-
        eta_o=eta_H*eta_m*eta_v;       //Overall
           Efficiency
        Q=P*1000/(rho*g*H*eta_o);          //m^3/s
        Vfi=Kf*sqrt(2*g*H);       //m/s
         Vfo=Vfi;
               Do=sqrt(Q/(%pi*bo_by_Do*Vfi));
                  //m
               Di=Do*Di_by_Do;          //m

    // (a) The Diameter of Wheel, Do
            //Calculated Above

    // (b) The Quantity of Water Supplied, Q
             //Calculated Above

   // (c) The Guide Blade Angle at Inlet , alpha_i

           ui=%pi*Do*N/60;       //m/s
           uo= %pi*Di*N/60;       //m/s
           Vwi=eta_H*g*H/ui;     //m/s
           alpha_i=atand(Vfi/Vwi);        //degrees

    // (d)Runner Vane Angles at Inlet and Outlet,
       beta_i, beta_o
               beta_i=atand(Vfi/(Vwi-ui));        //
                  Runner Vane Angle at Inlet,
                  degrees
               beta_o=atand(Vfo/uo);        //Runner
                  Vane Angle at Outlet, degrees


 //Results:-
```

```
    printf(" (a) The Diameter of Wheel, Do =%.3f m\n",Do )
    printf(" (b) The Quantity of Water Supplied, Q=%.4f m^3/s\n",Q )
    printf(" (c) The Guide Blade Angle at Inlet , alpha_i=%.2f Degrees\n",alpha_i )          //The Answer Vary due to Round off Error
    printf(" (d)Runner Vane Angles at Inlet and Outlet are:- \n      beta_i=%.2f Degrees , beta_o =%.2f Degrees \n",beta_i,beta_o )      //The Answer Vary due to Round off Error
```

Scilab code Exa 5.8 Theoritical Problem

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.8
   //Theoritical Problem .
```

Scilab code Exa 5.9 To Find i Guide Blade Angle at Inlet ii The Wheel Vane Angle a

```
//Fluid Systems - By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.9
//To Find  (i) Guide Blade Angle at Inlet    (ii) The Wheel Vane Angle at Inlet    (iii) Diameter of Wheel at inlet        (iv)Width of Wheel at Inlet

    clc
    clear

```

```
//Given Data:-
      //Data Required
       rho=1000;     //Density of water, Kg/m^3
       g=9.81;          //Acceleration due to gravity, m/s^2

           eta_o=76/100;       //Overall Efficiency
           P=150;          //Power Produced, kW
           H=8;         // Working Head, m
           ui=0.25*sqrt(2*g*H);       //Peripheral Velocity at Inlet, m/s
           Vfi=0.95*sqrt(2*g*H);       //Velocity of Flow at Inlet, m/s
           N=150;           //Speed, rpm
           H_loss=20;       //Percentage of Hydraulic Losses in the Turbine (of Available Energy)
    //As Discharge is Radial,
            alpha_o=90;   //Degrees          //Vfo=Vo
            Vwo=0;

//Computations:-
        Do=ui*60/(%pi*N);      //m
        Q=P*1000/(rho*g*H*eta_o);       //m^3/s
        bo=Q/(%pi*Do*Vfi);    //m

    //By Energy Balance Equation,
        Vwi=(g*H-(H_loss/100)*g*H)/ui;       //m/s

            alpha_i=atand(Vfi/Vwi);     //degrees
            beta_i=atand(Vfi/(Vwi-ui));       //degrees


//Results:-
      printf(" (i) Guide Blade Angle at Inlet, alpha_i=%.2f Degrees\n",alpha_i)         //
```

```
The Answer Vary due to Round off Error
printf(" (ii) The Wheel Vane Angle at Inlet, beta_i =%.2f Degrees\n", beta_i )                //The Answer Vary due to Round off Error
printf(" (iii) Diameter of Wheel at Inlet, Do =%.4f m\n",Do)            //The Answer Vary due to Round off Error
printf(" (iv)Width of Wheel at Inlet , bo =%.4f m\n",bo)
```

Scilab code Exa 5.10 To Find i Guide Blade Angle at Inlet ii The Wheel Vane Angle

```
//Fluid Systems - By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.10
//To Determine  (i) The Guide Blade Angle   (ii) The Wheel Vane Angle at Inlet   (iii) Diameter of Wheel at inlet      (iv)Width of Wheel at Inlet

    clc
    clear

//Given Data:-
    //Data Required
     rho=1000;     //Density of water, Kg/m^3
     g=9.81;           //Acceleration due to gravity, m/s^2

        eta_o=75/100;        //Overall Efficiency
        P=148.25;          //Power Produced, kW
        H=7.62;          // Working Head,  m
        ui=0.26*sqrt(2*g*H);        //Peripheral Velocity at Inlet, m/s
        Vfi=0.96*sqrt(2*g*H);        //Velocity of
```

```
             Flow at Inlet , m/s
            N=150;            //Speed , rpm
            H_loss=22;        //Percentage of
               Hydraulic Losses in the Turbine (of
               Available Energy)
    //As Discharge is Radial ,
             alpha_o=90;    //Degrees          //Vfo=
                Vo
             Vwo=0;

//Computations:-
        Do=ui*60/(%pi*N);       //m
        Q=P*1000/(rho*g*H*eta_o);        //m^3/s
        bo=Q/(%pi*Do*Vfi);     //m

    //By Energy Balance Equation ,
        Vwi=(g*H-(H_loss/100)*g*H)/ui;        //m/s

            alpha_i=atand(Vfi/Vwi);     //degrees
            beta_i=atand(Vfi/(Vwi-ui));        //
               degrees


//Results:-
      printf(" (i)The Guide Blade Angle , alpha_i=%
         .2f Degrees\n",alpha_i)
      printf(" (ii) The Wheel Vane Angle at Inlet ,
         beta_i =%.2f Degrees\n", beta_i )         //
         The Answer Vary due to Round off Error
      printf(" (iii) Diameter of Wheel at Inlet , Do
         =%.4f m\n",Do)          //The Answer Vary due
          to Round off Error
      printf(" (iv)Width of Wheel at Inlet , bo =%.4
         f m\n",bo)         //The Answer Vary due to
         Round off Error
```

Scilab code Exa 5.11 `To Determine The Flow Rate Guide Vane Angles Runner Vane Angl`

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.11
//To Determine  The Flow Rate, Guide Vane Angles, Runner Vane Angles  and Inner and Outer Diameters of the Runner.

    clc
    clear

//Given Data:-
        H=86.4;        //Net Head, m
        N=650;      //Speed, rpm
        P=397;      //Shaft Power, kW
        bo_by_Do=0.1;        //Breadth Ratio
        Di_by_Do=0.5;        //Di/Do
        Kf=0.17;              //Flow Ratio
        eta_H=95/100;       //Hydraulic Efficiency
        eta_o=85/100;      //Overall Efficiency
    //As Discharge is Radial and Flow Velocity is Constant,
          alpha_o=90;      //degrees          //Vfi=Vfo=Vo


//Data Required:-
    rho=1000;         //Density of Water, Kg/m^3
    g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
        Q=P*1000/(rho*g*H*eta_o);         //m^3/s
```

```
         Vfi=Kf*sqrt(2*g*H);      //m/s
          Vfo=Vfi;
                Do=sqrt(Q/(%pi*bo_by_Do*Vfi));      //m
                Di=Do*Di_by_Do;           //m
               ui=%pi*Do*N/60;       //m/s
               uo= %pi*Di*N/60;       //m/s
               Vwi=eta_H*g*H/ui;     //m/s
                alpha_i=atand(Vfi/Vwi);        // degrees
                beta_i=atand(Vfi/(Vwi-ui));        // Runner Vane Angle at Inlet, degrees
                beta_o=atand(Vfo/uo);        //Runner Vane Angle at Outlet, degrees


//Results:-
    printf(" (i) The Flow Rate, Q=%.3f m^3/s\n",Q )
    printf(" (ii) Guide Vane Angles are: \n   alpha_i=%.2f Degrees   ,   alpha_o=%.f Degrees\n",alpha_i,alpha_o)        //The Answer Vary due to Round off Error
    printf(" (iii) Runner Vane Angles are:-  \n         beta_i=%.2f Degrees  ,   beta_o =%.2f Degrees \n",beta_i,beta_o )        //The Answer Vary due to Round off Error
    printf(" (iv) Inner and Outer Diameters of the Runner are: \n        Di=%.2f m    ,     Do=%.2f m \n",Di,Do )
```

Scilab code Exa 5.12 To Determine a Overall Efficiency b The Direction of Flow rel

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
```

```
//Example 5.12
    clc
    clear

//Given Data:-
            Dp=5;         //Diameter at Penstock, m
            P=61000;      //Output Power, kW
            Q=110;        //Discharge, m^3/s
            N=160;       //Speed, rpm
            eta_H=94/100;           //Hydraulic Efficiency
            Do=4;            //Diameter of Runner at Inlet, m
            bo=1;            //Width of Runner at Inlet, m
            Ddi=4.2;       //Entry Diameter to Draft Tube, m
            V2=2.2;        //Velocity in Tail Race, m/s
            p_by_rho_g=58;      //Static Pressure Head (p/(rho*g)) , m
            Z=2.8;      //Level of Measurement above Tail Race, m
            loss=25;       //Percentage of loss in Draft Tube (of Velocity Head at its Entry)
            Z1=2.2;        //Level of Runner Exit above Tail Race, m

//Data Required:-
        rho=1000;       //Density of Water, Kg/m^3
        g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
          Vp=4*Q/(%pi*Dp^2);        //Velocity in Penstock, m/s
          Vo=4*Q/(%pi*Ddi^2);       //Velocity at
```

```
           Entry to the Draft Tube, m/s
        Hp=p_by_rho_g+Z+Vp^2/(2*g);        //Head just before Entry to Runner, m
        H=Hp-V2^2/(2*g);         //Working Head, m

    //(a)Overall Efficiency
            eta_o=P*1000/(rho*Q*g*H)*100;       // In Percentage

    // (b) The Direction of Flow relative to the Runner at Inlet
            ui=%pi*Do*N/60;       //m/s
            Vwi=eta_H*g*H/ui;       //m/s
            Vfi=Q/(%pi*Do*bo);      //m/s
            beta_i=180-atand(Vfi/(ui-Vwi));     //degrees

    // (c) The Pressure Head at entry to Draft Tube, p1/(rho*g)
            //By Applying Bernoulli's Equation with ,
                  Z2=0;
                  p2_by_rho_g=0;
                  hf=(loss/100)*Vo^2/(2*g);

        p1_by_rho_g=p2_by_rho_g+(V2^2-Vo^2)/(2*g)+(Z2-Z1)+hf;      //m


//Results:-
    printf("(a)The Overall Efficiency, eta_o=%.2f Percent\n",eta_o)          //The Answer Vary due to Round off Error
    printf("(b)The Direction of Flow relative to the Runner at Inlet, beta_i=%.2f Degrees \n",beta_i)         //The Answer Vary due to Round off Error
    printf("(c) The Pressure Head at entry to Draft
```

```
Tube,    p1/(rho*g)=%.2f m (vaccum)\n",abs(p1_by_rho_g))
```

Scilab code Exa 5.13 To Determine the Blade Angle at Entry and Exit

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.13
//To Determine  the Blade Angle at Entry and Exit.

    clc
    clear

//Given Data:-
            R=0.6;          //Degree
            ui=15;          //Peripheral velocity of Runner at entry, m/s
            Vfo=3.2;        //m/s
            Vfi=Vfo;
            Vo=Vfo;
    //As the Diameter of rotor at entry is Twice that at exit,
            Do_by_Di=2;


//Computations:-
              Vwi=(1-R)*2*ui;       //m/s
              beta_i=180-atand(Vfi/(ui-Vwi));   //degrees
              uo=ui/Do_by_Di;       //Velocity of Runner at Outlet, m/s
              beta_o=atand(Vfo/uo);         //degrees


```

```
//Results:-
    printf("The Blade Angle at Entry, beta_i=%.2f Degrees\n",beta_i)        //The Answer Vary due to Round off Error
    printf("The Blade angle at Exit, beta_o=%.3f Degrees \n",beta_o)
```

Scilab code Exa 5.14 To Find the Pressure Head at the Entrance

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.14
//To Find  the Pressure Head at the Entrance.

    clc
    clear

//Given Data:-
        Vo=5.6;         //Velocity at Inlet, m/s
        Vd=1.4;        //Velocity at Outlet, m/s
        h_f=0.12;     //Friction Losses, m
        Ho=5.2;        //Vertical Height betwen tail-race and entrance of Draft-tube, m

//Data Required:-
    g=9.81;    //Acceleration due to gravity,  m/s^2

//Calculations:-
        //Applying Bernoulli's Equation with,
            Z2=0;
            pa_by_rho_g=0;
            p1_by_rho_g=pa_by_rho_g+(Vd^2-Vo^2)/(2*g)+Z2-Ho+h_f;        //m

```

```
//Results:-
                printf("The Pressure Head at Entrance,
                    p1/(rho*g)=%.3f m\n",p1_by_rho_g)
```

Scilab code Exa 5.15 To Find a Pressure Head at Tube Entrance b Efficiency of Draf

```
//Fluid Systems- By Shiv Kumar
//Chapter 5- Francis Turbine
//Example 5.15
     clc
     clear

//Given Data:-
             Vo=4.5;       //Velocity of water at Tube
                 Entrance,  m/s
             D1=0.4;      //Diameter of Tube at Upper
                End, m
             D2=0.65;     //Diameter of Tube at Lower
                End, m
             l=4.8;       //Length of Tube, m
             h_f=0.14;        //Head Losses due to
                Friction, m
             h=1;         //Length of Tube immersed
                in Tail-race, m

//Data Required:-
           pa=1.013e5;      //Air(Atmospheric)
              Pressure, Pa
           rho=1000;        //Density of Water, Kg/m^3
           g=9.81;          //Acceleration due to
              gravity, m/s^2

//Calculations:-
             A1=(%pi/4)*D1^2;      //Cross-sectional
                Area at Upper End, m^2
```

```
            A2=(%pi/4)*D2^2;      //Cross-sectional Area at Lower End, m^2
        //Using Continuity Equation,
            Vd=A1*Vo/A2;         //Velocity of Water at Outlet, m/s

       //(a)  Using Bernoulli's Equation,
           p1_by_rho_g=pa/(rho*g)+h+(Vd^2-Vo^2)/(2*g)-l+h_f;      //Absolute Pressure Head at Inlet, m

           //For Vaccum Pressure Head,
             pa_by_rho_g=0;
             p1_by_rho_g_v=pa_by_rho_g+h+(Vd^2-Vo^2)/(2*g)-l+h_f;      //Vaccum Pressure Head at Inlet, m

     //(b)Efficiency of Draft Tube:
            eta_d=(Vo^2-Vd^2-2*h_f*g)*100/Vo^2;         //In Percentage

//Results:-
     printf("(a)The Pressure Head at Tube Entrance is\n\t")
     printf(" p1/(rho*g)=%.3f m (Absolute)\n\t p1/(rho*g)=%.3f m (Vaccum)\n ",p1_by_rho_g,p1_by_rho_g_v)          //The Answer Vary due to Round off Error
     printf("(b)Efficiency of Draft Tube, eta_d=%.2f Percent\n",eta_d)          //The Answer Vary due to Round off Error
```

Chapter 6

Kaplan and Propeller Turbines

Scilab code Exa 6.1 To Find a Discharge b Diameter of Hub And Diameter of Runner c

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.1
//To Find (a)Discharge  (b)Diameter of Hub And Diameter of Runner (c)Speed

    clc
     clear

//Given:
   P=37;    //Shaft Power, MW
   H=22;    //Head, m
   eta_0=92/100;  //Overall Efficiency
   dbyD=1/3;    //Ratio of Diameters of Hub and Runner
   Kf=0.6;      //Flow Ratio
   Ku=2;        //Speed Ratio
//Data Required:
   rho=1000;    //Density of Water, Kg/m^3
   g=9.81;      //Acceleration due to gravity, m/s^2

```

```
//Computations

  //(a)Discharge, Q
     Q=P*10^6/(rho*g*H*eta_0);    //m^3/s

  //(b)Diameter of Hub(d) And Diameter of Runner(D)
      d=sqrt(Q/((%pi/4)*Kf*sqrt(2*g*H)*(dbyD^-2-1)))
         ;    //m
      D=d/dbyD;   //m

  //(c) Speed,N
     N=Ku*60*sqrt(2*g*H)/(%pi*D);   // rpm

//Results
  printf("(a)Discharge, Q=%.2f m^3/s \n",Q)    //The
     answer vary due to round off error
  printf(" (b)Diameter of Hub, d=%.2f m \n",d)
  printf("    Diameter of Runner, D=%.2f m \n",D)
     //The answer vary due to round off error
  printf(" (c)Speed, N=%.2f rpm \n",N)    //The
     answer vary due to round off error
```

Scilab code Exa 6.2 To Find Diameter of Runner Speed of Runner and Specific Speed

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.2
//To Find Diameter of Runner, Speed of Runner and
   Specific Speed of Turbine

     clc
     clear

//Given:
   P=8;    //Shaft Power, MW
```

```
    H=6;    //Head, m
    Ku=2.09;        //Speed Ratio
    Kf=0.68;      //Flow Ratio
    eta_0=90/100;  //Overall Efficiency
    dbyD=1/3;   //Ratio of Diameters of Hub and
       Runner

//Data Required:
    rho=1000;   //Density of Water, Kg/m^3
    g=9.81;     //Acceleration due to gravity, m/s^2

//Computations

      Q=P*10^6/(rho*g*H*eta_0);  //Discharge, m^3/s
      d=sqrt(Q/((%pi/4)*Kf*sqrt(2*g*H)*(dbyD^-2-1)));
            //Diameter of hub, m
      D=d/dbyD;  //Diameter of runner, m
      N=Ku*60*sqrt(2*g*H)/(%pi*D);  //Speed of Runner
          , rpm
      Ns=N*(P*10^3)^(1/2)/(H^(5/4));   //Specific
         Speed of Turbine, SI Units

//Results
  printf("Diameter of Runner, D =%.1f m \n",D)
  printf("Speed of Runner, N = %.2f rpm \n",N)    //
     The answer provided in the textbook is wrong
  printf("Specific Speed of Turbine, Ns = %.2f (SI
     Units)",Ns)  //The answer provided in the
     textbook is wrong(Due to error in N)
```

Scilab code Exa 6.3 To Find a Inlet and Outlet blade Angles b Mechanical Efficienc

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.3
```

```
//To Find (a)Inlet and Outlet blade Angles  (b)Mechanical Efficiency  (c)Volumetric Efficiency

     clc
      clear

//Given:
   D=6;     //Outer Diameter of Runner, m
   d=2;     //Inner Diameter of Runner, m
   P=30;    //Shaft Power, MW
   N=75;    //Speed, rpm
   H=12;    //Head, m
   Q=310    //Discharge through the Runner, m^3/s
   eta_H=96/100;   //Hydraulic Efficiency

//Data Required:
   rho=1000;    //Density of Water, Kg/m^3
   g=9.81;      //Acceleration due to gravity, m/s^2

//Computations

   u=%pi*D*N/60;      //Velocity of runner, m/s
   ui=u;
   uo=u;
   Vf=Q/((%pi/4)*(D^2-d^2))      // m/s
   Vfi=Vf;
   Vfo=Vf;
   Vwi=eta_H*g*H/ui;    // m/s   //The Answer Vary Because Value of ui used in book is Wrong

//(a)Inlet and Outlet blade Angles, Beta_i and Beta_o

    Beta_i=180-atand(Vfi/(ui-Vwi));    //Degrees
    Beta_o=atand(Vfo/uo);     //Degrees

//(b)Mechanical Efficiency,eta_m

```

```
eta_M=P*10^6/(rho*Q*Vwi*ui)*100;    //percentage(
    %)     //The Answer Vary Because Value of Vwi
    used in book is Wrong

//(c)Volumetric Efficiency, eta_v

  eta_o=P*10^6/(rho*Q*g*H)*100;     //Overall
    Efficiency, percentage(%)
  eta_v=eta_o/(eta_M*eta_H);    //percentage(%)
    //The Answer Vary Because Value of eta_m used
    in book is Wrong

//Results

 printf("(a)Inlet Blade Angle, Beta_i=%.2f degrees
    and \n",Beta_i)     //The answer vary due to
    round off error
 printf("    Outlet Blade Angle, Beta_o=%.2f degrees
    \n",Beta_o)      //The answer vary due to round
    off error
 printf("(b)Mechanical Efficiency, eta_m=%.2f
    percent\n",eta_M)      //The answer provided in
    the textbook is wrong
 printf("(c)Volumetric Efficiency, eta_v=%.2f
    percent\n ",eta_o)     //The answer provided in
    the textbook is wrong
```

Scilab code Exa 6.4 To Find a Discharge b Hydraulic Efficiency c Overall Efficienc

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.4
//To Find (a)Discharge  (b)Hydraulic Efficiency (c)
    Overall Efficiency  (d)Specific Speed

```

```
  clc
  clear

//Given:
     N=30   //Speed, rpm
     Alpha_i=31;    //Inlet Guide Vane Angle,
        Degrees
     Beta_i=90;      //Inlet Runner Vane Angle,
        Degrees
     Beta_o=24;      //Outlet Runner Vane Angle,
        Degrees
     Dm=4;          //Mean Diameter of Runner, m
     A=31;         //Area of Flow, m^2
     ML=5;     //Percent of Mechanical Loss
//Data Required:
   rho=1000;   //Density of Water, Kg/m^3
   g=9.81;     //Acceleration due to gravity, m/s^2

//Computations

   u=%pi*Dm*N/60;     //Velocity of runner, m/s
   ui=u;
   uo=u;
   Vwi=ui;
     Vfi=ui*tand(Alpha_i);    //m/s
  Vf=Vfi;
  Vfo=Vfi;
 Vrwo=Vfo/tand(Beta_o);    //m/s
 Vwo=Vrwo-uo;
  Vo=sqrt(Vfo^2+Vwo^2);      //m/s
//(a)Discharge, Q
     Q=A*Vfi;     //m^3/s
//(b) Hydraulic Efficiency, eta_H
     H= (Vwi+Vwo) *u/g+Vo^2/(2*g);     // Head, m
    eta_H=(Vwi*ui+Vwo*uo)*100/(g*H);     //Percent(%
       )
//(c)Overall  Efficiency, eta_o
     P=rho*Q*(Vwi+Vwo)*u*(1-ML/100);    //Shaft
```

```
Power, Watt(w)
eta_o=P/(rho*Q*g*H)*100;        //Percent(%)
//(d)Specific Speed,Ns
Ns=N*sqrt(P/1000)/(H^(5/4));     //SI Units

//Results
printf("(a)Discharge, Q=%.2f m^3/s\n",Q)       //The answer vary due to round off error
printf("(b) Hydraulic Efficiency, eta_H =%.2f Percent\n", eta_H)      //The answer vary due to round off error
printf("(c) Overall Efficiency, eta_o =%.2f Percent\n", eta_o)      //The answer vary due to round off error
printf("(d)Specific Speed, Ns =%.2f (SI Units)\n", Ns)       //The answer vary due to round off error
```

Scilab code Exa 6.5 To Find a Guide Vane Angle at Inlet b Runner Vane Angle at Inl

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.5
//To Find (a)Guide Vane Angle at Inlet  (b)Runner Vane Angle at Inlet

clc
clear

//Given:
P=22500 //Shaft Power, KW
H=20;    //Head, m
N=148;    //Speed, rpm
eta_H=95/100;   //Hydraulic Efficiency
eta_o=89/100;   //Overall Efficiency
```

```
    D=4.5;      //Diameter of Runner, m
    d=2;     //Diameter of Hub, m
    Beta_o=34    //Runner Vane Angle at Outlet,
       Degrees

//Data Required:
    rho=1000;    //Density of Water, Kg/m^3
    g=9.81;      //Acceleration due to gravity, m/s^2

//Computations

    u=%pi*D*N/60;       //Velocity of runner, m/s
    Q=P*10^3/(rho*g*H*eta_o);    //Discharge, m^3/s
         Vfi=Q/((%pi/4)*(D^2-d^2));      // m/s
  //As Velocity of Flow is Constant
           ui=u;
           uo=u;
         Vfo=Vfi;
         Vf=Vfo;
     Vrwo=Vfo/tand(Beta_o);     //m/s
     Vwo=uo-Vrwo;
          Vo=sqrt(Vfo^2+Vwo^2);       //m/s
         Vwi=(g*H-Vo^2/2)/u+Vwo ;     //m/s
//(a)Guide Vane Angle at Inlet,Alpha_i
      Alpha_i=atand(Vfi/Vwi);      //Degrees
//(b)Runner Vane Angle at Inlet,Beta_i
       Beta_i=180-atand(Vfi/(ui-Vwi));    //Degrees

//Results
         printf("(a)Guide Vane Angle at Inlet,
            Alpha_i=%.2f Degrees\n",Alpha_i)     //The
             answer vary due to round off error
        printf("(b)Runner Vane Angle at Inlet, Beta_i
           =%.f Degrees\n",Beta_i)     //The answer
            provided in the textbook is wrong
```

Scilab code Exa 6.6 To Find a Diameter of Runner b Speed of Turbine c Specific Spe

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.6
//To Find (a)Diameter of Runner  (b)Speed of Turbine
    (c)Specific Speed of the turbine

      clc
      clear

//Given:
   P=9100;   //Shaft Power, KW
   H=5.6;   //Net Available Head, m
   Ku=2.09;       //Speed Ratio
   Kf=0.68;     //Flow Ratio
   eta_0=86/100;  //Overall Efficiency
   dbyD=1/3;   //Ratio of Diameters of Hub and
      Runner

//Data Required:
   rho=1000;   //Density of Water, Kg/m^3
   g=9.81;     //Acceleration due to gravity, m/s^2

//Computations

     Q=P*10^3/(rho*g*H*eta_0);   //Discharge, m^3/s


      d=sqrt(Q/((%pi/4)*Kf*sqrt(2*g*H)*(dbyD^-2-1)))
         ;   // Diameter of Hub ,m
  //(i) Diameter of Runner ,D
      D=d/dbyD;  //m

```

```
  //(ii) Speed of Turbine,N
     N=Ku*60*sqrt(2*g*H)/(%pi*D);  // rpm
//(iii) Specific Speed of Turbine, Ns
     Ns=N*(P)^(1/2)/(H^(5/4));   // SI Units


//Results
    printf("(i)Diameter of Runner , D=%.2f m\n",D)
    printf("(ii)Speed of Turbine, N =%.2f rpm\n",N)   //The answer vary due to round off error
    printf("(iii) Specific Speed of Turbine, Ns =%.2f (SI Units)\n",Ns)    //The answer provided in the textbook is wrong(Due to error in N)
```

Scilab code Exa 6.7 `To Find a Diameter of Runner b Speed c Specific Speed`

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.7
//To Find (a)Diameter of Runner  (b)Speed (c) Specific Speed

clc
clear

//Given:
   H=32;   //Head, m
   P=16000;   //Shaft Power, KW
   D_per=190;  //Percentage by which Diameter of Runner(D)is Larger than diameter of Boss(d)
   eta_0=91/100;  //Overall Efficiency
   Ku=2;       //Speed Ratio
   Kf=0.64;     //Flow Ratio

//Data Required:
```

```
    rho=1000;    //Density of Water, Kg/m^3
    g=9.81;      //Acceleration due to gravity, m/s^2

//Computations

      Vfi=Kf*sqrt(2*g*H);      //Velocity of Flow at Inlet, m/s
      ui= Ku*sqrt(2*g*H);      //Velocity of Runner at Inlet, m/s

      Q=P*10^3/(rho*g*H*eta_0);    //Discharge, m^3/s


       d=sqrt(Q/((%pi/4)*Kf*sqrt(2*g*H)*((D_per/100+1)^2-1)));    // Diameter of Hub ,m
  //(a) Diameter of Runner ,D
       D=d+(D_per/100)*d;   //m

  //(b) Speed,N
      N=ui*60/(%pi*D);   // rpm
//(iii) Specific Speed of Turbine, Ns
      Ns=N*P^(1/2)/(H^(5/4));    // SI Units


//Results
     printf("(a)Diameter of Runner , D=%.3f m\n",D)
     printf(" (b)Speed, N =%.2f rpm\n",N)        //The answer vary due to round off error
     printf(" (c)Specific Speed, Ns =%.2f (SI Units)\n",Ns)     //The answer provided in the textbook is wrong.
```

Scilab code Exa 6.8 To Find Inlet and outlet Angles of the Runner blades

```
//Fluid System By Shiv Kumar
```

```
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.8
//To Find Inlet and outlet Angles of the Runner
   blades

clc
clear

//Given:
   H=25;   //Head, m
   P=23000;   //Shaft Power, KW
   D=5;    //External Diameter of Runner, m
   d=3;    //Diameter of Hub, m
   N=60;    //Rotational Speed, rpm
   eta_H=95/100;  //Hydraulic Efficiency
   eta_0=88/100;  //Overall Efficiency
   Vw=0;    //As there is no exit whirl

//Data Required:
   rho=1000;   //Density of Water, Kg/m^3
   g=9.81;     //Acceleration due to gravity, m/s^2

//Computations
     Dm=(D+d)/2;   //Mean Diameter of Runner, m
     ui=%pi*Dm*N/60   //m/s
     Q=P*10^3/(rho*g*H*eta_0);   //Discharge, m^3/s
            Vfi=Q/((%pi/4)*(D^2-d^2))     // m/s
            Vwi=eta_H*g*H/ui;     //m/s
                     uo=ui;
                     Vfo=Vfi;
            Beta_i=atand(Vfi/(Vwi-ui));    //Degrees
            Beta_o=atand(Vfo/uo);      //Degrees

//Results
       printf("At the Mean Radius\n\t")
       printf("Runner Blade Angle at Inlet, Beta_i=%
          .2f Degrees\n\t",Beta_i)      //The answer
          vary due to round off error
```

```
        printf("Runner Blade Angle at Outlet, Beta_o=
          %.2f Degrees\n",Beta_o)    //The answer
          vary due to round off error
```

Scilab code Exa 6.9 To Determine Runner Vane Angles at the hub and at the Outer Pe

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
//Example 6.9
//To Determine Runner Vane Angles at the hub and at
   the Outer Periphery

clc
clear

//Given:
   P=22500;   //Power Available at Shaft, KW
   H=20;   //Head, m
   N=150;    //Rotational Speed, rpm
   eta_H=95/100;  //Hydraulic Efficiency
   eta_0=88/100;  //Overall Efficiency
   D=4.5;    //Outer Diameter of Runner, m
   d=2;    //Diameter of Hub, m
   Vw=0;    //As there is no exit whirl

//Data Required:
   rho=1000;   //Density of Water, Kg/m^3
   g=9.81;     //Acceleration due to gravity, m/s^2

//Computations
    //Runner Vane Angles at Hub
     uo=%pi*d*N/60;  //m/s
       ui=uo;
     Q=P*10^3/(rho*g*H*eta_0);   //Discharge, m^3/s
             Vwi=eta_H*g*H/ui;     //m/s
```

```
              Vfi=Q/((%pi/4)*(D^2-d^2))      // m/s
        Vfo=Vfi;
             Beta_i=180-atand(Vfi/(ui-Vwi));     // Degrees
             Beta_o=atand(Vfo/uo);       //Degrees

//Result1
        printf("Runner Vane Angles at the Hub \n\t")
        printf("Beta_i=%.2f Degrees\n\t",Beta_i)   //The answer vary due to round off error
        printf("Beta_o=%.2f Degrees\n\n",Beta_o)   //The answer vary due to round off error

      // Runner Vane Angles at outer periphery
     uo=%pi*D*N/60;   //m/s
               ui=uo;
            Vwi=eta_H*g*H/ui;      //m/s
             Beta_i=180-atand(Vfi/(ui-Vwi));     // Degrees
             Beta_o=atand(Vfo/uo);       //Degrees

//Result2
        printf("Runner Vane Angles at the Outer periphery \n\t")
        printf("Beta_i=%.2f Degrees\n\t",Beta_i)        //The answer vary due to round off error
        printf("Beta_o=%.2f Degrees\n\n",Beta_o)        //The answer vary due to round off error
```

Scilab code Exa 6.10 To Determine i Hydraulic Efficiency of turbine ii Discharge t

```
//Fluid System By Shiv Kumar
//Chapter 6 - Kaplan and Propeller Turbines
```

```
//Example 6.10
//To Determine (i)Hydraulic Efficiency of turbine (ii)Discharge through the turbine (iii)Power Developed by the Runner

clc
clear

//Given:
      D=4.5;     // Runner Diameter, m
      N=48;      // Speed, rpm
      Alpha_i=145;      //Guide Vane Angle at Inlet, Degrees
      Beta_o=25;          //Runner blade Angle at Outlet
      A=30;        //Flow Area, m^2
    //As runner blade angle at inlet is radial
      Beta_i=90     //Degrees

//Data Required:
   rho=1000;   //Density of Water, Kg/m^3
   g=9.81;     //Acceleration due to gravity, m/s^2

//Calculations
      u=%pi*D*N/60;  //Velocity of Runner,m/s
     ui=u;
     uo=u;
     Vwi=ui;
   Vfi=ui*tand(180-Alpha_i);    //m/s
     Vfo=Vfi;
   Vrwo=Vfo/tand(Beta_o);   //m/s
   Vwo=Vrwo-uo;      //The answer vary because wrong Value of uo is used to calculate Vwo in the textbook
   Vo=sqrt(Vfo^2+Vwo^2);   //m/s       //The answer vary because wrong Value of Vwo is used to calculate Vo in the textbook

```

```
//(i)Hydraulic Efficiency , eta_H
    H= (Vwi-Vwo)*u/g+Vo^2/(2*g);      // Head, m           //The answer vary because wrong Value of Vo and Vwo is used to calculate H in the textbook
   eta_H=(Vwi*ui-Vwo*uo)*100/(g*H);      //Percent(%)

//(ii) Discharge through the turbine, Q
    Q=A*Vfi;      //m^3/s
//(iii)Power Developed by the Runner, P
  P=rho*Q*(Vwi-Vwo)*u/10^6;     //MW
//Results
   printf("(i)Hydraulic Efficiency , eta_H=%.2f Percent\n",eta_H)      //The answer given in the textbook is wrong
   printf("(ii) Discharge through the turbine, Q =%.1fm^3/s\n",Q)      //The answer vary due to round off error
   printf("(iii)Power Developed by the Runner, P =%.3fMW\n",P)      //The answer given in the textbook is wrong
```

Chapter 7

Performance of water turbine

Scilab code Exa 7.1 To Calculate specific speed of turbine and state the type of t

```
//Fluid Systems by Shiv Kumar
//Chapter 7 − Performance of water turbine
//Example 7.1
//To Calculate specific speed of turbine and state
   the type of turbine
   clc
   clear
//Given
   P=8000;        //Power developed , KW
   H=30;        //Head , m
   N=140;        //Speed , rpm
//Computations
       Ns=N*P^(1/2)/(H^(5/4));        // specific
          speed of turbine , in SI UNITS

//Results
      printf("The Specific speed of Turbine is %.2f
         (SI Units)\n",Ns)
   //To Determine the type of turbine
       if Ns>51 & Ns<=255 then
              printf(" The type of turbine is
```

```
                Francis")
    elseif  Ns>=8.5 & Ns<=30 then
           printf("The type of turbine is Pelton
              Wheel with single jet")
    elseif Ns>30& Ns<=51 then
           printf("The type of turbine is Pelton
              Wheel with multi jet")
    elseif Ns>255 & Ns<=860 then
            printf("The type of turbine is Kaplan
               or Propeller Turbine")
 end
```

Scilab code Exa 7.2 To Find a Specific speed of turbine b Power Developed c Type o

```
//Fluid Systems by Shiv Kumar
//Chapter 7 - Performance of water turbine
//Example 7.2
//To Find (a) Specific speed of turbine (b) Power
   Developed  (c) Type of turbine
    clc
     clear
//Given:

   H=28;          //Head, m
   N=225;         //Speed, rpm
   Q=10;          //Discharge, cumec=m^3/s
   eta_o=90/100;          //Overall Efficiency
//Data Required
    rho=1000    // Density of Water, Kg/m^3
    g=9.81;     // Acceleration due to gravity,  m/ s
       ^2
//Computations
   P=eta_o*rho*Q*g*H/1000;      //Power developed, KW
   Ns=N*P^(1/2)/(H^(5/4));        // specific speed
      of turbine , in SI UNITS
```

```
//Result1

    printf("(a)The Specific speed of Turbine = %.2f (SI Units)\n",Ns)        //The Answer Vary due to Round off Error
  printf("(b)Power developed =%.2f kW\n",P)
//To Determine the type of turbine, Result2
       if Ns>51 & Ns<=255 then
              printf("(c)The type of turbine is Francis.")
     elseif  Ns>=8.5  &  Ns<=30 then
            printf("(c)The type of turbine is Pelton Wheel with single jet.")
     elseif  Ns>30 & Ns<=51 then
            printf("(c)The type of turbine is Pelton Wheel with multi jet.")
     elseif  Ns>255 & Ns<=860 then
             printf("(c)The type of turbine is Kaplan or Propeller turbine.")

    end
```

Scilab code Exa 7.3 To Find a The Discharge required b The Diameter of Wheel c The

```
//Fluid Systems by Shiv Kumar
//Chapter 7 - Performance of water turbine
//Example 7.3
//To Find (a) The Discharge required   (b) The Diameter of Wheel  (c) The Diameter and number of jets required    (d)The Specific Speed
       clc
       clear
//Given:
    P=8200;     //Power Developed, kW
```

```
    H=128;      // Head , m
    N=210;     // Speed, rpm
    Cv=0.98;    // Co-efficient of Velocity
    eta_H=89/100;     //Hydraulic Efficiency
    Ku=0.45;      // Speed Ratio
   dbyD=1/10;    //Ratio of jet diameter to wheel Diameter
   eta_m=92/100;    //Mechanical Efficiency
//Data required
    rho=1000;    //Density of Water, Kg/m^3
    g=9.81;     // Acceleration due to gravity, m/s^2
//Assumptions:
    eta_v=100/100;     // Volumetric efficiency is 100%

//Computations
    D=Ku*sqrt(2*g*H)*60/(%pi*N);    //Wheel Diameter, m
    d=D*dbyD;       // Jet diameter, m
    eta_o=eta_H*eta_m*eta_v;    //Overall Efficiency
    Q=P*1000/(rho*g*H*eta_o);     //Net Discharge, m^3/s
    q=(%pi/4)*d^2*Cv*sqrt(2*g*H);     //Discharge through one jet, m^3/s
     n=round(Q/q);     //Number of jets
     Ns= N*P^(1/2)/(H^(5/4));     //Specific Speed, SI Units

//Results
printf("(a) The Discharge required, Q =%.3f m^3/s\n",Q)
printf("(b) The Diameter of Wheel, D =%.2f m\n",D)
printf("(c) The Diameter,  d=%.3f m  and\n number of jets required =%.f \n",d,n)
printf("(d)The Specific Speed, Ns=%.2f  (SI Units)\n",Ns)      //The Answer Vary due to Round off Error
```

Scilab code Exa 7.4 To Find a The Diameter of Runner b The Diameter of jet

```
//Fluid Systems by Shiv Kumar
//Chapter 7 - Performance of water turbine
//Example 7.4
//To Find (a) The Diameter of Runner (b) The Diameter of jet
    clc
     clear
//Given:
     P=3200;     //Power Developed, kW
     H=310;      // Effective Head , m
     eta_o=82/100;     //Overall Efficiency
     Ku=0.46;      //     Speed Ratio
     Cv=0.98   // Co-efficient of Velocity
     Ns=18;    //Specific Speed (SI Units)
//Data required
    rho=1000;    //Density of Water, Kg/m^3
    g=9.81     // Acceleration due to gravity, m/s^2

//Computations
     N=Ns*H^(5/4)/sqrt(P);     //Speed, rpm
     D=Ku*sqrt(2*g*H)*60/(%pi*N);      //Diameter of runner, m
     Q=P*1000/(rho*g*H*eta_o);      //Discharge, m^3/s
     d=sqrt(Q/((%pi/4)*Cv*sqrt(2*g*H)));     //Diameter of Jet, m

//Results
  printf("(a) The Diameter of Runner, D =%.2f m\n",D)         //The Answer Vary due to Round Off Error
  printf("(c) The Diameter of Jet,  d=%.3f m \n",d)
```

Scilab code Exa 7.5 To Find a Number of Units to be installed b Diameter of Wheel

```
//Fluid Systems by Shiv Kumar
//Chapter 7 - Performance of water turbine
//Example 7.5
//To Find (a) Number of Units to be installed (b)
   Diameter of Wheel  (c) Diameter of Jet
  clc
   clear

//Given:

     H_G= 310;   //Gross Head,m
     l=2.5;      // Length, km
     h_f=25;     // Friction Loses, J/N=m
     TO=20;    //Total Output Power, MW
     N=660;    // Speed, rpm
     ubyVi=0.46    //Ratio of bucket to jet speed
     eta_o=88/100;   //Overall Efficiency
     Ns=28;      //Specific Speed, SI Units
     Cv=0.97;
     Cd=0.94;


//Data Required:
     rho=1000;       //Density of water, kg/m^3
     g=9.81;        //Acceleration due to gravity, m/
        s^2


//Computations:
   H=H_G-h_f;   //Effective Head, m
   P=(Ns*H^(5/4)/N)^2;    //Power Output of each Unit
      , KW
```

```
  //(a) The no. of units to be Installed,n
   n=round(TO*1000/P);
  //(b)Diameter of Wheel,D
    Vi=Cv*sqrt(2*g*H);    //m/s
    D=ubyVi*Vi*60/(%pi*N);   //m

//(c) Diameter of Jet,  d
    Q=TO*10^6/(rho*g*H*eta_o);    //Net Discharge, m^3/s
    q=Q/n;  // Discharge through one unit, m^/s
    d=sqrt(q/((%pi/4)*Cd*sqrt(2*g*H)))*1000;   //mm


//Results
   printf("(a) The no. of units to be Installed=%.f Units\n",n)
   printf("(b) Diameter of Wheel, D=%.3f m\n",D)
   printf("(c) Diameter of Jet, d=%.1f mm\n",d)          //The Answer Vary due to round off Error
```

Scilab code Exa 7.6 To Find Speed and Power Developed by the Turbine

```
//Fluid Systems by Shiv Kumar
//Chapter 7 - Performance of water turbine
//Example 7.6
//To Find Speed and Power Developed by the Turbine
      clc
       clear

//Given:
   //Ist Condition
      P1=8500;  //Power Developed, kW
      N1=120;   //Speed, rpm
      H1=32;    //Head, m

```

```
    //2nd Condition
        H2=25;      //Head, m

//Computations:
  P2=P1*(H2/H1)^(3/2);       //kW
  N2=N1*(H2/H1)^(1/2);      //rpm

//Results
    printf("The Speed Developed by the Turbine,N2=%.f rpm\n",N2)
    printf("The power developed= %.2f kW",P2)
```

Scilab code Exa 7.7 To Determine unit power unit speed and unit discharge and also

```
//Fluid Systems by Shiv Kumar
//Chapter 7 - Performance of water turbine
//Example 7.7
//To Determine unit power, unit speed and unit discharge and also find speed, discharge and power at condition 2
        clc
        clear

//Given:
    //At Condition 1
        P1=7200;  //Power Developed, KW
        N1=300;   //Speed, rpm
        H1=350;    //Head, m
        eta_o=85/100;    // Overall efficiency

    //At Condition 2
        H2=300;  //Head, m

//Data Used:
        rho=1000;      //Density of Water, kg/m^3
```

```
g=9.81;        //Acceleration due to gravity, m/s^@


//Computations:
Q1=P1*1000/(rho*g*H1*eta_o);    //m^3/s
Pu=P1/(H1^(3/2));    //Unit Power, KW
Nu=N1/sqrt(H1);        //Unit Speed, rpm
Qu=Q1/sqrt(H1);    //Unit Discharge, m^3/s
P2=P1*(H2/H1)^(3/2);        //KW
N2=N1*(H2/H1)^(1/2);      //rpm
Q2=Q1*sqrt(H2/H1);        //m^3/s

//Results
printf("Unit Power, Pu= %.3f kW\n Unit Speed, Nu=%.2f rpm\n Unit Discharge, Qu=%.4f m^/s\n",Pu,Nu, Qu)      //The Answer vary due to Round off Error

printf("At head of 300 m:\n\t")
printf("The Speed,N2=%.2f rpm\n\t",N2)        //The Answer vary due to Round off Error
printf("The power,P2= %.2f kW\n\t",P2)
printf("The Discharge, Q2=%.3f m^3/s\n",Q2)    //The Answer vary due to Round off Error
```

Scilab code Exa 7.8 To Find Model Runner Speed and Prototype to Model Scale ratio

```
//Fluid Systems- By Shiv Kumar
//Chapter 7- Performance of Water Turbine
//Example 7.8
// To Find Model Runner Speed and Prototype to Model Scale ratio
clc
clear
```

```
//Given:-
    //For Prototype
            Pp=30;          //Power Developed , MW
            Hp=55;          //Head ,  m
            Np=100;        //Speed ,  rpm
            Pp=Pp*1000;        //KW
     //For Model
            Pm=25 ;          //Power Developed , KW
            Hm=6;             //Head , m

//Computations:-
        Nm=Np*(Hm/Hp)^(5/4)*(Pp/Pm)^(1/2);
                            //rpm
         DpbyDm=((Pp/Pm)*(Nm/Np)^3)^(1/5);
                            //A Ratio(Dimensionless)
         Lr= DpbyDm;          //Scale Ratio


//Results
   printf("The Model Runner Speed , Nm=%.2f rpm And\n
      ",Nm)
   printf("Prototype to Model Scale Ratio ,Lr=%.2f",
      Lr)       //The Answer vary due to Round off
      Error
```

Scilab code Exa 7.9 To Determine the Performance of the Turbine Under a Head of 20

```
//Fluid Systems- By Shiv Kumar
//Chapter 7- Performance of Water Turbine
//Example 7.9
// To Determine the Performance of the Turbine Under
    a Head of 20 m
   clc
   clear
```

```
//Given:-
        //Condition 1:
             H1=25;      //Head, m
             N1=200;     //Speed, rpm
             Q1=9;         //Discharge, m^3/s
             eta_o=90/100;      //Overall Efficiency

         //Condition 2:
            H2=20;      //Head, m

//Data Required:-
     rho=1000;         //Density of Water, Kg/m^3
     g=9.81;           //Acceleration due to Gravity, m/s^2


//Calculations:-
          P1=rho*Q1*g*H1*eta_o/1000;            //KW
          N2=N1*sqrt(H2/H1);           //rpm
          Q2=Q1*sqrt(H2/H1);           //m^3/s
          P2=P1*(H2/H1)^(3/2);        //KW


//Results:-
   printf("At Condition 2 (Under a Head of 20 m):\n")
   printf("\tSpeed, N2=%.2f rpm\n      Discharge, Q2=%.2f m^3/s\n       Power Developed, P2=%.2f kW",N2,Q2,P2)           //The Answer vary due to Round off Error
```

Scilab code Exa 7.10 To Calculate Speed and Power Developed by the Prototype when

```
//Fluid Systems- By Shiv Kumar
```

```
//Chapter 7- Performance of Water Turbine
//Example 7.10
// To Calculate Speed and Power Developed by the
   Prototype when working Under a Head of 8 m.
   clc
   clear

//Given:-
      Lr=1/5;          //Scale Ratio
      DmbyDp=Lr;

     //For Prototype
            Hp=8;      //Head, m

      //For Model
          Pm=5;          //Power, kW
          Hm=2;        //Head, m
          Nm=600;    //rpm

//Computations
    Np=Nm*DmbyDp*(Hp/Hm)^(1/2);         //rpm
    Pp=Pm*(Np/Nm)^3/(DmbyDp^5);         //KW


//Results
    printf("For the Prototype (Working Under a Head
       of 8 m:\n")
    printf("       Speed, Np=%.f rpm\n        Power
       Developed, Pp=%.f kW",Np,Pp)
```

Scilab code Exa 7.11 To Find a Power Developed by Model b Ratio of Heads and Ratio

```
//Fluid Systems- By Shiv Kumar
//Chapter 7- Performance of Water Turbine
//Example 7.11
```

```
// To Find  (a)Power Developed by Model   (b)Ratio of Heads and Ratio of Mass Flow Rates between Prototype and Model.
   clc
   clear

//Given:-
      Pp=12;        //Power Developed by Prototype,MW
      Lr=1/10;          //Scale Ratio
      DmbyDp=Lr;
       LmbyLp=Lr;


//Computations:-

     //(a)Power Developed by the Model
                    //As Np=Nm and effeciencies of prototype and model are equal
          Pm=Pp*10^6*(DmbyDp)^5;       //W

     //(b)Ratio of Heads and Ratio of Mass flow Rates
         HpbyHm=DmbyDp^(-2);             //Dimensionless
         QpbyQm=DmbyDp^(-3)
        //As m=rho*Q   and  rho is Constant. So,
         m_pbym_m=QpbyQm;

//Results

    printf("(a)Power Developed by the Model,Pm=%.f W\n",Pm)
    printf(" (b)Ratio of Heads, Hp/Hm=%.f\n     Ratio of Mass flow rates, m_p/m_m=%.f\n",HpbyHm,m_pbym_m)
```

Scilab code Exa 7.12 To Find a The Speed Discharge and Power required for the Actu

```
//Fluid Systems- By Shiv Kumar
//Chapter 7- Performance of Water Turbine
//Example 7.12
// To Find    (a)The Speed ,Discharge and Power required for the Actual Pump    (b) The Discharge of the model.
   clc
   clear

//Given:-
      Lr=5;         //Scale Ratio
      DpbyDm=Lr;
       DmbyDp=1/DpbyDm;
        //For Model
            Pm=22;          //Power Required , kW
            Hm=7;         //Head , m
            Nm=410;      //Speed , rpm
            eta_m=1;      //Assumption that efficiency of the model is 100%
      //For Prototype
        Hp=35;          //Head , m
  //Data Required:-
       rho=1000;     //Density of Water , Kg/m^3
       g=9.81;       //Acceleration due to gravity , m/s^2

//Computations:-
       Np=Nm*DmbyDp*(Hp/Hm)^(1/2);      //rpm
       Pp=Pm*(Np/Nm)^3*DpbyDm^5;     //KW
       Qm=Pm*1000*eta_m/(rho*g*Hm);     //m^3/s
       Qp=Qm*(Np/Nm)^2*DpbyDm^2;        //m^3/s

```

```
//Results:-
        printf("(a)For the Actual Pump(Prototype):\n             Speed, Np=%.2f rpm   , \n Discharge, Qp=%.3f m^3/s  and \n Power,Pp=%.2fKW\n",Np,Qp,Pp)          //The Answer vary due to Round off Error(For Qp),  The Answer Provided in the Textbook is Wrong (For Np and Pp).

        printf("(b)The Discharge of the Model, Qm=%.4f m^3/s",Qm)         //The Answer vary due to Round off Error
```

Scilab code Exa 7.13 To Determine the maximum flow rate and specific speed for the

```
//Fluid Systems- By Shiv Kumar
//Chapter 7- Performance of Water Turbine
//Example 7.13
// To Determine the maximum flow rate and specific speed for the Turbine and To Find Speed, Power Output and Water Consumption of the Model.
   clc
   clear

//Given:-
      Lr=10;          //Scale Ratio
      DpbyDm=Lr;
       DmbyDp=1/DpbyDm;
        //For Prototype
             Pp=1000;           //Power  , kW
             Hp=14;              //Head, m
             Np=130;      //Speed, rpm
             eta_o=91/100;      //Overall efficiency
      //For  Model
        Hm=6;           //Head, m
```

```
  //Data Required:-
        rho=1000;       //Density of Water, Kg/m^3
        g=9.81;         //Acceleration due to gravity,
           m/s^2

//Computations:-
         Qp=Pp*1000/(rho*g*Hp *eta_o );      //m^3/s
         Ns=Np*Pp^(1/2)/(Hp^(5/4));          //Specific
            Speed, In SI UNITS
         Nm=Np*DpbyDm*(Hm/Hp)^(1/2);       //rpm
         Qm=Qp*(Nm/Np)*(DmbyDp)^3;         //m^3/s
         Pm=Pp*(Nm/Np)^3*DmbyDp^5;      //KW

//Results:-
        printf("For the Turbine : \n\t")
         printf("Maximum Flow Rate, Qp=%.f m^3/s\n\t"
            ,Qp)
         printf("Specific Speed, Ns=%.2f (SI Units)\n
            \n",Ns)
         printf("For the Model : \n\t")
         printf("Speed, Nm=%.2f rpm\n        Power
            Output, Pm=%.2f kW\n          Water
            Consumption, Qm=%.4f m^3/s \n", Nm,Pm,Qm)
                  //The Answer vary due to Round off
            Error
```

Scilab code Exa 7.14 To Determine the Size Scale Ratio of the Model and To Find th

```
//Fluid Systems- By Shiv Kumar
//Chapter 7- Performance of Water Turbine
//Example 7.14
//To Determine the Size (Scale Ratio) of the Model
   and To Find the Model Speed and  Power.

  clc
```

```
    clear

//Given:-
     TP=240000;        //Total Power Produced, kW
      n=4;        //No. of Turbines
      eta_o=91/100;         //Effeciency of each turbine
       Np=120;        //Speed of each Turbine, rpm
       Hp=70;        //Head for each Turbine, m

       Qm=0.45;        //Discharge for Model, m^3/s
       Hm=5;           //Head for testing the Model, m

//Data Required:-
         rho=1000;      //Density of Water, Kg/m^3
         g=9.81;         //Acceleratrion due to gravity, m/s^2

//Calculations:-
       Pp=TP/n;        //Power produced from each Turbine, kW
       Qp=Pp*1000/(rho*g*Hp*eta_o);      //Discharge passing through one Turbine, m^3/s
       DmbyDp=(Qm/Qp)^(1/2)*(Hp/Hm)^(1/4);    //From Relation of Flow Coefficient
        Lr=DmbyDp;        //Scale Ratio
        Nm=(Np/DmbyDp)*(Hm/Hp)^(1/2);      //rpm
        Pm=Pp*(Nm/Np)^3*DmbyDp^5;        //KW

//Results
    printf("The Scale Ratio is  1:%.2f\n ",1/Lr)
    printf("Model Speed, Nm=%.2f rpm\n",Nm)
    printf("Model Power, Pm=%.2f kW\n",Pm)        //The Answer vary due to Round off Error
```

Scilab code Exa 7.15 To Determine the rpm of Prototype Ratio of Power Developed by

```
//Fluid Systems- By Shiv Kumar
//Chapter 7- Performance of Water Turbine
//Example 7.15
//To Determine the rpm of Prototype, Ratio of Power Developed by Model and Prototype and Efficiency of Prototytpe .

   clc
    clear

//Given:-
         Lr=1/8;          //Scale Ratio
     //For Model,
          Hm=5;       //Head, m
          Nm=350;      //Speed,rpm
           eta_m=78/100;        //Effiency of model
      //For Prototype,
             Hp=100;      //Head, m

//Calculations:-
      DpbyDm=1/Lr;     //  Dp/Dm
      //(a) Speed of Prototype, Np
               Np=Nm*Lr*(Hp/Hm)^(1/2);      //rpm
      //(b)Ratio of Power Developed,  Pp/Pm
               PpbyPm=DpbyDm^5*(Np/Nm)^3;
      //(c)Efficiency of Prototype when Scale Effect is Considered
            //From Moody's Equation,
                eta_p=(1-Lr^0.2*(1-eta_m))*100;      //In Percentage

//Results
```

```
printf(" (a)The Speed of Prototype, Np=%.2f rpm\n",
    Np)        //The Answer vary due to Round off
    Error
printf(" (b)Ratio of Power Developed,  Pp/Pm =%.2f \
    n",PpbyPm)        //The Answer vary due to Round
    off Error
printf(" (c)Efficiency of Prototype, eta_p =%.2f
    Percent\n",eta_p)        //The Answer vary due to
    Round off Error
```

Chapter 11

Centrifugal Pumps

Scilab code Exa 11.1 To Find the Work done by the Impeller on the water per unit w

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.1
//To Find the Work done by the Impeller on the water
    per unit weight of water.

     clc
      clear

//Given Data:-
        Di=210;        //Internal diameter of
           Impeller, mm
        Do=420;       // External diameter of
           Impeller, mm
        N=1100;       //speed, rpm
        beta_i=20;     //Vane Angle at Inlet, degrees
        beta_o=30;     //Vane Angle at Outlet,
           degrees
    //As water enters the impeller radially,
        alpha_i=90;       //degrees

```

```

//Data Used:-
        g=9.81;         //Acceleration due to gravity , m/s^2


//Computations:-
         Di=Di/1000;        //m
         Do=Do/1000;         //m

        ui=%pi*Di*N/60;         //m/s
        uo=%pi*Do*N/60;        //m/s
        Vfi=ui*tand(beta_i);      //m/s
        Vfo=Vfi;
        Vwo=uo-Vfo/tand(beta_o);       //m/s
        Work=Vwo*uo/g;        //N-m/N

//Result:-
      printf(" The Work done by the Impeller on the water per unit weight of water =%.2f N-m/N \n",Work)        //The answer vary due to round off error
```

Scilab code Exa 11.2 To Find the Vane Angle at Outer Periphery of the Impeller

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.2
//To Find the Vane Angle at Outer Periphery of the Impeller.

     clc
      clear

//Given Data:-
```

```
        N=1470;      //Speed, rpm
        Q=100;       //Discharge, litres/s
        Hm=24;      //manometric Head,  m
        Do=240;      // Diameter of Impeller at Outlet, mm
        b_o=50;       //Width of Impeller at Outlet, mm
        eta_man=76/100;      //Manometric EEfficiency


//Data Used:-
        g=9.81;       //Acceleration due to gravity, m/s^2


//Computations:-
         Q=Q/1000;      //m^3/s
         Do=Do/1000;        //m
         b_o=b_o/1000;      //m

        uo=%pi*Do*N/60;       //m/s
        Vwo=g*Hm/(uo*eta_man);        //m/s
        Vfo=Q/(%pi*Do*b_o);        //m/s
    //From Outlet Velocity Triangle (OVT),
      beta_o=atand(Vfo/(uo-Vwo));       //degrees

//Result:-
      printf("The Vane Angle at Outer Periphery of Impeller, beta_o=%.2f Degrees \n",beta_o)      //The answer vary due to round off error
```

Scilab code Exa 11.3 To Find the Power of the Pump

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.3
//To Find the  Power of the Pump.

     clc
      clear

//Given Data:-
        H=40;        //Total Head,  m
        Q=50;         //Discharge,  litres/s
        eta_o=62/100;       //Overall EEfficiency


//Data Used:-
        rho=1000;      //Density of Water, kg/m^3
        g=9.81;        //Acceleration due to gravity, m/s^2


//Computations:-
         Q=Q/1000;      //m^3/s

         P=rho*Q*g*H/(eta_o*1000);       //kW

//Result:-
        printf("The Power of the Pump, P=%.3f kW \n",P)
```

Scilab code Exa 11.4 To Find a Vane Angle at Inlet b Work done by Impeller on wate

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.4
//To Find     (a)Vane Angle at Inlet        (b)Work
```

```
   done by Impeller on water per second      (c)
   Manometric Efficiency

      clc
       clear

//Given Data:-
      //As Outer Diameter equals two times Inner
          Diameter,
         Do_by_Di=2;         //Do/Di
         N=980;        //Speed, rpm
         Hm=52;        //Manometric Head, m
         Vfo=2.6;       //Velocity of Flow, m/s
         Vfi=Vfo;
         beta_o=42;         //Vane Angle at outlet,
            degrees
         Do=600;          //Outer Diameter of the
            Impeller, mm
         bo=60;        //Width at Outlet, mm


//Data Used:-
           rho=1000;         //Density of water, kg/
             m^3
            g=9.81;        //Acceleration due to
               gravity, m/s^2

//Computations:-
          Do=Do/1000;        //m
          bo=bo/1000;       //m

          Di=Do/Do_by_Di;         //Diameter at
             Inlet of Impeller, m
          ui=%pi*Di*N/60;        //Tangential
             velocity of Impeller at Inlet,m/s
          uo=%pi*Do*N/60;      // Tangential
             velocity of Impeller at Outlet, m/s
          Q=%pi*Do*bo*Vfo;      //Discharge, m^3/s
```

```
    //(a)Vane Angle at Inlet , beta_i
        beta_i=atand(Vfi/ui);        //degrees

    //(b) Work done by Impeller on water per sec , W
         Vwo=uo-Vfo/tand(beta_o);         //m/s
        W=rho*Q*Vwo*uo/1000;          //kN-m/s

     //(c) Manometric Efficiency , eta_man
         eta_man=g*Hm/(Vwo*uo)*100;          //In
            Percentage


//Results:-
    printf(" (a)Vane Angle at Inlet , beta_i=%.2f
       Degrees \n ",beta_i)
    printf(" (b) Work done by Impeller on water
       per sec =%.3f kN-m/s \n ",W)       //The
       answer provided in the textbook is wrong.
    printf(" (c) Manometric Efficiency , eta_man =%
       .2f Percent \n ",eta_man)       //The answer
        provided in the textbook is wrong.
```

Scilab code Exa 11.5 To Find the Discharge of Pump

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.5
//To Find the Discharge of Pump.

       clc
        clear

//Given Data:-
          Hm=14.5;         //Manometric Head, m
```

```
          N=1000;          //Speed , rpm
          beta_o=30;           //Vane Angle at outlet ,
             degrees
          Do=300;          //Outer Diameter of the
             Impeller , mm
          bo=50;         //Width at Outlet , mm
          eta_man=95/100;        //Manometric
             Efficiency


//Data Used:-
           g=9.81;         //Acceleration due to
              gravity , m/s^2

//Computations:-
           Do=Do/1000;         //m
           bo=bo/1000;        //m

          uo=%pi*Do*N/60;        //m/s
          Vwo=g*Hm/(uo*eta_man);         //m/s
          Vfo=tand(beta_o)*(uo-Vwo);        //m/s
          Q=%pi*Do*bo*Vfo*1000;        //Discharge ,
             litres/s

//Results:-
        printf("The Discharge of the Pump=%.2f litres
           /s\n",Q)      //The answer vary due to
           round off error
```

Scilab code Exa 11.6 To Calculate the Blade angle at Outlet Power Required and Ove

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.6
//To Calculate  the Blade angle at Outlet , Power
```

```
    Required and Overall Efficiency of Pump.

clc
clear

//Given Data:-
        Do=80;          //Outer Diameter of the Impeller, cm
        Q=1;        //Discharge, m^3/s
        H=80;         //Head, m
        N=1000;          //Speed, rpm
        bo=8;          //Width at Outlet, cm
        Delta_Q_per=3;       //Percentage of Leakage Loss(of the Discharge)
        Delta_P=10;         //Mechanical Loss, kW
        eta_H=80/100;       //Hydraulic Efficiency


//Data Used:-
        rho=1000;         //Density of water, kg/m^3
         g=9.81;          //Acceleration due to gravity, m/s^2

//Computations:-
         Do=Do/100;          //m
         bo=bo/100;         //m

        uo=%pi*Do*N/60;        //m/s
        Vfo=Q/(%pi*Do*bo);          //m/s
        Vwo=g*H/(uo*eta_H);       //m/s
        Vrwo=uo-Vwo;      //m/s

    //(a)
            beta_o=atand(Vfo/Vrwo);        //Blade Angle at Outlet, degrees

        //Result1
            printf(" Blade Angle at Outlet, beta_o=%
```

```
.2f Degrees \n",beta_o)      //The answer vary due to round off error

//(b)Power Required
        Pi=rho*(1+Delta_Q_per/100)*Q*Vwo*uo;           //Power delivered by the Impeller, W
        P=Pi/1000+Delta_P;        //Power required, kW

    //Result2
        printf(" Power Required, P =%.3f kW \n",P)      //The answer vary due to round off error

 //(c)Overall Efficiency, eta_o
        eta_V=1/(1+Delta_Q_per/100);        //Volumetric Efficiency
        eta_m=(P-Delta_P)/P;        //Mechanical Efficiency
        eta_o=eta_H*eta_V*eta_m*100;        //In Percentage

    //Result3
        printf(" Overall Efficiency, eta_o =%.2f Percent \n",eta_o)      //The answer vary due to round off error

  //Also,  Overall Efficiency
       eta_o=rho*Q*g*H/(P*1000)*100;        //In Percentage

    printf("Also, Overall Efficiency, eta_o=%.2f Percent\n",eta_o)
```

Scilab code Exa 11.7 To Determine the Impeller Speed and Torque produced by it

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.7
//To Determine the Impeller Speed and Torque
   produced by it.

       clc
        clear

//Given Data:-
         Q=60;          //Discharge, litres/s
         Ri=75;            //Radius of the Impeller at
             Inlet, mm
         Ro=150;            //Radius of the Impeller at
             Outlet, cm
         beta_o=30;       //Vane Angle at Outlet,
            degrees
         beta_i=30;       //Vane Angle at Inlet,
            degrees
         Ai=0.025;          //Impeller Area at Inlet, m
            ^2


//Data Used:-
         rho=1000;          //Density of water, kg/m^3


//Computations:-
             Q=Q/1000;       //m^3/s
             Ri=Ri/1000;       //m
             Ro=Ro/1000;         //m

          Di=2*Ri;          //m
          Do=2*Ro;        //m
          Vfi=Q/Ai;           //m/s
          Vfo=Vfi;
```

```
            ui=Vfi/tand(beta_i);        //m/s
            N=ui*60/(%pi*Di);         //rpm

            uo=%pi*Do*N/60;           //m/s
            Vrwo=Vfo/tand(beta_o);        //m/s
            Vwo=uo-Vrwo;         //m/s
            P=rho*Q*Vwo*uo;       //Impeller Power, W
            Ti=P*60/(2*%pi*N);       //Impeller Torque, N-m

//Results:-
          printf("Impeller Speed, N=%.2f rpm\n",N)       //The answer vary due to round off error
          printf("Impeller Torque, Ti=%.2f N-m\n",Ti)        //The answer vary due to round off error
```

Scilab code Exa 11.8 To Determine the Power Required to drive the centrifugal Pump

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.8
//To Determine the Power Required to drive the centrifugal Pump.

       clc
        clear

//Given Data:-
          Q=40;        //Discharge, litres/s
          Hst=20;       //Static Head, m
          D=150;       //Diameter of Pipe, mm
          L=100;       //length of pipe, m
          eta_o=70/100;       //Overall Efficiency
```

```
            f=0.015;        //Coefficient of friction


//Data Used:-
           rho=1000;        //Density of water, kg/m^3
           g=9.81;        //Acceleration due to gravity
              , m/s^2


//Computations:-
               Q=Q/1000;      //m^3/s
               D=D/1000;        //m

              A=(%pi/4)*D^2;       //m^2
              V=Q/A;       //m/s
               Vd=V;

             h_f=4*f*L*V^2/(2*g*D);          //
                Frictional Head Loss in Pipe, m
             Hm=Hst+h_f+Vd^2/(2*g);        //Manometric
                 Head, m
             P=rho*Q*g*Hm/(eta_o*1000);       //kW

//Result:-
       printf("Power Required to drive the
          Centrifugal Pump=%.3f kW\n",P)       //The
          answer vary due to round off error
```

Scilab code Exa 11.9 To Find i Vane Angle at Inlet ii Work done by Impeller on wat

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.9
//To Find      (i)Vane Angle at Inlet       (ii)Work
   done by Impeller on water per second and       (
```

```
    iii)Manometric Efficiency.

        clc
         clear

//Given Data:-
            Do=500;          //Outer Diameter of the Impeller, mm
            Di=250;          //Inner Diameter of the Impeller, mm
            N=1000;         //Speed, rpm
            Hm=40;         //Manometric Head, m
            Vfo=2.5;        //Velocity of Flow, m/s
            Vfi=Vfo;
            beta_o=40;          //Vane Angle at outlet, degrees
            bo=50;         //Width at Outlet, mm


//Data Used:-
              rho=1000;          //Density of water, kg/m^3
               g=9.81;         //Acceleration due to gravity, m/s^2

//Computations:-
             Do=Do/1000;         //m
             Di=Di/1000;          //m
             bo=bo/1000;        //m

             ui=%pi*Di*N/60;        //Tangential velocity of Impeller at Inlet,m/s
             uo=%pi*Do*N/60;       // Tangential velocity of Impeller at Outlet, m/s
             Q=%pi*Do*bo*Vfo;       //Discharge, m^3/s

    //(i)Vane Angle at Inlet, beta_i
             beta_i=atand(Vfi/ui);       //degrees
```

```
    //(ii) Work done by Impeller on water per sec, W
            Vwo=uo-Vfo/tand(beta_o);        //m/s
           W=rho*Q*Vwo*uo/1000;          //kN-m/s

     //(iii) Manometric Efficiency, eta_man
            eta_man=g*Hm/(Vwo*uo)*100;          //In Percentage


//Results:-
      printf(" (i)Vane Angle at Inlet, beta_i=%.2f Degrees \n",beta_i)      //The answer vary due to round off error
      printf(" (ii) Work done by Impeller on water per sec =%.3f kN-m/s \n",W)      //The answer vary due to round off error
      printf(" (iii) Manometric Efficiency, eta_man =%.2f Percent \n",eta_man)      //The answer vary due to round off error
```

Scilab code Exa 11.10 To Find i Manometric Head ii Manometric Efficiency iii Overa

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.10
//To Find     (i)Manometric Head             (ii) Manometric Efficiency          (iii)Overall Efficiency of the Pump.

       clc
       clear

//Given Data:-
          Do=480;          //External Diameter of the
```

```
        Impeller , mm
Di=240;          //Internal Diameter of the
        Impeller , mm
N=1000;          //Speed , rpm
Q=0.0576;        //Rate of Flow, m^3/s
Vfo=2.4;         //Velocity of Flow, m/s
Vfi=Vfo;
Ds=180;          //Diameter of Suction Pipe,
        mm
Dd=120;          //Diameter of Delivery Pipe,
        mm
h_s=6.2;         //Suction Head,  m of water (
        abs)
h_d=30.2;        //Delivery Head,  m of water
        (abs)
P=35;            //Power required to drive
        the pump, kW
beta_o=45;           //Vane Angle at outlet ,
        degrees


//Data Used:-
    rho=1000;          //Density of water, kg/
        m^3
    g=9.81;          //Acceleration due to
        gravity , m/s^2

//Computations:-
    Do=Do/1000;          //m
    Di=Di/1000;           //m
    Ds=Ds/1000;         //m
    Dd=Dd/1000;        //m
    P=P*1000;          //W

  //(i)Manometric Head, Hm

As=(%pi/4)*Ds^2;          //m^2
Ad=(%pi/4)*Dd^2;          //m^2
```

```
            Vd=Q/Ad;        //m/s
            Vs=Q/As;         //m/s
            Hm=(h_d+Vd^2/(2*g))-(h_s+Vs^2/(2*g));
               //m


             uo=%pi*Do*N/60;       // Tangential
                velocity of Impeller at Outlet, m/s
             Vwo=uo-Vfo/tand(beta_o);       //m/s

        //(ii) Manometric Efficiency, eta_man
               eta_man=g*Hm/(Vwo*uo)*100;          //In
                  Percentage

        //(iii) The Overall Efficiency of the Pump,
           eta_o
              eta_o=rho*Q*g*Hm/P*100;       //In
                 percentage

//Results:-
      printf(" (i)Manometric Head, Hm =%.2f m \n ",
         Hm)
      printf(" (ii) Manometric Efficiency, eta_man =
         %.2f Percent \n ",eta_man)      //The answer
          vary due to round off error
      printf(" (iii) The Overall Efficiency of the
         Pump, eta_o =%.2f Percent \n ",eta_o)
         //The answer vary due to round off error
```

Scilab code Exa 11.11 To Find Vane Angle at Outer periphery of Impeller

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.11
//To Find  Vane Angle at Outer periphery of Impeller
```

```
.

clc
clear

//Given Data:-
Q=0.118;        //discharge, m^3/s
N=1450;         //Speed, rpm
Hm=25;          //Manometric Head, m
Do=250;         //Diameter of the Impeller at Outlet, mm
bo=50;          //Width at Outlet, mm
eta_man=75/100;         //Manometric Efficiency


//Data Used:-
g=9.81;         //Acceleration due to gravity, m/s^2

//Computations:-
Do=Do/1000;         //m
bo=bo/1000;         //m

uo=%pi*Do*N/60;         // Tangential velocity of Impeller at Outlet, m/s
Vwo=g*Hm/(uo*eta_man);          //m/s
Vfo=Q/(%pi*Do*bo);          //m/s
beta_o=atand(Vfo/(uo-Vwo));         //degrees

//Results:-
printf(" Vane Angle at Outlet, beta_o=%.2f Degrees \n ",beta_o)       //The answer vary due to round off error
```

Scilab code Exa 11.12 To Determine i Manometric Efficiency ii Vane Angle at Inlet

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.12
//To Determine     (i)Manometric Efficiency     (ii)Vane Angle at Inlet       (iii)The Least Speed at which the pump commence to work.

      clc
       clear

//Given Data:-
         Do=0.5;         //Outer Diameter of the Impeller, m
         N=600;          //Speed, rpm
         Q=8000;         //Discharge, litres/min.
         Hm=8.5;         //Manometric Head, m
         Di=0.25;          //Inner Diameter of Impeller, m
         beta_o=45;          //Vane Angle at outlet, degrees
         Af=0.06;         //Area of Flow, m^2


//Data Used:-
         g=9.81;         //Acceleration due to gravity, m/s^2

//Computations:-
       Q=Q/60000;       //m^3/s

       Vfo=Q/Af;        //m/s
       Vfi=Vfo;
```

```
        ui=%pi*Di*N/60;        //Tangential velocity of Impeller at Inlet ,m/s
        uo=%pi*Do*N/60;       // Tangential velocity of Impeller at Outlet , m/s
        Vwo=uo-Vfo/tand(beta_o);         //m/s

    //(i) Manometric Efficiency , eta_man
            eta_man=g*Hm/(Vwo*uo)*100;           //In Percentage


    //(ii) Vane Angle at Inlet , beta_i
             beta_i=atand(Vfi/ui);        //degrees

     //(iii) The Least Speed at which the pump commence to work , Nmin
          Nmin=120*Vwo*Do*(eta_man/100)/(%pi*(Do^2-Di^2));        //rpm



//Results:-
      printf(" (i) Manometric Efficiency , eta_man =%.2f Percent \n ",eta_man )      //The answer vary due to round off error
      printf(" (ii) Vane Angle at Inlet , beta_i=%.2f Degrees \n ",beta_i )      //The answer vary due to round off error
      printf(" (iii) The Least Speed at which the pump commence to work , Nmin=%.2f rpm \n",Nmin )      //The answer vary due to round off error
```

Scilab code Exa 11.13 To Find i The Discharge of the Pump ii The Pressure at Sucti

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.13
//To Find          (i)The Discharge of the Pump
            (ii)The Pressure at Suction and Delivery
    side of the Pump.

       clc
        clear

//Given Data:-
         h_st=35;       //Static Head, m
         h_s=4;        //Suction Head, m
         D=150;          //Diameter of Pipes, mm
         Ds=D;         //Diameter of Suction Pipe, mm
         Dd=D;         //Diameter of Delivery Pipe,
            mm
         h_fs=1.6;       //Head loss in Suction pipe,
              m
         h_fd=6.5;      //Head loss in Delivery Pipe,
              m
         Do=380;       //Diameter of Impeller at
            Outlet, mm
         bo=25;         //Width of Impeller at Outlet
            , mm
         N=1200;         //Speed, rpm
         beta_o=35;          //Ezxit Blade Angle,
            degrees
         eta_man=80/100;        //Manometric
            Efficiency


//Data Used:-
         g=9.81;         //Acceleration due to
            gravity, m/s^2

//Computations:-
          Do=Do/1000;          //m
```

```
        D=D/1000;           //m
        Ds=Ds/1000;         //m
        Dd=Dd/1000;        //m
        bo=bo/1000;       //m

       Hm=h_st+h_fs+h_fd;       // Manometric Head, m
        uo=%pi*Do*N/60;       // Tangential velocity of Impeller at Outlet, m/s
        Vwo=g*Hm/(uo*eta_man);        //m/s
        Vfo=(uo-Vwo)*tand(beta_o);         //m/s

    //(i)The Discharge of the Pump, Q
        Q=%pi*Do*bo*Vfo*1000;        //litres/s

   // (ii)The Pressure at Suction and Delivery side of the Pump

       A=(%pi/4)*D^2;         //m^2
       Vd=Q*10^-3/A;        //m/s
       Vs=Vd;         //m/s
       Hs=h_s+h_fs+Vs^2/(2*g);         //Pressure on Suction Side, m of water
       h_d=h_st-h_s;       //m
       Hd=h_d+h_fd+Vd^2/(2*g);         //Pressure on Delivery Side, m of water


//Result:-
      printf(" (i)The Discharge of the Pump, Q =%.2f litres/s\n",Q)  //The answer vary due to round off error
      printf(" (ii) Pressure on Suction Side, Hs =-%.3f m of water \n",Hs)  //The answer vary due to round off error
     printf("       Pressure on Delivery Side, Hd =%.2f m of water \n",Hd)  //The answer vary due to round off error
```

Scilab code Exa 11.14 To Find a Vane Angle of Impeller at Inlet b Overall Efficien

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.14
//To Find      (a)Vane Angle of Impeller at Inlet
               (b) Overall Efficiency of the Pump
           (c) Manometric Efficiency of the Pump.

       clc
        clear

//Given Data:-
         Do=400;          //Diameter of the Impeller at Outlet, mm
         Di=200;          //Diameter of the Impeller at Inlet, mm
         N=1000;          //Speed, rpm
         Q=39;      //Discharge, litres/s
         Vfo=2.2;         //Velocity of Flow, m/s
         Vfi=Vfo;
         Ds=150;          //Diameter of Suction Pipe, mm
         Dd=100;          //Diameter of Delivery Pipe, mm
         h_s=6;       //Suction Head, m of water (abs)
         h_d=30;       //Delivery Head, m of water (abs)
         P=15.75;           //Power required to drive the pump, kW
         beta_o=45;          //Vane Angle at outlet, degrees

```

```

//Data Used:-
            rho=1000;           //Density of water, kg/m^3
             g=9.81;          //Acceleration due to gravity, m/s^2

//Computations:-
           Do=Do/1000;         //m
           Di=Di/1000;          //m
           Ds=Ds/1000;        //m
           Dd=Dd/1000;       //m
            Q=Q/1000;        //m^3/s
            P=P*1000;        //W

    //(a)Vane Angle of Impeller at Inlet, beta_i
           ui=%pi*Di*N/60;          //m/s
           beta_i=atand(Vfi/ui);          //degrees

   // (b) Overall Efficiency of the Pump
          As=(%pi/4)*Ds^2;          //m^2
          Ad=(%pi/4)*Dd^2;          //m^2
          Vd=Q/Ad;        //m/s
          Vs=Q/As;         //m/s
          Hm=(h_d+Vd^2/(2*g))-(h_s+Vs^2/(2*g));    //m
         eta_o=rho*Q*g*Hm/P*100;       //In percentage


     // (c) Manometric Efficiency of the Pump, eta_man
           uo=%pi*Do*N/60;       // Tangential velocity of Impeller at Outlet, m/s
           Vwo=uo-Vfo/tand(beta_o);        //m/s
           eta_man=g*Hm/(Vwo*uo)*100;          //In Percentage


```

```
//Results:-
      printf(" (a)Vane Angle of Impeller at Inlet ,
         beta_i=%.2f Degrees \n ",beta_i)  //The
         answer vary due to round off error
      printf(" (b) The Overall Efficiency of the
         Pump, eta_o =%.2f Percent \n ",eta_o)  //
         The answer vary due to round off error
      printf(" (c) Manometric Efficiency of the Pump
         , eta_man =%.2f Percent \n ",eta_man)  //
         The answer vary due to round off error
```

Scilab code Exa 11.15 To Determine Minimum Starting Speed of the Pump

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.15
//To Determine Minimum Starting Speed of the Pump.

       clc
        clear

//Given Data:-
         Di=300;        //Diameter of Impeller at
            Inlet , mm
         Do=600;         //Diameter of the Impeller
            at Outlet , mm
         Vfo=2.6;        //Velocity of Flow at Outlet
            , m/s
         beta_o=42;          //Vane Angle at outlet ,
            degrees
         eta_man=65/100;          //Manomwtric
            Efficiency , m^2


//Computations:-
```

```
        Di=Di/1000;             //m
        Do=Do/1000;           //m

       uo_by_N=%pi*Do/60;        // uo/N

      //Minimum Starting Speed of The Centrifugal
         Pump, Nmin
          Nmin=(120*Do*eta_man*Vfo/(tand(beta_o)*%pi
             *(Do^2-Di^2)))/(120*eta_man*Do*uo_by_N/(
             %pi*(Do^2-Di^2))-1);        //rpm



//Results:-
       printf("The Minimum Starting Speed of the
          Centrifugal Pump, Nmin =%.2f rpm \n",Nmin )
            //The answer vary due to round off error
```

Scilab code Exa 11.16 To Determine Minimum Starting Speed of the Pump

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.16
//To Determine Minimum Starting Speed of the Pump.

        clc
         clear

//Given Data:-
          Di=200;        //Diameter of Impeller at
             Inlet , mm
          Do=400;         //Diameter of the Impeller
             at Outlet , mm
          Hm=25;         //Manometric Head, m

```

```
//Data Used:-
        g=9.81;         //Acceleration due to gravity, m/s^2


//Computations:-
      Di=Di/1000;             //m
      Do=Do/1000;           //m

     uo_by_Nmin=%pi*Do/60;       // uo/Nmin
     ui_by_Nmin=%pi*Di/60;       // ui/Nmin

    //Minimum Starting Speed of The Centrifugal Pump, Nmin
        Nmin=sqrt(2*g*Hm/(uo_by_Nmin^2-ui_by_Nmin^2));       //rpm



//Results:-
     printf("The Minimum Starting Speed of the Centrifugal Pump, Nmin =%.f rpm \n",Nmin )  //The answer vary due to round off error
```

Scilab code Exa 11.17 To Find a Manometric Efficiency b Minimum Starting Speed

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.17
//To Find       (a)Manometric Efficiency.         (b)Minimum Starting Speed

        clc
        clear

```

```
//Given Data:-
      Di=1200;            //Inner Diameter of the Impeller, mm
      Do=600;             //Outer Diameter of the Impeller, mm
      N=200;              //Speed, rpm
      Hm=6;            //Manometric Head, m
      beta_o=26;            // Vane Angle at Outlet, degrees
      Vfo=2.5;         // Velocity of flow at Outlet, m/s


//Data Used: -
        g=9.81;        //Acceleration due to gravity, m/s^2


//Computations:-
            Di=Di/1000;          //m
            Do=Do/1000;         //m

             uo=%pi*Di*N/60;          //Tangential Velocity of Impeller at Outlet, m/s
             Vwo=uo-Vfo/tand(beta_o);       //m/s

        //(a)Manometric Efficiency, eta_man
              eta_man=g*Hm/(Vwo*uo)*100;          //In Percentage

       //(b) Minimum Starting Speed, Nmin
                     Nmin =sqrt(2*g*Hm*60^2/(%pi^2*(Di^2-Do^2)));          //rpm


//Results:-
            printf("(a)Manometric Efficiency =%.2f Percent \n",eta_man)  //The answer
```

```
vary due to round off error
printf(" (b)Minimum Starting Speed, Nmin
    =%.f rpm",Nmin)  //The answer vary
    due to round off error
```

Scilab code Exa 11.18 To Find a Manometric Efficiency b Inlet Vane Angles c Loss o

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.18
//To Find      (a)Manometric Efficiency.          (b
   )Inlet Vane Angles.            (c)Loss of Head at
    Inlet of Impeller

          clc
          clear

//Given Data:-
      Q=0.21;            //Discharge, m^3/s
      Af=0.085;        //Cross-sectional Area of Flow
         , m^2
      Di=300;            //Inner Diameter of the
         Impeller,  mm
      Do=600;             //Outer Diameter of the
         Impeller, mm
      N=600;              //Speed, rpm
      Hm=19;            //Manometric Head,  m
      beta_o=35;        //degrees
      Q_per=30;         //Percentage by which
         Discharge is reduced


//Data Used: -
        g=9.81;         //Acceleration due to gravity,
           m/s^2
```

```
//Computations:-
              Di=Di/1000;          //m
              Do=Do/1000;         //m

               ui=%pi*Di*N/60;            //Tangential Velocity of Impeller at Inlet, m/s
               uo=%pi*Do*N/60;          //Tangential Velocity of Impeller at Outlet, m/s
               Vfo=Q/Af;          //Velocity of Flow, m/s
               Vfi= Vfo;
               Vwo=uo-Vfo/tand(beta_o);       //m/s

        //(a)Manometric Efficiency, eta_man
             eta_man=g*Hm/(Vwo*uo)*100;       //In Percentage

      //(b)Inlet Vane Angle,  beta_i
               beta_i=atand(Vfi/ui);        //degrees

      //(c)Loss of Head at inlet,  H_L
                 Q_dash=Q-Q_per/100*Q;       //m^3/s
                 Vfi_dash=Q_dash/Af;            //m/s
                H_L=(ui-Vfi_dash*cotd(beta_i) )^2/(2*g);       // m of water

//Results
    printf("(a)Manometric Efficiency, eta_man =%.2f Percent \n",eta_man)        //The answer vary due to round off error
    printf ("(b)Inlet Vane Angle, beta_i =%.2f Degrees \n",beta_i)        //The answer vary due to round off error
    printf ("(c)Loss of Head at Inlet to the Impeller =%.3f m of water", H_L)  //The answer vary due to round off error
```

Scilab code Exa 11.19 To Find a Head generated and b Power consumed

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.19
//To Find         (a)Head generated       and          (b)
    Power consumed

            clc
            clear

//Given Data:-
        n=2;             //Number of Stages
        Q=100;             //Discharge, litres/s
        N=1000;              //Speed, rpm
        Do=500;             //Diameter of the Impeller
            at Outlet, mm
        bo=25;             //Width of Impeller at outlet
            , mm
        beta_o=30;        //degrees
        Area_per=10;           //Percentage of Total
            Area which is covered due to blade
            thickness
        eta_o=78/100;         //Overall Efficiency
        eta_man=85/100;            //Manometric
            Efficiency


//Data Used: -
            rho=1000;                //Density of water
                , kg/m^3
            g=9.81;        //Acceleration due to gravity
                , m/s^2

```

```

//Computations:-
              Q=Q/1000;            //m^3/s
              Do=Do/1000;          //m
              bo=bo/1000;          //m
             A=%pi*Do*bo*(1-Area_per/100);           //Actual Area of Flow, m^2

               uo=%pi*Do*N/60;           //Tangential Velocity of Impeller at Outlet, m/s
               Vfo=Q/A;           //Velocity of Flow, m/s
               Vfi= Vfo;
               Vwo=uo-Vfo/tand(beta_o);       //m/s

        //(a)Head generated, H_Tm
                Hm=eta_man*Vwo*uo/g;         //m
                H_Tm=n*Hm;           //m

         //(b) Power consumed, P
                   P=rho*Q*g*H_Tm/(eta_o*1000);           //kW


//Results:-
             printf("(a)Head Generated, H_Tm=%.2f m \n",H_Tm)  //The answer vary due to round off error
             printf(" (b)Power consumed, P =%.2f kW \n",P)  //The answer vary due to round off error
```

Scilab code Exa 11.20 To Determine i Head generated by the Pump ii Shaft Power req

```
//Fluid Systems - By - Shiv Kumar
```

```
//Chapter 11- Centrifugal Pumps
//Example 11.20
//To Determine        (i)Head generated by the Pump        (ii)Shaft Power required to run the Pump.

            clc
            clear

//Given Data:-
      n=3;            //Number of Stages
      Do=400;            //Diameter of the Impeller at Outlet, mm
      bo=20;            //Width of Impeller at outlet, mm
      beta_o=45;       //degrees
      Area_per=10;          //Percentage of Total Area which is reduced.
      eta_o=80/100;          //Overall Efficiency
      eta_man=90/100;             //Manometric Efficiency
      N=1000;             //Speed, rpm
      Q=0.05;            //Discharge, m^3/s


//Data Used: -
            rho=1000;                  //Density of water, kg/m^3
         g=9.81;        //Acceleration due to gravity, m/s^2


//Computations:-
              Do=Do/1000;          //m
              bo=bo/1000;          //m
             A=%pi*Do*bo*(1-Area_per/100);          //Actual Area of Flow, m^2

```

```
uo=%pi*Do*N/60;          //Tangential
   Velocity of Impeller at Outlet, m/s
Vfo=Q/A;          //Velocity of Flow, m/
   s
Vfi= Vfo;
Vwo=uo-Vfo/tand(beta_o);       //m/s   (
   Value given in book is wrong due to
   incorrect value of beta_o is used)

// (i)Head generated by the Pump , H_Tm
  Hm=eta_man*Vwo*uo/g;          //m
  H_Tm=n*Hm;          //m

 //(ii) Shaft Power required to run the Pump ,
    P
     P=rho*Q*g*H_Tm/(eta_o*1000);
                   //kW


//Results:-
printf(" (i)Head generated by the Pump ,
   H_Tm=%.2f m \n",H_Tm)      //The answer
   provided in the textbook is wrong
printf(" (ii) Shaft Power required to run
   the Pump , P =%.2f kW \n",P)      //The
   answer provided in the textbook is
   wrong
```

Scilab code Exa 11.21 To Find the Manometric Efficiency

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11- Centrifugal Pumps
//Example 11.21
//To Find  the Manometric Efficiency
          clc
```

```
            clear

//Given Data:-
      n=4;            //Number of Pumps
      N=400;             //Speed, rpm
      H_Tm=40;          //Total Manometric Head, m
      Q=0.2;            //Discharge, m^3/s
      beta_o=40;        //Vane Angle at Outlet, degrees
      Do=600;            //Diameter of the Impeller at Outlet, mm
      bo=50;            //Width of Impeller at outlet, mm


//Data Used: -
          rho=1000;               //Density of water, kg/m^3
         g=9.81;        //Acceleration due to gravity, m/s^2


//Computations:-
            Do=Do/1000;          //m
            bo=bo/1000;          //m
           A=%pi*Do*bo;            //Area of Flow, m^2
           Hm=H_Tm/n;              //Manometric Head of each Pump, m

             uo=%pi*Do*N/60;          //Tangential Velocity of Impeller at Outlet, m/s
             Vfo=Q/A;          //Velocity of Flow, m/s
             Vfi= Vfo;
             Vwo=uo-Vfo/tand(beta_o);      //m/s

              eta_man=g*Hm/(Vwo*uo)*100;       //Manometric Efficiency in Percentage
```

```
//Results:-
        printf("Manometric Efficiency , eta_man=%.2
           f Percent \n",eta_man)        //The
           answer vary due to round off error
```

Scilab code Exa 11.22 To Find a Working Speed of the Protype b Shaft Power of the

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11 - Centrifugal Pumps
//Example 11.22

      clc
      clear

//Given Data:-
          //For Model,
             H_mM=7.5;        //Manometric Head, m
             Nm=1000;         //Speed, rpm
             Pm=25;           //Shaft Power, kW

        //For Prototype,
             H_mP=23;            //Manometric Head, m

      Dm_by_Dp=1/6;              //Scale Ratio


//Computations:-

         // (a)Working Speed of the Prototype, Np
           Np=Nm*Dm_by_Dp*sqrt(H_mP/H_mM);        //
              rpm

       // (b)Shaft Power of the Prototype, Pp
```

```
                Pp=Pm*(Np/Nm)^3*(1/Dm_by_Dp)^5;        //kW

        // (c)Ratio of Flow Rates handled by the protoytpe and the Model, Qp/Qm
            Qp_by_Qm=(Np/Nm)*(1/Dm_by_Dp)^3;

//Results:-
            printf(" (a)Working Speed of the Prototype, Np =%.2f rpm\n",Np)        //The answer vary due to round off error
            printf(" (b)Shaft Power of the Prototype, Pp =%.2f kW\n",Pp)        //The answer vary due to round off error
            printf(" (c)Ratio of Flow Rates handled by the protoytpe and the Model=%.2f ",Qp_by_Qm)        //The answer provided in the textbook is wrong
```

Scilab code Exa 11.23 To Find the Head and Impeller Diameter of the other Pump

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11 - Centrifugal Pumps
//Example 11.23
//To Find the Head and Impeller Diameter of the other Pump.

      clc
      clear

//Given Data:-
            //For Pump-1,
                N1=1000;         //Speed, rpm
                D1=320;           //Impeller Diameter, mm
```

```
                Hm1=16;         //Manometric Head, m
                Q1=0.021;         //Discharge, m^3/s

        //For Pump-2,
                  N2=1000;              //Speed, rpm
            //As other Pump has to deliver half the discharge,
                   Q2=Q1/2;          //m^3/s


//Computations:-
                Hm2=Hm1*(N2/N1)*sqrt(Q2/Q1);          //m
                D2=D1*(N1/N2)*sqrt(Hm2/Hm1);          //mm

//Results:-
        printf("Head of the other Pump(Pump-2), Hm2=%.2f m\n",Hm2)
        printf("Impeller Diameter of the other Pump(Pump-2), D2=%.2f mm\n",D2)          //The answer vary due to round off error
```

Scilab code Exa 11.24 To Find the the number of stages and Diameter of each Impell

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11 - Centrifugal Pumps
//Example 11.24
//To Find the the number of stages and Diameter of each Impeller of the similar multistage Pump.

      clc
      clear

//Given Data:-
```

```
            //For Single Stage Pump,
               N1=2000;         //Speed, rpm
               D1=300;           //Impeller Diameter, mm
               Hm1=32;        //Manometric Head, m
               Q1=3;        //Discharge, m^3/s

          //For Multi Stage Pump,
                 N2=1600;              //Speed, rpm
                 H_mT2=200;          //Total Manometric Head, m
                 Q2=5;          //Discharge,  m^3/s


//Computations:-
               Hm2=Hm1*(N2/N1)*sqrt(Q2/Q1);          //m
               n=round(H_mT2/Hm2);          //No. of stages
               D2=D1*(N1/N2)*sqrt(Hm2/Hm1);          //Diameter of Each Impeller, mm

//Results:-
        printf("Number of  the Stages for the Multi stage Pump, n=%.f  \n",n)
        printf("Diameter of each Impeller for the Multi stage Pump, D2=%.2f mm\n",D2)        //The answer vary due to round off error
```

Scilab code Exa 11.25 To Find the Discharge and Head of the Pump at Condition 2 an

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11 - Centrifugal Pumps
//Example 11.25
```

```
//To Find the Discharge and Head of the Pump at
    Condition '2' and '3' and Compare the Power
    Consumed in all the cases.

        clc
        clear

//Given Data:-
          //At Condition '1'
                N1=750;          //Speed, rpm
                Q1=60;             //Discharge, l/s
                H1=20;            //Head, m

         //At Condition '2'
               N2=1200;           //Speed, rpm

          //At Condition '3'
               N3=4200;           //Speed, rpm

//Computations:-
          Q2=Q1*(N2/N1);          // l/s
          H2=H1*(N2/N1)^2;         //m
          Q3=Q1*(N3/N1);         // l/s
          H3=H1*(N3/N1)^2;        //m

//Results:-
        printf("At Condition -2   Discharge, Q2=%.f
           l/s  and  Head, H2=%.1f m\n",Q2,H2)
        printf(" At Condition -3   Discharge, Q3=%.f
            l/s  and  Head, H3=%.1f m\n",Q3,H3)
        printf(" P1: P2 : P3 = 1 : %.2f : %.2f ",Q2*
           H2/(Q1*H1),Q3*H3/(Q1*H1))        //The
           answer vary due to round off error
```

Scilab code Exa 11.26 `To Calculate the Specific Speed of Pump and the Power Input`

```
//Fluid Systems - By - Shiv Kumar
//Chapter 11 - Centrifugal Pumps
//Example 11.26
//To Calculate the Specific Speed of Pump and the
   Power Input and Find the Head, Discharge and
   Power required at 900 rpm.

      clc
      clear

//Given Data:-

                N=1500;          //Speed, rpm
                Q=0.2;             //Discharge, m^3/s
                H=15;            //Head, m
                eta_o=0.68;          //Overall
                   Efficiency
              N2=900;           //Speed, rpm

 //Data Used:-
        rho=1000;         //Density of water, kg/m^3
         g=9.81;            //Acceleratio due to
            gravity, m/s^2


//Computations:-
          Ns=N*Q^(1/2)/(H^(3/4));         //Specific
             Speed of Pump, SI Units
          P=rho*g*Q*H /eta_o;           //Power Input
             , W

         Q1=Q;     H1=H;        N1=N;       P1=P;
          Q2=Q1*(N2/N1);         // m^3/s
          H2=H1*(N2/N1)^2;        //m
          P2=P1*(N2/N1)^3;        //W

//Results:-
        printf("Specific Speed of Pump, Ns=%.2f (SI
```

```
    Units)\n",Ns)
printf(" Power Input, P=%.2f W\n",P)
printf(" At 900 rpm (Condition 2)\n\t ")
    printf(" Head, H2=%.1f m \n\t Discharge,
        Q2=%.2f m^3/s,\n\t Power required,
        P2=%.2f W",H2,Q2,P2)
```

Chapter 12

Reciprocating Pumps

Scilab code Exa 12.1 To Determine 1 The Slip 2 The Coefficient of Discharge 3 Theo

```
//Fluid Systems - By Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.1

      clc
      clear

//Given Data:-
            Hs_th=4.8;                //Suction Head (Theoretical), m
            Hd_th=12;                 //Delivery Head (Theoretical), m
            N=90;                     //Speed of Pump, rpm
            D=100;                 //Piston Diameter, mm
            L=150;                 //Length of Stroke, mm
            Q=102;              //Actual Discharge, lit./min
            eta_s=60/100;             //Efficiency of Suction Stroke
            eta_d=75/100;            //Efficiency of
```

```
Delivery Stroke

//Data Used:-
        rho=1000;        //Density of Water, kg/m^3
          g=9.81;          //Accelerationdue to gravity , m/s^2

//Computations:-
        Vs=(%pi/4)*(D/1000)^2*(L/1000);          // Swept volume in one revolution , m^3
        Vth=Vs*N/60;                    //Theoritical Volume of Water pumped per second , m^3
        m=Vth*rho;          //Theoritical Mass Flow rate , kg/s
        m_act=Q*1000/(60*1000);       //Actual mas flow rate , kg/s

          Slip=(m-m_act)*100/m;    //Slip in Percentage
          Cd=m_act/m*100;         //Co-efficient of Discharge in Percentage
          Hs=Hs_th/eta_s;      //Suction Head taking suction efficiency in account , m
          Hd=Hd_th/eta_d;      //Delivery Head taking delivery efficiency in account , m
          H=Hs+Hd;      //Total Head, m
          Pth=m*g*H;         //Theoritical power required to Drive the Pump, W
            A=(%pi/4)*(D/1000)^2;      //Cross section Area of piston , m^2
          Fs=rho*g*Hs*A;         //Average Force during Suction , N
          Fd=rho*g*Hd*A;         //Average Force during Delivery , N
          P=(Fs+Fd)*L*N/60;        //Power required by Pump (Same as Pth), W

//Results:-
```

```
        printf(" 1. Slip=%.2f Percent \n",Slip)           //The answer vary due to round off error
        printf(" 2. The Co-efficient of Discharge = %.2f Percent \n",Cd)        //The answer vary due to round off error
        printf(" 3. Theoretical Power Required to Drive the Pump =%.2f W \n",Pth)        //The answer vary due to round off error
        printf(" 4. Force Required to Work the Piston during Suction Stroke =%.2f N \n",Fs)
        printf(" 5. Force Required to Work the Piston during Delivery Stroke =%.2f N \n",Fd)
```

Scilab code Exa 12.2 To Determine 1 The Slip 2 The Coefficient of Discharge 3 Theo

```
//Fluid Systems - By Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.2
//Referring to Example 12.1
//To Determine        1.The Slip        2. The Co-efficient of Discharge         3. Theoretical Power Requied to Drive the Pump        4. Force Required to Work the Piston during Suction Stroke        5. Force Required to Work the Piston during Delivery Stroke.

    clc
    clear

//Given Data:-
    //The Pump is Double Acting
    //From Example 12.1
```

```
            Hs_th=4.8;                //Suction Head (
               Theoretical), m
            Hd_th=12;                 //Delivery Head (
               Theoretical), m
            N=90;                     //Speed of Pump,
               rpm
            D=100;                    //Piston Diameter, mm
            L=150;                    //Length of Stroke, mm
            eta_s=60/100;             //Efficiency of
               Suction Stroke
            eta_d=75/100;             //Efficiency of
               Delivery Stroke

          Q=200;                //Actual Discharge, lit./
             min
          d=20;             //Diameter of Piston Rod, mm


//Data Used:-
          rho=1000;         //Density of Water, kg/m^3
           g=9.81;          //Accelerationdue to
              gravity, m/s^2

//Computations:-
         A=(%pi/4)*(D/1000)^2;      //m^2
         a= (%pi/4)*(d/1000)^2;      //m^2
         L=L/1000;          //m
         Vs=2*A*L;             //Swept volume in one
            revolution, m^3
         Vth=A*L*N/60+(A-a)*L*N/60;
            //Theoritical Volume of Water pumped per
            second, m^3
         m=Vth*rho;           //Theoritical Mass Flow
            rate, kg/s
         m_act=Q*1000/(60*1000);      //Actual mas
            flow rate, kg/s

           Slip=(m-m_act)*100/m;   //Slip in
```

```
Percentage
            Cd=m_act/m*100;         //Co-efficient of Discharge in Percentage
            Hs=Hs_th/eta_s;      //Suction Head taking suction efficiency in account , m
            Hd=Hd_th/eta_d;      //Delivery Head taking delivery efficiency in account , m
            H=Hs+Hd;       //Total Head, m
            Pth=m*g*H;          //Theoritical power Required to Drive the Pump, W
            Fb=rho*(Hs*A+Hd*(A-a));          //Force to be provided by Pump during Backward Stroke , kg
            Ff=rho*(Hs*(A-a)+Hd*A);         // Force to be provided by Pump during Forward Stroke , kg

//Results:-
         printf(" 1. Slip=%.1f Percent \n",Slip)         //The answer vary due to round off error
         printf(" 2. The Co-efficient of Discharge = %.1f Percent \n",Cd)        //The answer vary due to round off error
         printf(" 3. Theoretical Power Requied to Drive the Pump =%.2f W \n",Pth)        // The answer vary due to round off error
         printf(" 4. Force to be provided by Pump during Backward Stroke =%.1f kg \n",Fb)
         printf(" 5. Force to be provided by Pump during Forward Stroke =%.f kg \n",Ff)
```

Scilab code Exa 12.3 To Calculate The Maximum Speed at which pump may be run and D

```
//Fluid Systems - By Shiv Kumar
```

```
//Chapter 12- Reciprocating Pumps
//Example 12.3
//To Calculate The Maximum Speed at which pump may
   be run and Determine Resultant Suction Head at
   Begining, Middle and End of the Stroke.

      clc
      clear

//Given Data:-
    D=150;        //Diameter of Plunger, mm
    L=250;        //Stroke length, mm
    l_s=10;         //Length of Suction Pipe, m
    d=75;          //Diameter of Suction Pipe, mm
    hs=4;         //Suction Head, m of water
    Ha=10.34;          //Atmospheric Pressure, m of
       water
    Habs=2.44;        //Absolute Pressure Head, m of
       water

//Data Used:-
       g=9.81;          //Acceleration due to gravity
          , m/s^2


//Computations:-
           Hv=Ha-Habs;       //Vaccume Pressure, m of
              water
     //For Maximum Resultant Suction Head,
            Hs=Hv;
      A=(%pi/4)*(D/1000)^2;          //m^2
      a_s=  (%pi/4)*(d/1000)^2;          //m^2
      r=L/2000;       //m
      omega=sqrt((Hs-hs)*g*a_s/(l_s*A*r));      //
         radian/sec
      N=60*omega/(2*%pi);       //rpm

//Result 1
```

```
        printf(" The Maximum Speed at which pump may be run, N=%.2f rpm \n",N)           //The answer vary due to round off error

    //At Begining
        Has=(l_s/g)*(A/a_s)*omega^2*r*cosd(0);       //m
        Hs=hs+Has;            //Resultant Head at Begining of Stroke, m of water

//Result 2
        printf(" Resultant Head at Begining of Stroke, Hs=%.1f m of water \n",Hs)


     //At Middle
        Has=(l_s/g)*(A/a_s)*omega^2*r*cosd(90);       //m
        Hs=hs+Has;        //Resultant Head at Middle of Stroke (Has=0), m of water

//Result 3
        printf(" Resultant Head at Middle of Stroke, Hs=%.f m of water \n",Hs)


    //At the End
          Has=(l_s/g)*(A/a_s)*omega^2*r*cosd(180);          //m
          Hs=hs+Has;           //Resultant Head at End of Stroke, m of water
            // Resultant Head at End of Stroke is not calculated and displayed as result in the textbook.

//Result 4
        printf(" Resultant Head at End of Stroke, Hs=%.1f m of water \n ",Hs)
```

Scilab code Exa 12.4 To Find whether seperation will take place and if so at which

```
//Fluid Systems - By Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.4
//To Find whether seperation will take place, and if so, at which section of pipe.

    clc
    clear

//Given Data:-
     ld=60.96;          //Length of Delivery Pipe, m
     a=1.83;           //Acceleration of Plunger Pump, m/s^2
     A_by_ad=2;       //ratio of Sectional Area of Plunger to that of Delivery Pipe.
    //Referring to Fig 12.6 in the textbook,
       ef=18.3;          //m
       eq=12.19;      //m
       dq=1.83;         //m
       slope=3;

    Hsp=2.44;        //Pressure Head in pipe when seperation takes place, m of water
    Hatm=10.36;      //Atmospheric Pressure Head (Barometer Reading), m of water

//Data Used:-
       g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
```

```
        Had=-(ld/g)*A_by_ad*a;                //Head
           at end of stroke,   a=acceleration=omega
           ^2*r,  Had in m
        dp=Had;    // Referring to Fig 12.6 in the
           textbook
        ed=eq+dq;
        Hd=ed;          //Total Delivery Head, m
        Hrd=Had+Hd;          //Resultant Pressure in
           Delivery pipe at end of Stroke, m
        Habs=Hatm+Hrd;        //Absolute Pressure. m
            of water

    Hv=Hatm-Hsp;        //Vaccum pressure, m
    x=-Hv-Had;       //m

     if Habs<Hsp then
        printf("The Seperation Will Take Place  at x=
          %.2f m\n",x)        //The answer vary due
          to round off error
        else
        printf("The Seperation Will Not Take Place \
           n")
        end
```

Scilab code Exa 12.5 To Determine the Pressure Head on Piston at Begining Middle a

```
//Fluid Systems - By Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.5
//To Determine the Pressure Head on Piston at
   Begining, Middle and End of Suction Stroke.

      clc
      clear

```

```
//Given Data:-
         L=150;        //Length of Stroke, mm
         l_s=7;           //Length of Suction Pipe, m
         ds_by_D=3/4;           //Ratio of Suction Pipe Diameter to Piston Diameter, ds/D
         hs=2.5;        //Suction Head, m
         ds=75;       //Diameter of Suction Pipe, mm
         N=75;          //Crank Speed, rpm
         f=0.01;         //Co-efficient of Friction


//Data Used:-
     g=9.81;        //Acceleration due to gravity, m/s^2
     h_atm=10.33;         //Atmospheric Pressure Head, m of water


//Computations:-
        L=L/1000;      //m
        ds=ds/1000;       //m

          r=L/2;       //Crank radius, m
          A_by_as=(1/ds_by_D)^2;
         omega=2*%pi*N/60;           //Angular Velocity, rad/s

//At Begining of Suction Stroke,
        theta=0;          //degrees
        h_as=(l_s/g)*A_by_as*omega^2*r*cosd(theta);          //Acceleration Head, m of water
        h_fs=(4*f*l_s/(2*g*ds))*(A_by_as*omega*r*sind(theta))^2;          //Head loss due to friction, m of water
        h_v=hs+h_fs+h_as;           //Pressure Head on Piston, m of water Vaccum
        h_abs=h_atm-h_v;           //Pressure Head on Piston, m of water Absolute
```

```
    //Result 1
        printf("At Begining of Suction Stroke\n Pressure Head on Piston=%.2f m of water Vaccum \n\t\t\t =%.2f m of water Absolute\n \n",h_v,h_abs)        //The answer vary due to round off error


//At Mid of Suction Stroke,
        theta=90;           //degrees
        h_as=(l_s/g)*A_by_as*omega^2*r*cosd(theta);          //Acceleration Head, m of water
        h_fs=(4*f*l_s/(2*g*ds))*(A_by_as*omega*r*sind(theta))^2;          //Head loss due to friction, m of water
        h_v=hs+h_fs+h_as;            //Pressure Head on Piston, m of water Vaccum
        h_abs=h_atm-h_v;           //Pressure Head on Piston, m of water Absolute
    //Result 2
        printf("At Middle of Suction Stroke\n Pressure Head on Piston=%.4f m of water Vaccum \n\t\t\t =%.3f m of water Absolute\n \n",h_v,h_abs)        //The answer vary due to round off error


//At End of Suction Stroke,
        theta=180;           //degrees
        h_as=(l_s/g)*A_by_as*omega^2*r*cosd(theta);          //Acceleration Head, m of water
        h_fs=(4*f*l_s/(2*g*ds))*(A_by_as*omega*r*sind(theta))^2;          //Head loss due to friction, m of water
        h_v=hs+h_fs+h_as;            //Pressure Head on Piston, m of water Vaccum
        h_abs=h_atm-h_v;           //Pressure Head on Piston, m of water Absolute
```

```
  //Result 3
     printf("At End of Suction Stroke\n  Pressure
        Head on Piston=%.2f m of water Vaccum \n\t\
        t\t =%.2f m of water Absolute\n\n",h_v,
        h_abs)        //The answer vary due to round
         off error
```

Scilab code Exa 12.6 To Find the Pressure Head on Piston at the begining middle an

```
//Fluid Systems - By- Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.6

    clc
     clear

//Given Data:-
        D=200;          //Piston Diameter, mm
        L=300;         //Stroke length, mm
        H_s=4;        //Suction Head, m
        H_d=35;       //Delivery Head, m
        d_s=100;        //Diameter of Suction Pipe, mm
        d_d=d_s;        //Diameter of Delivery Head
        l_d=50;          //Length of Delivery Pipe, m
        l_s=10;          //Length of Suction Pipe, m
        f_s=0.04;      //Co-efficient of friction for
           Suction Pipe
        f_d=f_s;        //Co-efficient of friction for
            Delivery Pipe
        N=30;          //Speed of Pump, rpm


//Data Used:-
       g=9.81;           //Acceleration due to gravity
          , m/s^2
```

```
        rho=1000;       //Density of water, kg/m^3


//Computations:-
           D=D/1000;       //m
           L=L/1000;       //m
           d_s=d_s/1000;       //m
           d_d=d_d/1000;        //m

         a_s=(%pi/4)*d_s^2;        //m^2
         a_d=(%pi/4)*d_d^2;       //m^2
         A=(%pi/4)*D^2;         //m^2
         omega=2*%pi*N/60;       //rad/s
          r=L/2;         //m

    // (1) Suction Stroke
          //At end of Stroke,
           H_as=(l_s/g)*(A/a_s)*omega^2*r;         //m
               of water

          //At middle of Stroke,
              h_fs=f_s*(l_s/d_s)*(1/(2*g))*((A/a_s)*
                 omega*r)^2;        //m of water

          H_sb=H_s+H_as;       //Pressure at begining
             of suction stroke, m of water (vaccum)
          H_se=H_s-H_as;       //Pressure at end of
             suction stroke, m  of water
          H_se=abs(H_se);     //m above atmosphere
          H_sm=H_s+h_fs;        //Pressure at middle
             of suction stroke, m of water (vaccum)

    // (1) Delivery Stroke
          //At end of Stroke,
           H_ad=(l_d/g)*(A/a_d)*omega^2*r;         //m
               of water

          //At middle of Stroke,
```

```
            h_fd=f_d*(l_d/d_d)*(1/(2*g))*((A/a_d)*omega*r)^2;        //m of water

        H_db=H_d+H_ad;      //Pressure at begining of delivery stroke, m of water (above atmosphere)
        H_de=H_d-H_ad;      //Pressure at end of delivery stroke, m  of water (above atm.)
        H_dm=H_d+h_fd;        //Pressure at middle of delivery stroke, m of water (above atm.)

        m=rho*A*L*N/60;      //Mass of Water Discharge, kg/s
    //Referring to Equation 12.18 in the textbook,
        Work= m*g*(H_s+H_d+(2/3)*h_fs+(2/3)*h_fd);        //Total Work done by Pump, W

//Results:-
    printf("(1)Suction Stroke\n\t")
        printf("Pressure at Begining of the Stroke=%.2f m of water (vaccum)\n\t",H_sb)        //The answer vary due to round off error
        printf("Pressure at End of the Stroke=%.1f m of water (above atmosphere\n\t",H_se)          //The answer vary due to round off error
        printf("Pressure at Middle of the Stroke=%.3f m of water (vaccum)\n\n",H_sm)        //The answer vary due to round off error

    printf("(2)Delivery Stroke\n\t")
        printf("Pressure at Begining of the Stroke=%.2f m of water ( above atmosphere )\n\t",H_db)        //The answer vary due to round off error
        printf("Pressure at End of the Stroke=%.2f m
```

```
    of water (above atm.)\n\t",H_de)
     //The answer vary due to round off error
    printf("Pressure at Middle of the Stroke=%.2
     f m of water ( above atm. )\n",H_dm)
            //The answer vary due to round off
     error

  printf("  Power Required to drive the Pump=%.2f
     W",Work)          //The answer vary due to
    round off error
```

Scilab code Exa 12.7 To Calculate a The Absolute Head in the Pump corresponding to

```
//Fluid Systems - By- Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.7
//To Calculate (a)The Absolute Head in the Pump
    corresponding to the four corners of the cord and
     also the mid strokes       (b)The Work done/
    minute.

    clc
     clear

//Given Data:-
        D=125;          //Bore of the Pump, mm
        L=125;        //Stroke length , mm
        N=30;         //Speed of Pump, rpm
        H_s=3;       //Suction Head, m
        H_d=15;      //Delivery Head, m
        d_s=62.5;       //Diameter of Suction Pipe,
          mm
        d_d=d_s;       //Diameter of Delivery Head
        l_d=18;         //Length of Delivery Pipe, m
        l_s=l_d;          //Length of Suction Pipe
```

```
        f=0.032;    //Co−efficient of friction for both Pipes


//Data Used:−
       g=9.81;          //Acceleration due to gravity , m/s^2
       rho=1000;       //Density of water , kg/m^3
       H_a=10.2;        //Atmospheric Pressure Head , m of water

//Computations:−
          D=D/1000;       //m
          L=L/1000;       //m
          d_s=d_s/1000;       //m
          d_d=d_d/1000;        //m

        a=(%pi/4)*d_s^2;         //m^2
        A=(%pi/4)*D^2;          //m^3
        omega=2*%pi*N/60;        //rad/s
         r=L/2;          //m

        H_as=(l_s/g)*(A/a)*omega^2*r;         //m
        h_fs_max=f*(l_s/d_s)*(1/(2*g))*((A/a)*omega*r)^2;            //m
    //As Pipes are of same diameter and length ,
        H_ad=H_as;
        h_fd_max=h_fs_max;

        H_m=H_a-H_s-H_as;          //Pressure Head at 'm' , m of water
        H_r= H_a-H_s-h_fs_max ;          //Pressure Head at 'r' , m of water
        H_n=H_a-H_s+H_as ;          //Pressure Head at 'n' , m of water
        H_at_s= H_a+H_s+H_as ;          //Pressure Head at 's' , m of water
        H_o=H_a+H_d+h_fd_max ;          //Pressure
```

```
Head at 'o' , m of water
        H_q=H_a+H_d+H_ad ;          //Pressure Head at 'q' , m of water

    m=rho*A*L*N*2/60;          //mass of water/s,  kg/s
    Work_s=m*g*(H_s+H_d+(2/3)*h_fs_max+(2/3)*h_fd_max);      //Word done/s, W
    Work_m=Work_s*60;       //Work done/min. , J/min

//Results:-
      printf("Pressure Head at m =%.2f m of water\n",H_m)         //The answer vary due to round off error
      printf("Pressure Head at r =%.3f m of water\n",H_r)         //The answer vary due to round off error
      printf("Pressure Head at n =%.2f m of water\n",H_n)         //The answer provided in the textbook is wrong
      printf("Pressure Head at s =%.2f m of water\n",H_at_s )       //The answer provided in the textbook is wrong
      printf("Pressure Head at o =%.3f m of water\n",H_o)         //The answer vary due to round off error
      printf("Pressure Head at q =%.2f m of water\n\n ",H_q)         //The answer provided in the textbook is wrong

       printf("Work done/s=%.1f W  \n Work done/minute=%.2f J/min. \n",Work_s,Work_m)          //The answer provided in the textbook is wrong
```

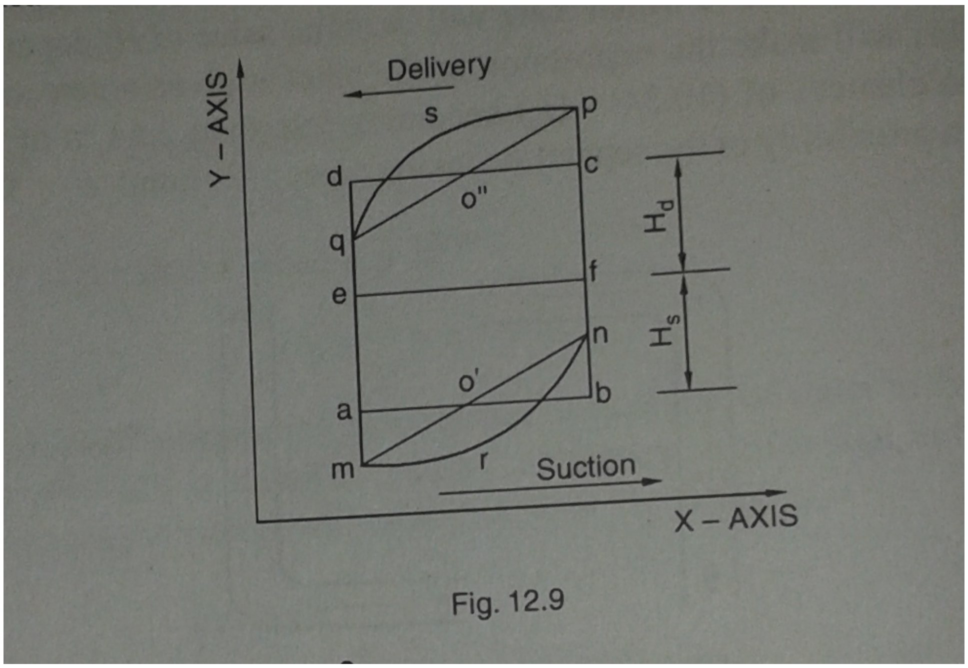

Figure 12.1: To Calculate a The Absolute Head in the Pump corresponding to the four corners of the cord and also the mid strokes b The Work done per minute

Scilab code Exa 12.8 To a Find the Speed at which seperation may take place at com

```
//Fluid Systems - By- Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.8
//To    (a) Find the Speed at which seperation may take place at commencement of suction stroke,
        (b)Find the  change in Speed of Pump if an air vessel is fitted in the suction side.

    clc
     clear

//Given Data:-
        H_s=3.60;      //Suction Head, m
        d_s=225;      //Diameter of Suction Pipe, mm
        l_s=9.6;        //Length of Suction Pipe, m
        D=300;        //Pump cylinder diameter, mm
        L=450;       //Stroke length, mm

        H_a=9.6;      //Barometric Head, m of water
        H_sp=2.4;     //Head (m of water) for seperation
        f=0.04;


//Data Used:-
       g=9.81;          //Acceleration due to gravity, m/s^2


//Computations:-
          D=D/1000;      //m
          L=L/1000;      //m
```

```
        d_s=d_s/1000;      //m

      a_s=(%pi/4)*d_s^2;        //m^2
      A=(%pi/4)*D^2;         //m^2
      r=L/2;         //m

   //Without Air Vessel
      H_as_by_omega2=(l_s/g)*(A/a_s)*r;         //H_as/omega^2
      omega=sqrt((H_a-H_s-H_sp)/H_as_by_omega2);        //rad/s
      N=omega*60/(2*%pi);        //rpm

  //With Air Vessel
       Us_by_N=(A/a_s)*L/60;       //Us/N
       l_v=H_sp/2;      //m
       H_as_by_N2=(l_v/g)*(A/a_s)*(2*%pi/60)^2*r;        //H_as/N^2
       h_fs_by_N2=f*(l_s-l_v)*Us_by_N^2/(r*2*g);
       N1=sqrt((H_a-H_sp-H_s)/(H_as_by_N2+h_fs_by_N2));      //Speed of Pump if air vessel is fitted , rpm
       Change_In_Speed=N1-N;         //rpm


//Results:-
      printf("(a)Speed at which Seperation may take place , N=%.f rpm\n",N)
      printf("(b)Change in Speed with air vessel=%.f rpm\n",Change_In_Speed)        //The answer provided in the textbook is wrong
```

Scilab code Exa 12.9 To Determine the Pressure on the Cylinder at the Begining of

```
//Fluid Systems - By - Shiv Kumar
```

```
//Chapter 12- Reciprocating Pumps
//Example 12.9
//To Determine the Pressure on the Cylinder at the Begining of the Stroke          (a)When no air vessel is fitted ,          (b)When air vessel is fitted at the cylinder level.

        clc
         clear

//Given Data:-
        d_s=150;        //Diameter of Suction Pipe, mm
        l_s=12;         //Length of Suction pipe, m
        H_s=3;        //Suction Head, m
        D=225;        //Cylinder Diameter, mm
        L_s=375;          //Stroke Length, mm
        L=1.5;         //Length of Connecting Rod, m
        N=20;        //Crank Speed, rpm
        l_v=1.5;      //m
        f=0.04;       //Co-efficient of friction

//Data Used:-
      g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
         d_s=d_s/1000;      //m
         D=D/1000;        //m
         L_s=L_s/1000;       //m

         a_s=(%pi/4)*d_s^2;       //m^2
         A=(%pi/4)*D^2;       //m^2
         omega=2*%pi*N/60;        //rad/s
          r=L_s/2;        //m

          printf("Without Air Vessel : \n\t")
           //(i) Assuming Simple Harmonic Motion :
```

```
            printf("(i) Assuming Simple Harmonic Motion\n\t\t")
            H_as=(l_s/g)*(A/a_s)*omega^2*r;        //m of water
            H=H_s+H_as;        //Pressure at the begining of stroke, m of water (vaccum)
    //Result (a) (i)
        printf(" Pressure at the begining of stroke=%.2f m of water (vaccum)\n\t",H)         //The answer vary due to round off error

    //(ii) If Simple Harmonic Motion is not assumed :
        printf(" (ii) If Simple Harmonic Motion is not assumed : \n\t\t")
            H_as=H_as*(1+r/L);
            H=H_s+H_as;        //Pressure at the begining of stroke, m of water (vaccum)
    //Result (a) (ii)
        printf(" Pressure at the begining of stroke=%.3f m of water (vaccum)\n\n",H)         //The answer vary due to round off error


//(b) When Air Vessel is fitted
    printf(" When Air Vessel is fitted : \n\t")

        Us=(A/a_s)*L_s*N/60;        //m/s
        h_fs=(f*(l_s-l_v)/d_s)*(Us^2/(2*g));        //m of water

    //(i) Assuming Simple Harmonic Motion :
```

```
                printf("(i) Assuming Simple Harmonic Motion\n\t\t")
                H_as=(l_v/g)*(A/a_s)*omega^2*r;          //m of water (vaccum)
                H=H_s+H_as+h_fs;          //Total Pressure Head in the Cylinder, m of water below atmospheric
        //Result (b) (i)
            printf(" Total Pressure Head in the Cylinder =%.4f m of water below atmospheric or vaccum \n\t",H)          //The answer vary due to round off error

        //(ii) If Simple Harmonic Motion is not assumed :
            printf(" (ii) If Simple Harmonic Motion is not assumed : \n\t\t")
                H_as=H_as*(1+r/L);
                H=H_s+H_as+h_fs;          // Total Pressure Head in the Cylinder, m of water below atmospheric
        //Result (b) (ii)
            printf(" Total Pressure Head in the Cylinder =%.4f m of water below atmospheric \n",H)          //The answer vary due to round off error
```

Scilab code Exa 12.10 To Find the Power required to overcome the friction of Deliv

```
//Fluid Systems - By - Shiv Kumar
//Chapter 12- Reciprocating Pumps
```

```
//Example 12.10
//To Find the Power required to overcome the
   friction of Delivery pipe when        (a)No air
   vessel is fitted on it ,         (b)A large air
   vessel is fitted at the centre line of the pump.

        clc
         clear

//Given Data:-
        N=60;        //Speed of the Pump, rpm
        D=250;        //Plunger Diameter , mm
        L=450;         //Stroke Length , mm
        d_d=112.5;         //Diameter of Delivery Pipe
           , mm
        l_d=48;          //Length of Delivery Pipe , m
        f=0.04;       //Co-efficient of friction

//Data Used:-
      g=9.81;        //Acceleration due to gravity , m
        /s^2
      rho=1000;     //Density of water , kg/m^3


//Computations:-
         d_d=d_d/1000;      //m
         D=D/1000;        //m
         L=L/1000;       //m

         a=(%pi/4)*d_d^2;       //m^2
         A=(%pi/4)*D^2;       //m^2
         omega=2*%pi*N/60;        //rad/s
          r=L/2;        //m

     //(a)Without Air Vessel
           H_fd=f*(l_d/d_d)*(omega*r*A/a)^2/(2*g);
                    //Maximum loss of head due to
              friction in delivery pipe ,  m
```

```
            m=rho*A*L*N/60;      //Mass of water
               lifted , kg/s
            Power=(2/3)*H_fd*m;       //W

      //Result (a)
          printf("(a)Without Air Vessel\n\t")
             printf("Power Required to Overcome
                Friction=%.2f W\n\n",Power)      //
                The answer provided in the textbook
                is wrong

      //(b)With Air Vessel
         Ud=A*L*N/(a*60);        //m/s
         H_fd=f*(l_d/d_d)*(Ud^2/(2*g));         //m
         Power=m*H_fd;     //W
      //Result (a)
          printf("(a)With Air Vessel\n\t")
             printf("Power Required to Overcome
                Friction=%.2f W\n",Power)       //The
                 answer vary due to round off error
```

Scilab code Exa 12.11 c To Find the Rate of flow into or from the air vessel when

```
//Fluid Systems - By - Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.11
//(a)Theoritical Question.
//(b)Theoritical Question.
//(c)To Find the Rate of flow into or from the air
   vessel when crank makes angle of 30, 90 and 120
   degrees with inner dead centre and
      //Also Determine crank angle at which there is
         no flow to or from the air vessel.

         clc
```

```
          clear

//Given Data:-
        D=200;          //Bore of the Pump, mm
        L=350;           //Stroke Length, mm
        d_s=150;          //Diameter of Suction Pipe, mm
        N=120;          //Speed of the Pump, rpm


//Computations:-
         d_s=d_s/1000;       //m
         D=D/1000;         //m
         L=L/1000;        //m

         A=(%pi/4)*D^2;        //m^2
         omega=2*%pi*N/60;         //rad/s
          r=L/2;         //m

        //Using the Equation 12.28 from the textbook, Rates of Flow are
          Q_30=A*omega*r*(2/%pi-sind(30))*1000;        //For 30 degree angle, litres/s
          Q_90=A*omega*r*(2/%pi-sind(90))*1000;        //For 90 degree angle, litres/s
          Q_120=A*omega*r*(2/%pi-sind(120))*1000;       //For 120 degree angle, litres/s

        theta=asind(2/%pi);      //Angle at which there is no flow, degrees
            //This is NOT Calculated in the Textbook.

//Results:-
    printf("Rate of Flow from the Air Vessel=%.1f litre/s  for 30 Degree Angle\n\t\t\t\t",Q_30)
    printf(" =%.f litre/s  for 90 Degree Angle\n\t\
```

```
        t\t\t",Q_90)
      printf(" =%.1f litre/s  for 120 Degree Angle\n"
        ,Q_120)

       printf("The angle at which there is no flow
         from or to the air vessel = %.2f Degrees\n"
         ,theta)
```

Scilab code Exa 12.12 To Find the Maximum Speed at which the Pump may run without

```
//Fluid Systems - By - Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.12
//To Find the  Maximum Speed at which the Pump may
   run without seperation.

        clc
         clear

//Given Data:-
        D=10;          //Plunger Diameter, cm
        L=20;           //Stroke Length, cm
        H_s=4;         //Suction Head, m
        H_d=14;        //Delivery Head, m
        d_s=4;          //Diameter of Suction Pipe, cm
        l_s=6;           //Length of Suction Pipe, m
        d_d=3;          //Diameter of Delivery Pipe, cm
        l_d=18;            //Length of Delivery Pipe, m
        p=7.85;         //Pressure (below atm.) for
           seperation, N/cm^2
        H_a=10.3;            //Atmospheric Pressure
           Head, m of water


//Data Used:-
```

```
      g=9.81;         //Acceleration due to gravity, m
         /s^2
      rho=1000;     //Density of water, kg/m^3


//Computations:-
         d_s=d_s/100;     //m
         d_d=d_d/100;      //m
         D=D/100;        //m
         L=L/100;       //m

         a_s=(%pi/4)*d_s^2;       //m^2
         a_d=(%pi/4)*d_d^2;       //m^2
         A=(%pi/4)*D^2;       //m^2
         r=L/2;        //m

        H_sp=p*100^2/(rho*g);      //Pressure Head of
            water for seperation, m (below
           atmosphere)     (Value given in textbook
           is wrong due to incorrect value of p is
           used)
        H_abs=H_a-H_sp;       //Absolute Pressure
           Head of water for seperation, m
        H_as_by_omega2=(l_s/g)*(A/a_s)*r;        //
           H_as/omega^2
        omega=sqrt((H_sp-H_s)/H_as_by_omega2);     //
           rad/s
        N_s=omega*60/(2*%pi);      //rpm

        H_ad_by_omega2=(l_d/g)*(A/a_d)*r;        //
           H_as/omega^2
        omega=sqrt((H_sp+H_d)/H_ad_by_omega2);     //
           rad/s
        N_d=omega*60/(2*%pi);      //rpm

    //Selecting maximum speed,
     if N_s>N_d then
       N=N_s;
```

```
      else
        N=N_d;

//Result:-
    printf("Hence, The Maximum Speed at which Pump
       should be Run is %.2f rpm\n",N)        //The
       answer vary due to round off error
```

Scilab code Exa 12.13 To Determine the Crank Angle at which there is no flow of wa

```
//Fluid Systems - By - Shiv Kumar
//Chapter 12- Reciprocating Pumps
//Example 12.13
//To Determine the  Crank Angle, at which there is
   no flow of water to or from the vessel.

        clc
         clear

//Given Data:-
        D=17.5;      //Bore diameter, cm
        L=35;      //Stroke Length, cm
        d_s=15;        //Diameter of Suction pipe, cm
        N=150;       //Speed, rpm

//Computations:-
       D=D/100;        //m
       L=L/100;        //m
       d_s=d_s/100;         //m

      omega=2*%pi*N/60;       //rad/s
       A=(%pi/4)*D^2;       //m^2
       r=L/2;       //m
       Q_s=2*A*omega*r/%pi;        //Rate of flow from
           sump upto air vessel, m^3/s
```

```
      theta=asind(Q_s/(A*omega*r));        //degrees


//Result:-
        printf("The Crank Angle at which there is
          no flow, theta=%.2f Degrees\n",theta)
```

Chapter 16

Hydraulic Power and Its Transmission

Scilab code Exa 16.1 To Find the Maximum Power Available at the Outlet of Pipe

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.1
//To Find the Maximum Power Available at the Outlet of Pipe.
    clc
    clear

//Given Data:-
  d=300;        //Diameter of the Pipe, mm
  l=3000;       //Length of the Pipe, m
  H=400;       //Total Head at Inlet, m
   f=0.005;

//Data Required:-
      rho=1000;     //Density of Water, Kg/m^3
      g=9.81;       //Acceleration due to gravity, m/s^2

```

```
//Computations:-
        //Condition for Maximum Power transmission
              hf=H/3;       //m
        V=sqrt(hf*(2*g*d/1000)/(4*f*l));       //m/s
        Q=(%pi/4)*(d/1000)^2*V;       //Discharge, m^3/s
        Pmax=rho*g*Q*(H-hf)/1000;       //Maximum Power Available at Outlet of Pipe, kW


//Results:-
    printf("The Maximum Power Available at Outlet of Pipe=%.3f kW",Pmax)       //The answer vary due to round off error
```

Scilab code Exa 16.2 To Determine the Flow Rate and the Minimum Diameter of Pipe

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.2
//To Determine the Flow Rate and  the Minimum Diameter of Pipe.
      clc
      clear

//Given Data:-
     P=1000;     //Power Transmitted, kW
     eta=85/100;      //Efficiency
     l=500;       //Length of the Pipe, m
     H=150;       //Head of Water at Inlet, m
     f=0.006;

//Data Required:-
        rho=1000;     //Density of Water, Kg/m^3
        g=9.81;       //Acceleration due to gravity,
```

```
            m/s^2

//Computations:-
        hf=H*(1-eta);    //m
        Q=P*10^3/(rho*g*(H-hf));        //m^3/s
        d=(64*f*l*Q^2/(2*g*%pi^2*hf))^(1/5);    //m

//Results:-
        printf("The Required Flow Rate, Q=%.4f m^3/s\n",Q)
        printf("The Minimum Diameter, d=%.4f m\n",d)        //The answer vary due to round off error
```

Scilab code Exa 16.3 To Determine the Minimum Number of Pipes

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.3
//To Determine the Minimum Number of Pipes.
    clc
    clear

//Given Data:-
    l=7500;        //Length of each Pipe, m
    d=125;       //Diameter of each Pipe, mm
    Pr=6000;      //Pressure at Discharge End, kPa
    eta=85/100;        //Efficiency
    P=156;       //Power Delivered, kW
    f=0.006;

//Data Required:-
        rho=1000;       //Density of Water, Kg/m^3
        g=9.81;         //Acceleration due to gravity, m/s^2
```

```
//Computations:-
        H_minus_hf=Pr*10^3/(rho*g);        //H-hf, m
        H=H_minus_hf/eta;          //m
        hf=H-H_minus_hf;           //m
        Q=P*1000/(rho*g*(H-hf));        //m^3/s
         q=sqrt((hf*2*g*%pi^2*(d/1000)^5)/(64*f*l))
            ;       //Discharge in each Pipe, m^3/s
        n=Q/q;          //Number of Pipes


//Results:-

        printf("The Minimum Number of Pipes
           Required=%.f\n",n)
```

Scilab code Exa 16.4 To Find the Diameter of Pipe

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.4
//To Find the Diameter of Pipe.
      clc
      clear

//Given Data:-
    l=2100;        //Length of the Pipe, m
    P=103;       //Power Transmitted, kW
    pi=392.4;      //Pressure at Inlet of Pipe, N/cm
       ^2
    eta=80/100;       //Efficiency
    f=0.005;

//Data Required:-
        rho=1000;      //Density of Water, Kg/m^3
```

```
        g=9.81;        //Acceleration due to gravity ,
            m/s^2

//Computations:-
          H=pi*10^4/(rho*g);      //m
          hf=H*(1-eta);      //m
         Q=P*1000/(rho*g*(H-hf));      //m^3/s
         d=((64*f*l*Q^2)/(hf*2*g*%pi^2))^(1/5)*1000;
                 //mm


//Results:-

         printf("The Diameter of Pipe=%.2f mm\n",d)
                 //The answer vary due to round off
             error
```

Scilab code Exa 16.5 To Calculate the Increase in Pressure Intensity

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.5
//To Calculate the Increase in Pressure Intensity.
      clc
      clear

//Given Data:-
          d=200;    //diameter of Pipe, mm
          Q=40;        //Discharge, Litres/s
          l=600;      //Length of Pipe, m
          t=1.5;       //Time taken to close the
             Valve gradually, s

//Data Required:-
        rho=1000;      //Density of Water, Kg/m^3
```

```
//Computations:-
            A=(%pi/4)*(d/1000)^2;      //m^2
            V=(Q/1000)/A;      //m/s
            p=rho*l*V/(t*1000);       //Pressure Rise, kPa


//Results:-

           printf("The Pressure Rise due to Gradual Closure of Valve=%.f kPa\n",p)       //The answer vary due to round off error
```

Scilab code Exa 16.6 `To Calculate the Rise in Pressure due to Valve Closure in i 1`

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.6
//To Calculate the Rise in Pressure due to Valve Closure in (i)10 seconds, (ii)2.5 seconds.
      clc
      clear

//Given Data:-
            l=2500;            //Lenfth of Pipe, m
            V=1.2 ;             //Velocity of Flow, m/s
            K=20*10^8;        //Bulk Modulus of Water, N/m^2

//Data Used:-
          rho=1000;        //Density of Water, Kg/m^3

//Computations:-
```

```
            a=sqrt(K/rho);          //Velocity of Pressure Wave, m/s
            t_c=2*l /a;           //Critical time,    s

        // (i)
               t=10;       // s
             //t>t_c. so, This is a case of Gradual valve closure.
              p=rho*l*V/(t*1000);         //Pressure Rise, kPa

        //Result (i)
            printf("(i)Pressure Rise, p=%.f kPa\n",p)

        //(ii)
             t=2.5;       // s
           // t<t_c.  This is a case of Instantaneous Valve Closure.
             p=rho*V*a/1000;            // Pressure Rise, kPa

        //Result (ii)
            printf("(ii)Pressure Rise, p=%.2f kPa\n",p)        //The answer vary due to round off error
```

Scilab code Exa 16.7 To Determine the Increasse in Pressure

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.7
//To Determine the Increasse in Pressure.
      clc
      clear

```

```
//Given Data:-
          d=800;              //Diameter of pipe, mm
          Q=0.75;          //Discharge, m^3/s
          t=10;                 //Thickness of Pipe, nmmm
          Es=20*10^10;         //Elastic Modulus of Steel, N/m^2
          E=2*10^9;         //Elastic Modulus of Water, N/m^2
          l=3500;              //Lenfth of Pipe, m
          T=5;          //Time of Valve Closure, s


//Data Used:-
        rho=1000;          //Density of Water, Kg/m^3

//Computations:-
         K=E/(1+(d/t)*(E/Es));        //Combined Modulus of Elasticity, N/m^2
         a=sqrt(K/rho);         //Velocity of Pressure Wave, m/s
          Tc=2*l /a;          //Critical time,    s

         //t<t_c. So, valve closure is rapid.
              A=(%pi/4)*(d/1000)^2;            //m^2
              V=Q/A;              //Average Velocity of Flow, m/s
              p=rho*V*a/1000;         //Pressure Rise, kPa


//Result
          printf("The Rise of Pressure=%.2f kPa\n",p)       //The answer provided in the textbook is wrong
```

Scilab code Exa 16.8 To Find i Displacement of Accumulator ii Capacity of Accumula

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.8
//To Find   (i)Displacement of Accumulator   (ii)
   Capacity of Accumulator     (iii)Total weight
   placed on the ram.
    clc
    clear

//Given Data:-
     p=200;          //Pressure of oil, kPa
     D=1.5;         //Diameter of Ram,  m
     L=6;           //Stroke or Lift of Ram, m

//Computations:-
     A=(%pi/4)*D^2;      //m^2
     Disp=A*L;         //Displacenmenmt  of
        Accumulator, m^3
     Capacity=p*Disp;          //Capacity of
        Accumulator, kNm
     W=p*A;        //Total Weight on the Ram,  kN

//Results:-
   printf("(i) Displacenmenmt of Accumulator=%.2f m
      ^3\n ",Disp)        //The answer vary due to
      round off error
   printf("(ii) Capacity of Accumulator =%.f kNm \n
       ",Capacity)      //The answer given in the
      textbook is wrong
   printf("(iii) Total Weight on the Ram, W =%.1f
      kN \n ",W)        //The answer vary due to
      round off error
```

Scilab code Exa 16.9 To Deternmine the Diameter of the ram

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.9
//To Deternmine the Diameter of the ram.
      clc
      clear

//Given Data:-
      d=125;        //Diameter of Pipe, mm
      l=2;         //Lenght of Pipe, km
      P=35;      //Power Transmitted, kW
      W=1250;       //Load on ram, kN
      loss_per=3;      //Percentage of Power Loss due to friction
      f_dash=0.04;        //Pipe Friction Factor

//Data Used:-
      rho=1000;      //Density of Water, kg/m^3
      g=9.81;        //Acceleration due to gravity, m/s^2

//Computations:-
       Delta_P=loss_per/100*P*1000;        //Power Loss due to friction , W
     //By Darcy's Formula,
        hf_by_V2=f_dash*(l*1000)/(2*g*d/1000);    //hf/V^2

      QbyV=(%pi/4)*(d/1000)^2;        //Q/V
       V=( Delta_P/(rho*g*QbyV*hf_by_V2))^(1/3);      //m/s
       Q=QbyV*V;       //m^3/s
```

```
        p=P*1000/Q;        //N/m^2
        D=sqrt(W*1000/(p*%pi/4))*1000;          //mm

//Result:-
     printf("The Diameter of ram, D=%.2f mm",D)          //The answer vary due to round off error
```

Scilab code Exa 16.10 `To Find i The Weight of Loaded Cylinder and energy stored by`

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.10
//To Find  (i)The Weight of Loaded Cylinder and energy stored by the Cylinder  (ii)Ther Power supplied by the Accumulator   (iii)The Diameter of ram of an ordinary Accumulator.
      clc
      clear

//Given Data:-
         D=180;          // mm
        d=150;        //mm
        L=1.25;       //Stroke length, m
         p=100;       //Pressure of Water, bar

//Computations:-
        D=D/1000;        //m
        d=d/1000;        //m
        p=p*10^5;        //N/m^2

        A=(%pi/4)*(D^2-d^2);        //Annular area of Ram, m^2
    //(i)
          W=p*A/1000;         //Weight of Loaded
```

```
            Cylinder, kN
            Energy=W*L;          //Energy stored in the Accumulator, kNm
    //(ii)
            t=90;        //Time taken by ram to complete the stroke, seconds
            P=W*L/t;        //kW
    //(iii)
             D=(W*1000/(p*%pi/4))^(1/2)*1000;    //mm

//Results:-
          printf("(i)Weight of Loaded Cylinder, W=%.2f kN\n",W)        //The answer vary due to round off error
              printf("    Energy stored in the Accumulator=%.3f kNm\n",Energy)        //The answer vary due to round off error
          printf("(ii)Power Supplied by the Accumulator=%.3f kW\n",P)        //The answer vary due to round off error
          printf("(iii)Ram Diameter (In case of Ordinary Accumulator) = %.2f mm\n",D)        //The answer vary due to round off error
```

Scilab code Exa 16.11 To Find the Diameters of Fixed ram and Sliding Cylinder

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.11
//To Find the Diameters of Fixed ram and Sliding Cylinder.
      clc
```

```
      clear

//Given Data:-
          p1=50;          //Pressure Intensity of
             Low Pressure Liquid,  bar
          p2=150;         // Pressure Intensity of
             High Pressure Liquid,  bar
          Capacity=32;       //Capacity of
             Intensifier, Litres
           l=1.5;             //Stroke Length, m

//Computations:-
          Capacity=Capacity/1000;      //m^3

         D2=sqrt(Capacity/((%pi/4)*l))*1000;
            //mm
         D1=sqrt((p2/p1)*D2^2);        //mm

//Results:-
         printf("Diameter of Fixed Cylinder, D2=%.2f
             mm\n",D2)        //The answer vary due
            to round off error
         printf("Diameter of Sliding Ram, D1=%.2f mm
            \n",D1)        //The answer vary due to
            round off error
```

Scilab code Exa 16.12 To Calculate the Diameters of Fixed ram and Sliding Cylinder

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.12
//To Calculate the Diameters of Fixed ram and
   Sliding Cylinder.
      clc
      clear
```

```
//Given Data:-
            p1=50;            //Pressure Intensity of Low Pressure Liquid, bar
            p2=150;           // Pressure Intensity of High Pressure Liquid, bar
            Capacity=0.025;         //Capacity of Intensifier, m^3
             l=1.25;                //Stroke Length, m

//Computations:-

           D2=sqrt(Capacity/((%pi/4)*l))*1000;   //mm
           D1=sqrt((p2/p1)*D2^2);         //mm

//Results:-
           printf("Diameter of Fixed Cylinder, D2=%.2f mm\n",D2)         //The answer vary due to round off error
          printf("Diameter of Sliding Ram, D1=%.2f mm\n",D1)         //The answer vary due to round off error
```

Scilab code Exa 16.13 To Find the Diameter of Cylinder

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.13
//To Find  the  Diameter of Cylinder.
      clc
      clear

//Given Data:-
        F=400;        //Force, N
```

```
        p=4000;         //Pressure, kPa

//Computations:-

            d=sqrt(4*F/(%pi*p*1000))*1000;         //
               mm

//Results;-
      printf("Cylinder Diameter, d=%.2f mm\n",d)
```

Scilab code Exa 16.14 To Find i The Force applied in Plunger ii The Number of Stro

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.14
//To Find   (i)The Force applied in Plunger      (ii)
    The Number of Strokes performed by Plunger
        (iii)  Work done by the Press Ram and
        (iv)   Power required to drive the Plunger.

      clc
      clear

//Given Data:-
          D=180;          //Diameter of ram,    mm
          d=36;          //Diameter of Plunger,  mm
          W=7 ;       //Weight exerted by Press ram,
             kN
          L=300;        //Stroke Length of Plunger,
             mm
          l=0.9;         //Distance moved by ram, m
          t=15;        //Time, minutes

//Computations:-
       D=D/1000;          //m
```

```
        A=(%pi/4)*D^2;        //m^2
        d=d/1000;       //m
        a= (%pi/4)*d^2;        //m^2
        W=W*1000;        //N
        L=L/1000;       //m
        t=t*60;      //seconds(s)

      // (i)The Force applied in Plunger, F1
         F1=(a/A)*W;         //N

     //(ii) The Number of Strokes performed by Plunger, n
            n=(A/a)*(l/L);

     // (iii)  Work done by the Press Ram
              Work=W*l;      //N-m

     // (iv)   Power required to drive the Plunger, P
               P=Work/t;        //W


//Results:-
        printf(" (i) The Force applied in Plunger, F1=%.2f N \n",F1)        //The answer vary due to round off error
        printf(" (ii) The Number of Strokes performed by Plunger, n =%.f  \n",n)
        printf(" (iii) Work done by the Press Ram =%.f N.m \n",Work)
        printf(" (iv) Power required to drive the Plunger, P =%.f W \n",P)
```

Scilab code Exa 16.15 To Find i The Force applied in Plunger ii The Number of Stro

```
//Fluid Systems - By Shiv Kumar
```

```
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.15
//To Find   (i)The Force applied in Plunger     (ii)
    The Number of Strokes performed by Plunger
          (iii)  Work done by the Press Ram and
          (iv)   Power required to drive the Plunger.

      clc
      clear

//Given Data:-
          D=165;          //Diameter of ram,   mm
          d=33;          //Diameter of Plunger,  mm
          W=5.5;       //Weight exerted by Press ram,
              kN
          L=250;        //Stroke Length of Plunger,
             mm
          l=1.2;         //Distance moved by ram, m
          t=20;        //Time, minutes

//Computations:-
       D=D/1000;          //m
       A=(%pi/4)*D^2;         //m^2
       d=d/1000;        //m
       a= (%pi/4)*d^2;        //m^2
       W=W*1000;         //N
       L=L/1000;        //m
       t=t*60;      //seconds(s)

     // (i)The Force applied in Plunger, F1
          F1=(a/A)*W;         //N

    //(ii) The Number of Strokes performed by
       Plunger, n
             n=(A/a)*(l/L);

    // (iii)  Work done by the Press Ram
              Work=W*l;      //N-m
```

```
    // (iv)   Power required to drive the Plunger, P
                P=Work/t;         //W


//Results:-
        printf(" (i) The Force applied in Plunger,
           F1=%.f N \n",F1)
        printf(" (ii) The Number of Strokes
           performed by Plunger, n =%.f  \n",n)
        printf(" (iii) Work done by the Press Ram =
           %.f N.m \n",Work)
        printf(" (iv) Power required to drive the
           Plunger, P =%.1f W \n",P)
```

Scilab code Exa 16.16 To Find i Power required to drive the Lift ii Working Period

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.16
//To Find   (i) Power required to drive the Lift
   (ii) Working Period of Lift      and        (iii)
   Ideal Period of Lift.

      clc
      clear

//Given Data:-
         W=60;       //Load lifted by Lift, kN
         H=14;        //Height,  m
         V=0.5;         //Speed of Lift,  m/s
         t=60;        //Time for one operation, s

//Computations:-

```

```
    // (i) Power required to drive the Lift , P
            P=W*H/t;         //kJ/s

    // (ii) Working Period of Lift , tw
           tw=H/V;         //s

    // (iii)  Ideal Period of Lift ,  ti
             ti=t-tw;         //s

//Results
            printf(" (i) Power required to drive the
                Lift , P=%.f kW \n",P)
            printf(" (ii) Working Period of Lift ,
               tw =%.f  s \n",tw)
            printf(" (iii)  Ideal Period of Lift ,
               ti =%.f  s \n",ti)
```

Scilab code Exa 16.17 To Find the Efficiency of Hydraulic Crane

```
//Fluid Systems - By Shiv Kumar
//Chapter 16- Hydraulic Power and Its Transmissions
//Example 16.17
//To Find the Efficiency of Hydraulic Crane.

      clc
      clear

//Given Data:-
          V=340;        //Volume of water utilized ,
              litres
          p=50;       //Pressure Intensity ,  bar
          W=125;      //Load Lift , kN
          l=10;       //Displacement of Weight ,  m


```

```
//Computations:-
            Energy=p*10^5*V/1000;         //Energy Supplied to Crane, J
            Work=W*1000*l;            //Work done by crane in lifting load, J
            eta=Work/Energy*100;        //Efficiency In Percentage

//Result:-
          printf("Efficiency of Hydraulic Crane, eta=%.2f Percent\n",eta)        //The answer vary due to round off error
```

Scilab code Exa 16.18 To Find i The Load Lifted by Crane ii The Quantity of Water

```
//Fluid Systyems - By Shiv Kumar
//Chapter 16- Hydraulic Power  and Its Transmission
//Example 16.18
//To Find       (i)The Load Lifted by Crane          (ii)The Quantity of Water needed to Lift the Load.

    clc
     clear

//Given Data:-
      d=200;           //Diameter of Ram, mm
      p=7.5;           //Pressure of Water Supplied, MPa
      VR=6;            //Velocity Ratio
      eta=50/100;         //Efficiency of Crane
      h=10;           //Height through which water is to be lifted,  m]

//Computations:-
        d=d/1000;          //m
```

```
p=p*10^6;       //Pa

Fp=(%pi/4)*d^2*p;        //Pressure Force Exerted on Ram, N  (answer vary due to value of %pi)
   W=Fp*eta/VR;        //Load Lifted by Crane , N
   Vw=(%pi/4)*d^2*h/VR*1000;        //Quantity of Water needed , Litres

//Results:-
printf(" (i)The Load Lifted by Crane, W=%.f N \n",W)     //The answer provided in textbook is wrong
printf(" (ii)The Quantity of Water needed to Lift the Load by 10 m =%.2f Litres \n",Vw)       //The answer vary due to round off error
```

Chapter 17

Dimensional and Model Analysis

Scilab code Exa 17.1 Theoritical Problem to Check Dimensions

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.1
      //Theoritical  Problem to Check Dimensions.
```

Scilab code Exa 17.2 Theoritical Problem to Obtain Expression for Velocity of Prop

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.2
      //Theoritical  Problem to Obtain Expression
         for Velocity of Propagation of Wave
```

Scilab code Exa 17.3 Theoritical Problem

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.3
      //Theoritical  Problem.
```

Scilab code Exa 17.4 Theoritical Problem to Find expression for Drag Force

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.4
      //Theoritical  Problem to Find expression for
         Drag Force.
```

Scilab code Exa 17.5 Theoritical Problem

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.5
      //Theoritical  Problem .
```

Scilab code Exa 17.6 Theoritical Problem

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.6
      //Theoritical  Problem .
```

Scilab code Exa 17.7 `Theoritical Problem`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.7
      //Theoritical  Problem.
```

Scilab code Exa 17.8 `Theoritical Problem`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.8
      //Theoritical  Problem.
```

Scilab code Exa 17.9 `Theoritical Problem to Find Expression for Force exerted by a`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.9
      //Theoritical  Problem to Find Expression for
         Force exerted by a Flowing Liquid.
```

Scilab code Exa 17.10 `Theoritical Problem`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.10
      //Theoritical  Problem (Same as 17.9).
```

Scilab code Exa 17.11 `Theoritical Problem`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.11
      //Theoritical  Problem .
```

Scilab code Exa 17.12 `Theoritical Problem`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.12
      //Theoritical  Problem to Find Expression for
         Delta(p).
```

Scilab code Exa 17.13 `Theoritical Problem`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.13
      //Theoritical  Problem .
```

Scilab code Exa 17.14 `Theoritical Problem to obtain Expression for Drag Force`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.14
```

```
  //Theoritical  Problem to obtain Expression
    for Drag Force.
```

Scilab code Exa 17.15 `Theoritical Problem to Develop an Expression for the Thrust`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.15
  //Theoritical  Problem to Develop an
    Expression for the Thrust developed by a
    Propeller.
```

Scilab code Exa 17.16 `Theoritical Problem`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.16
  //Theoritical  Problem.
```

Scilab code Exa 17.17 `To Find the Velocity of Oil flowing in the Pipe for the cond`

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.17
//To Find the Velocity of Oil flowing in the Pipe
  for the condition of Dynamic Similarity.

  clc
  clear

```

```
//Given:-
    //For Model ( Working Fluid is Oil),
        Dm=80;      //Diameter, mm
        nu_m=0.03;      //Kinematic Viscosity of Oil, Stoke

    //For Prototype ( Working Fluid is Water),
        Dp=200;      //Diameter, mm
        Vp=3.5;      //Velocity of Water in the Pipe, m/s
        nu_p=0.01;      //Kinematic Viscosity of Water, Stoke

//Computations:-
      //From Reynold's Law of Similarity,
          Vm=Vp*(Dp/Dm)*(nu_m/nu_p);      //Velocity of Oil, m/s

//Results:-
      printf("The Velocity of Oil , Vm=%.2f m/s\n",Vm)
```

Scilab code Exa 17.18 To Find the Velocity and Rate of Flow in the Model

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.18
//To Find the Velocity and Rate of Flow in the Model.

    clc
    clear

//Given:-
    //For Model ( Working Fluid is Water),
```

```
            Dm=150;        //Diameter of Pipe, mm
            mu_m=0.01;         //Viscosity of Water,
               Poise

       //For Prototype ( Working Fluid is Oil),
             Dp=1.5;         //Diameter, m
             Sp=0.9;         //Specific Gravity of Oil
             mu_p=3*10^-2;        //Viscosity of Oil,
                Poise
             Qp=3000;           //Discharge of Oil,
                Litres/sec

//Data Required:-
          rho_m=1000;                //Density of Water, Kg
             /m^3


//Computations:-
               Dm=Dm/1000;       //m
               Qp=Qp/1000;       //m^3/s
               Ap=(%pi/4)*Dp^2;      //m^2
               Am= (%pi/4)*Dm^2 ;      //m^2
               Vp=Qp/Ap;        //m/s
               rho_p=Sp*rho_m;          //Kg/m^3

         //From Reynold's Law of Similarity,
                  Vm=Vp*(Dp/Dm)*(mu_m/mu_p)*(rho_p/
                     rho_m);        //Velocity of Water
                     in Model, m/s
                  Qm=Am*Vm*1000;             //Rate of
                     Flow in Model, Litres/sec

//Results:-
           printf("The Velocity in the Model, Vm=%.3f
              m/s\n",Vm)        //The Answer Vary due to
                Round off Error
           printf("The Rate of Flow in the Model, Qm=%
              .2f Litres/sec\n",Qm)            //The
```

Answer Vary due to Round off Error

Scilab code Exa 17.19 To Find the Speed of Air in Wind Tunnel and Determine the Th

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.19
//To Find the Speed of Air in Wind Tunnel and
   Determine the The Ratio of Drag(Resistance)
   between the Model and its Prototype.

     clc
     clear

//Given:-
         Lr=30;         //Scale Ratio (Lp/Lm)
     //For Model ( Working Fluid is Air),
             nu_m=0.016;        //Kinematic Viscosity
                 of Air, Stoke
             rho_m=1.24;      //Density of Air, Kg/m
                ^3

     //For Prototype ( Working Fluid is Sea Water),
           Vp=10;        //Speed of Sub-marine (
              Prototype), m/s
           nu_p=0.012;       //Kinematic Viscosity of
               Sea Water, Stoke
           rho_p=1030;       //Density of Sea Water,
              Kg/m^3

//Computations:-
        //From Reynold's Law of Similarity,
              Vm=Vp*(nu_m/nu_p)*Lr;       //Velocity
                  of Air, m/s

```

```
                 Fp_by_Fm=(rho_p/rho_m)*Lr^2*(Vp/Vm)
                    ^2;          //Ratio of Drag Force (
                    Resistance)


//Results:-
        printf("The Speed of Air in Wind Tunnel,
           Vm=%.f m/s\n",Vm)
        printf("The Ratio of Drag Force (Resistance
           ), Fp/Fm=%.3f  \n",Fp_by_Fm)
```

Scilab code Exa 17.20 To Find the Discharge and the Velocity over the Prototype

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.20
//To Find the Discharge and the Velocity over the
   Prototype.

     clc
     clear

//Given Data:-
       //For Model,
           Qm=3;    //Discharge over the Model, m^3/
              s
           Vm=1.5;    //Velocity of Flow over the
              Model, m/s
    Lr=40;          //Scale Ratio (Lp/Lm)


//Computations:-
        //By Froude's Law of Similarity,
            Vp=Vm*Lr^(1/2);       //Velocity of
               Flow ovre the Prototype, m/s
```

```
            Qp=Lr^2*(Vp/Vm)*Qm;        //Discharge
               over the Prototype, m^/s



//Results:-
        printf("The Velocity over the Prototype, Vp=%
           .2f m/s \n",Vp)       //The Answer Vary due
            to Round off Error.
        printf("The Discharge over the Prototype, Qp=
           %.f m^3/s \n",Qp)        //The Answer
           provided in the Textbook is Wrong.
```

Scilab code Exa 17.21 To Find the Ship Velocity and Propulsive Force in the Protot

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.21
//To Find the  Ship Velocity and Propulsive Force in
    the Prototype.

      clc
      clear

//Given Data:-
        //For Model,
            Lm=1;     //Length of Model, m
            Vm=0.7;    //Speed in the Model, m/s
            Fm=5;     //Force in the Model, N

       //For Prototype,
            Lp=50;        //Length of Prototype, m


//Computations:-
          //By Froude's Law of Similarity,
```

```
            Vp=Vm*(Lp/Lm)^(1/2);        //Velocity
               of the Prototype(Ship), m/s
            Fp=Fm*(Lp/Lm)^3/1000;       //
               Propulsive Force in the Prototype,
               kN


//Results:-
      printf("The Ship(Prototype) Velocity , Vp=%.2
         f m/s \n",Vp)
      printf("The Propulsive Force in the Prototype
         , Fp=%.f kN \n",Fp)
```

Scilab code Exa 17.22 To Determine for the Model i The Size and the Velocity of Wa

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.22
//To Determine for the Model:    (i) The Size and
   the Velocity of Waves        (ii)The Tidal Period

   clc
   clear

//Given Data:-
               Lr=200;        //Scale Ratio
      //For Prototype,
            Ap=20;     //Amplititude of Waves, m
            Vp=10;    //Velocity , m/s
            Tp=12;    //Time Period , hrs.

//Computations:-
        //By Froude's Law of Similarity,
            Vm=Vp/Lr^(1/2);       //Velocity of
               Wave in the Model, m/s
```

```
                Am=Ap/Lr;          //Amplitude of waves in the Model, m
                Tm=Tp*60/Lr^(1/2);        //Tidal Period in the Model, min.


//Results:-
      printf("(i)For the Model:\n     Velocity of Wave, Vm=%.3f m/s\n     Size(Amplitude) of Wave, Am=%.1f m\n",Vm,Am)
      printf("(ii)The Tidal Period in the Model, Tm=%.2f min. \n",Tm)
```

Scilab code Exa 17.23 To Find the Velocity of the Prototype and Force Required to

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.23
//To Find the Velocity of the Prototype and Force Required to Propel the Prototytpe.

    clc
    clear

//Given Data:-
         Lr=40;         //Scale Ratio (Lp/Lm)
      //For Model,
             Vm=2;    //Velocity for the Model, m/s
             Fm=0.5;     //Propulsive Force in Model, N
    //For Prototype,
          Lp=45;     //m


//Computations:-
```

```
            //By Froude's Law of Similarity,
                Vp=Vm*Lr^(1/2);        //Velocity for
                   the Prototype, m/s
                 Fp=Fm*Lr^3;        //Force Required to
                    Propel the Prototytpe, N


//Results:-
        printf("The Velocity of the Prototype, Vp=%.2
           f m/s \n",Vp)          //The Answer vary due
            to Round off Error
        printf("The Force Required to Propel the
           Prototytpe , Fp=%.f N \n",Fp)
```

Scilab code Exa 17.24 To Find the Prototype to Model Scale Ratios for i Velocity i

```
//Fluid Systems - By Shiv Kumar
//Chapter 17- Dimensional and Model Analysis
//Example 17.24
//To Find the Prototype to Model Scale Ratios for :
   (i)Velocity     (ii)Time      (iii)Acceleration
         (iv)Force .    and Wave Height and Time
   taken for Model.

     clc
     clear

//Given Data:-
            Lr=50;          //Scale Ratio (Lp/Lm)
        //For Prototype,
              Hp=1.5;          //m
              Tp=25;          //Seconds(s)

//Computations:-
             Vr=Lr^(1/2);         //Velocity Ratio
```

```
        Tr=Lr^(1/2);          //Time Ratio
        ar=Vr/Tr;             //Acceleration Ratio
        Fr=Lr^3;            //Force Ratio

        Hm=Hp/Lr;       //m
        Tm=Tp/Tr;        //Seconds(s)


//Results:-
    printf("(i)Velocity Ratio, Vr=%.2f\n (ii)Time
        Ratio, Tr=%.2f \n (iii)Acceleration Ratio
       , ar=%.f \n(iv)Force Ratio, Fr=%.f\n\n",
       Vr,Tr,ar,Fr)
    printf("Wave Height in the Model, Hm=%.2f m\n
       ",Hm)
    printf("Time taken in the Model, Tm=%.2f  s",
       Tm)      //The Answer Vary due to Round off
        Error
```