Scilab Textbook Companion for Electrical Machine Design by A. K. Sawhney[1]

Created by
Shiv Singh Meena
B.Tech
Electrical Engineering
National Institute of Technology,Kurukshetra
College Teacher
None
Cross-Checked by
None

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Book Description

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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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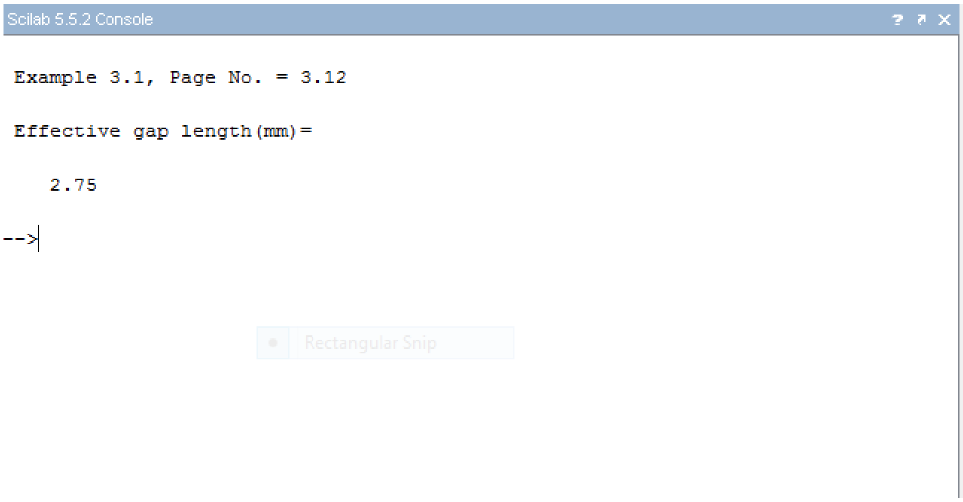
Chapter 3

Principles of Magenetic Circuit Design

Scilab code Exa 3.1 `Calculating effective length of air gap`

```
// Calculating effective length of air gap
clc;
disp('Example 3.1, Page No. = 3.12')
// Given Data
Ws = 12;// Slot width in mm
Wt = 12;// Tooth width in mm
lg = 2;// Length of air gap in mm
Kcs = 1/(1+(5*lg/Ws));//Carter's co-efficient for slots
// Calculation of effective length of air gap
ys=Ws+Wt;//Slot Pitch in mm
Kgs=ys/(ys-(Kcs*Ws));//Gap contraction for slots
Kgd=1;//Gap contracion factor for ducts//Since there are no ducts
Kg=Kgs*Kgd;//Total gap contracion factor
lgs=Kg*lg;//Effective gap length in mm
disp(lgs,'Effective gap length(mm)=');
```



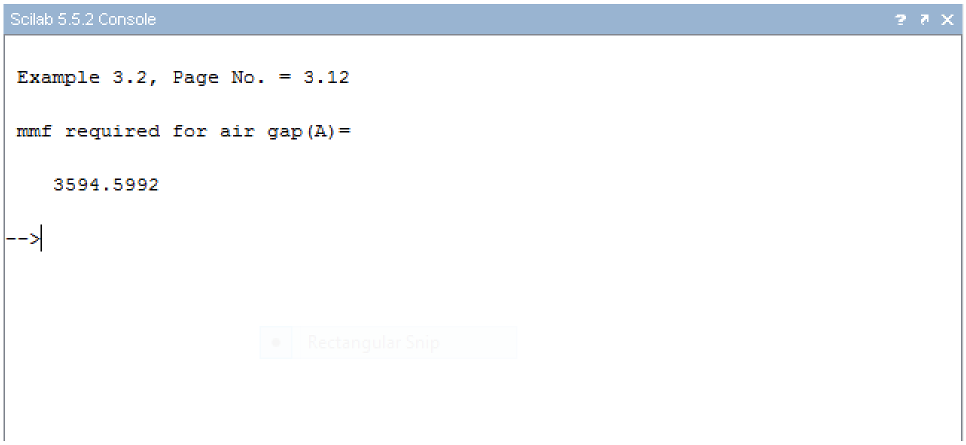
```
 Example 3.1, Page No. = 3.12

 Effective gap length(mm)=

    2.75

-->
```

Figure 3.1: Calculating effective length of air gap

```
//in book answer is 2.74 mm.  The answers vary due to round off error
```

Scilab code Exa 3.2 `Calculating the mmf required for the air gap of a machine`

```
// Calculating the mmf required for the air gap of a machine
clc;
disp('Example 3.2, Page No. = 3.12')
// Given Data
L = 0.32;// Core length in meter
nd = 4;// Number of ducts
Wd = 10;// Duct width in mm
Pa = 0.19;// Pole arc in meter
ys=65.4;//Slot Pitch in mm
lg = 5;// Length of air gap in mm
Wo = 5;// Slot opening in mm
```



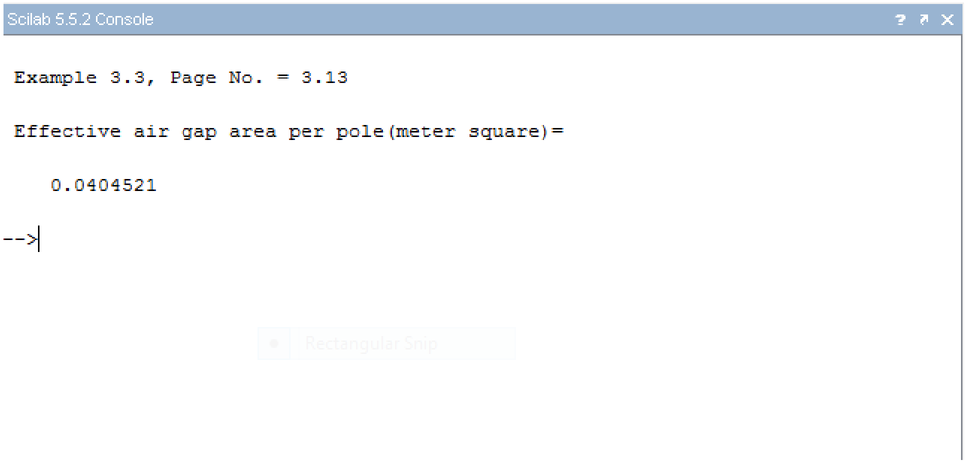
```
Example 3.2, Page No. = 3.12

mmf required for air gap(A)=

   3594.5992

-->
```

Figure 3.2: Calculating the mmf required for the air gap of a machine

```
Fpp = 52;// Flux per pole in mWb
Kcs = 0.18;//Carter's co-efficient for slots
Kcd = 0.28;//Carter's co-efficient for ducts
// Calculation of mmf required for the air gap
Kgs=ys/(ys-(Kcs*Wo));//Gap contraction for slots
Kgd=L/(L-(Kcd*nd*Wd*10^(-3)));//Gap contraction for ducts
Kg=Kgs*Kgd;//Total gap contracion factor
Bg=Fpp*10^(-3)/(Pa*L);//Flux density at the centre of pole in Wb per meter square
ATg=800000*Kg*Bg*lg*10^(-3);//mmf required for air gap in A
disp(ATg,'mmf required for air gap(A)=');
//in book answer is 3587 A. The answers vary due to round off error
```

Scilab code Exa 3.3 `Estimating the effective air gap area per pole`

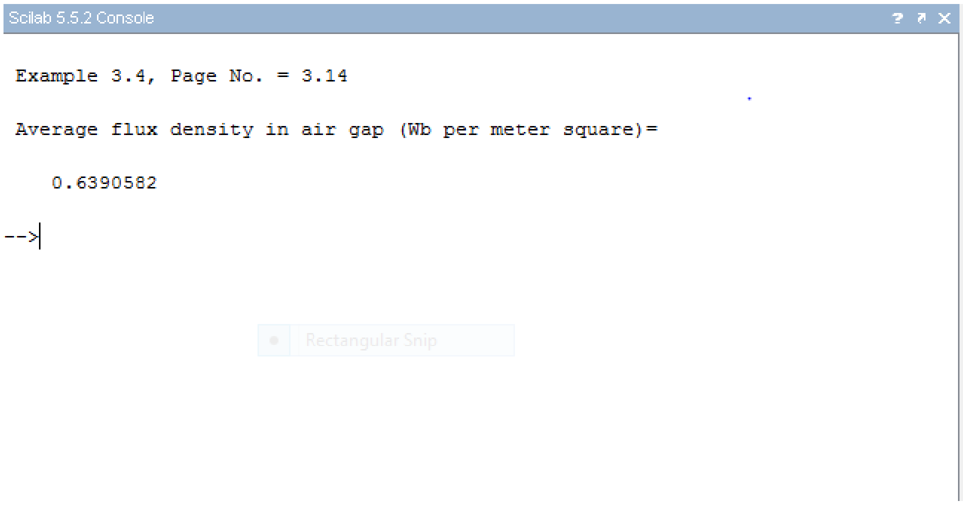
```
// Estimating the effective air gap area per pole
```



```
 Example 3.3, Page No. = 3.13

 Effective air gap area per pole(meter square)=

    0.0404521

-->
```

Figure 3.3: Estimating the effective air gap area per pole

```
clc;
disp('Example 3.3, Page No. = 3.13')
// Given Data
P = 10;// Number of pole
Sb = 0.65;// Stator bore in meter
L = 0.25;// Core length in meter
Nss = 90;// Number of stator slots
Wos = 3;// Stator slot opening in mm
Nrs = 120;// Number of rotor slots
Wor = 3;// Rotor slot opening in mm
lg = 0.95;// Length of air gap in mm
Kcs = 0.46;//Carter's co-efficient for slots
Kcd = 0.68;//Carter's co-efficient for ducts
nd = 3;// Number of ventilating ducts
Wd = 10;// Width of each ventilating Duct in mm
// Estimation of effective air gap area per pole
ys = 3.141592654*Sb*10^(3)/Nss;// Stator slot pitch
Kgss=ys/(ys-(Kcs*Wos));//Gap contraction factor for
    stator slots
Rd = Sb-2*lg*10^(-3);// Rotor diameter in meter
yr = 3.141592654*Rd*10^(3)/Nrs;// Rotor slot pitch
Kgsr=yr/(yr-(Kcs*Wor));//Gap contraction factor for
```



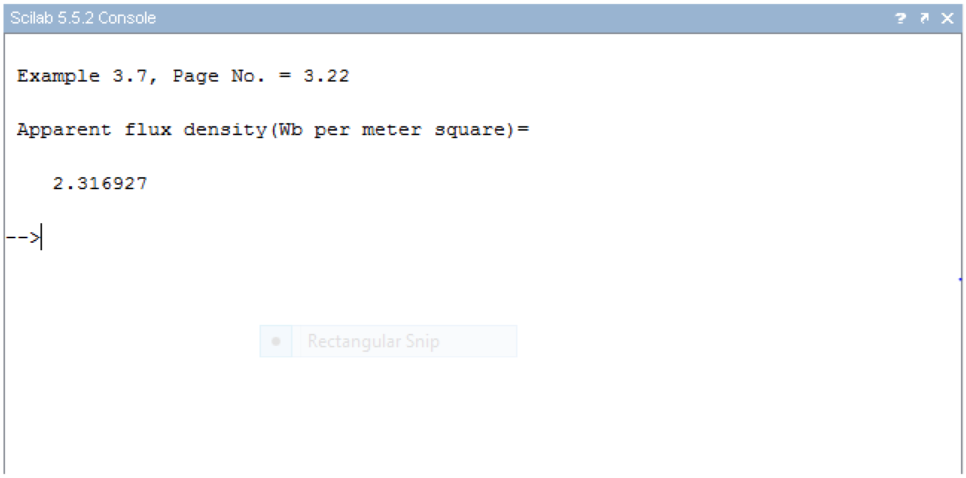
```
Example 3.4, Page No. = 3.14

Average flux density in air gap (Wb per meter square)=

   0.6390582

-->
```

Figure 3.4: Estimating the average flux density in the air gap

```
rotor slots
Kgs=Kgss*Kgsr;//Gap contraction factor for slots
Kgd=L*10^(3)/(L*10^(3)-(Kcd*nd*Wd));//Gap contraction for ducts
Kg=Kgs*Kgd;//Total gap contracion factor
Ag = 3.141592654*Sb*L/P;// Actual area of air gap per pole in meter square
Age = Ag/Kg;// Effective air gap area per pole in meter square
disp(Age,'Effective air gap area per pole(meter square)=');
//in book answer is .04052 A.  The answers vary due to round off error
```

Scilab code Exa 3.4 `Estimating the average flux density in the air gap`

```
// Estimating the average flux density in the air gap
clc;
disp('Example 3.4, Page No. = 3.14')
// Given Data
MVA = 172;// MVA rating
P = 20;// Number of pole
D = 6.5;// Diameter in meter
L = 1.72;// Core length in meter
ys = 64;//Slot Pitch in mm
Ws = 22;// Stator slot (open) width in mm
lg = 30;// Length of air gap in mm
nd = 41;// Number of ventilating ducts
Wd = 6;// Width of each ventilating Duct in mm
mmf = 27000// Total mmf per pole in A
Kf = 0.7;// Field form factor
// Estimation of effective air gap area per pole
y=Ws/(2*lg);//Ratio for slots
Kcs= (2/%pi)*(atan(y)-log10(sqrt(1+y^2))/y);//Carter's co-efficient for slots
Kgs=ys/(ys-(Kcs*Ws));//Gap contraction for slots
y=Wd/(2*lg);//Ratio for ducts
Kcd= (2/%pi)*(atan(y)-log10(sqrt(1+y^2))/y);//Carter's co-efficient for slots
Kgd=L*10^(3)/(L*10^(3)-(Kcd*nd*Wd));//Gap contraction for ducts
Kg=Kgs*Kgd;//Total gap expansion factor
ATg = 0.87*mmf;// The required for the air gap is 87% of the total mmf per pole in A
Bg = ATg/(800000*Kg*lg*10^(-3));// Maximum flux density in air gap in Wb per meter square
Bav= Kf*Bg;// Average flux density in air gap in Wb per meter square
disp(Bav,'Average flux density in air gap (Wb per meter square)=');
//in book answer is .615 Wb per meter square. The provided in the textbook is wrong
```

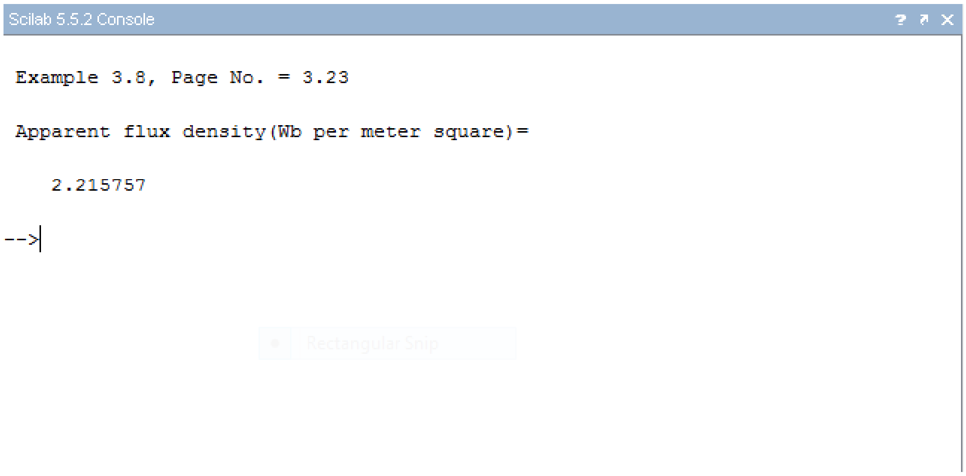


```
Example 3.7, Page No. = 3.22

Apparent flux density(Wb per meter square)=

   2.316927

-->
```

Figure 3.5: Calculating the apparent flux density

Scilab code Exa 3.7 `Calculating the apparent flux density`

```
// Calculating the apparent flux density
clc;
disp('Example 3.7, Page No. = 3.22')
// Given Data
Ws = 10;// Slot width in mm
Wt = 12;// Tooth width in mm
L = .32;// Grass core Length in meter
nd = 4;// Number of ventilating ducts
Wd = 10;// Width of each ventilating Duct in mm
Breal = 2.2;// Real flux density in Wb per meter
    square
p = 31.4*10^(-6);// Permeability of teeth
    corresponding to real flux density in henry per
    meter
Ki = 0.9;// Stacking Factor
```



```
Example 3.8, Page No. = 3.23

Apparent flux density(Wb per meter square)=

   2.215757

-->
```

Figure 3.6: Calculating the apparent flux density

```
// Calculation of apparent flux density
at = Breal/p;// mmf per meter corresponding to real flux density and permeability
Li = Ki*(L-nd*Wd*10^(-3));// Net iron length
ys = Wt+Ws;// Slot pitch
Ks = L*ys/(Li*Wt);
Bapp = Breal+4*%pi*10^(-7)*at*(Ks-1);
disp(Bapp,'Apparent flux density(Wb per meter square)=');
//in book answer is 2.317 Wb per meter square. The answers vary due to round off error
```

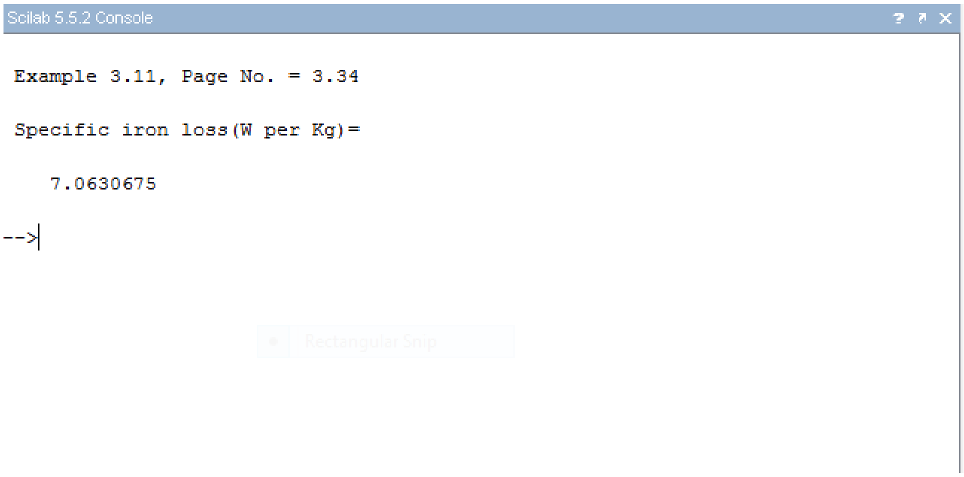
Scilab code Exa 3.8 `Calculating the apparent flux density`

```
// Calculating the apparent flux density
clc;
disp('Example 3.8, Page No. = 3.23')
// Given Data
```

```
Ws = 10;// Slot width in mm
ys = 28;// Slot pitch in mm
L = .35;// Grass core Length in meter
nd = 4;// Number of ventilating ducts
Wd = 10;// Width of each ventilating Duct in mm
Breal = 2.15;// Real flux density in Wb per meter square
at = 55000;// mmf per meter corresponding to real flux density and permeability
Ki = 0.9;// Stacking Factor
// Calculation of apparent flux density
Li = Ki*(L-nd*Wd*10^(-3));// Net iron length
Wt = ys-Ws;// Tooth width in mm
Ks = L*ys/(Li*Wt);
Bapp = Breal+4*%pi*10^(-7)*at*(Ks-1);
disp(Bapp,'Apparent flux density(Wb per meter square)=');
//in book answer is 2.2156 Wb per meter square.  The answers vary due to round off error
```

Scilab code Exa 3.11 `Calculating the specific iron loss`

```
// Calculating the specific iron loss
clc;
disp('Example 3.11, Page No. = 3.34')
// Given Data
Bm = 3.2;// Maximum flux density in Wb per meter square
f = 50;// Frequency in Hz
t = 0.5*10^(-3);// Thickness of sheet in mm
p = .3*10^(-6);// Resistivity of alloy steel in ohm*meter
D = 7.8*10^(3);// Density in kg per meter cube
```



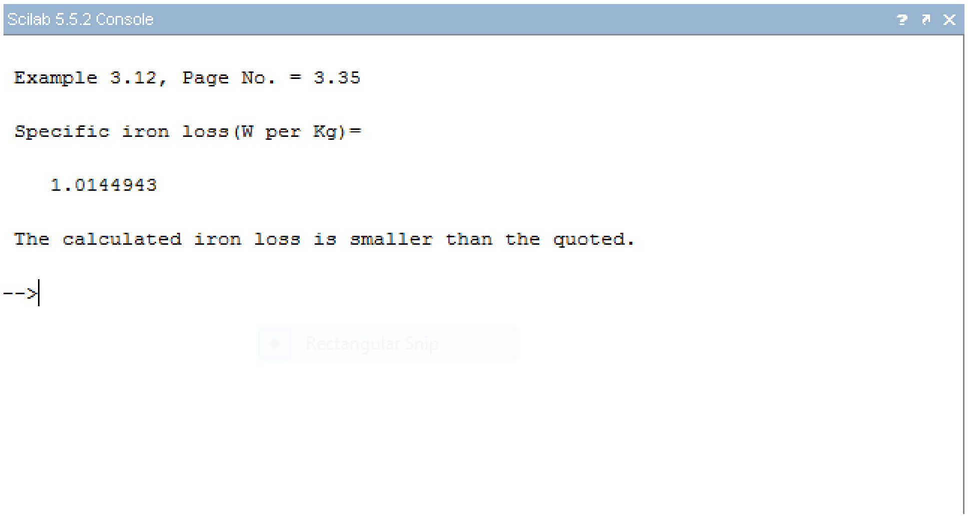
```
 Example 3.11, Page No. = 3.34

 Specific iron loss(W per Kg)=

    7.0630675

-->
```

Figure 3.7: Calculating the specific iron loss

```
ph_each = 400;// Hysteresis loss in each cycle in Joule per meter cube
// Calculation of total iron loss
pe = %pi*%pi*f*f*Bm*Bm*t*t/(6*p*D);// Eddy current loss in W per Kg
ph = ph_each*f/D;// Hysterseis loss in W per Kg
Pi = pe+ph;// Total iron loss in W per Kg
disp(Pi,'Specific iron loss(W per Kg)=');
//in book answer is 3.2 W per Kg. The provided in the textbook is wrong
```

Scilab code Exa 3.12 `Calculating the specific iron loss`

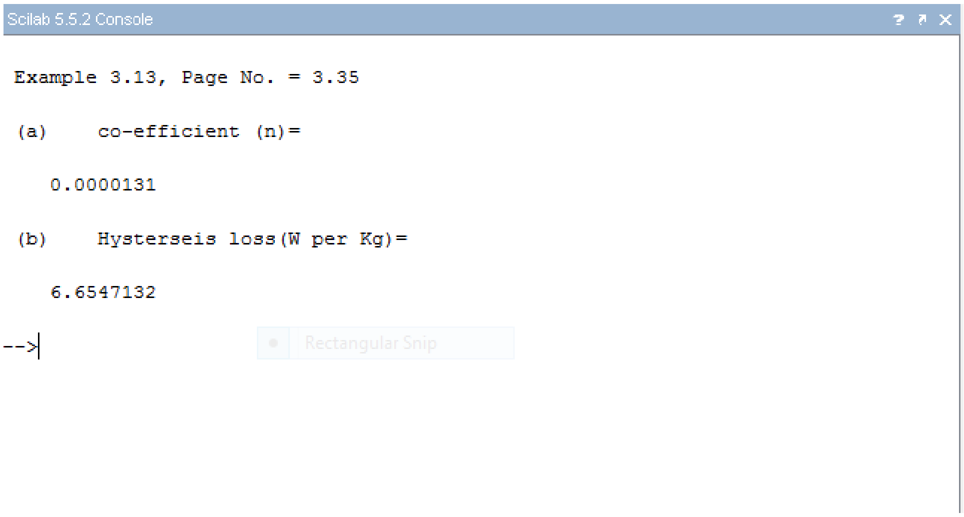
```
// Calculating the specific iron loss
clc;
disp('Example 3.12, Page No. = 3.35')
```



```
Example 3.12, Page No. = 3.35

Specific iron loss(W per Kg)=

   1.0144943

The calculated iron loss is smaller than the quoted.

-->
```

Figure 3.8: Calculating the specific iron loss

```
// Given Data
Bm = 1.0;// Maximum flux density in Wb per meter square
f = 100;// Frequency in Hz
t = 0.3*10^(-3);// Thickness of sheet in mm
p = .5*10^(-6);// Resistivity of alloy steel in ohm*meter
D = 7650;// Density in kg per meter cube
pi_quoted = 1.2;// Quoted iron loss in W per Kg
// Calculation of total iron loss
S1 = 2*12;// Sides of hysteresis loop in A/m
S2 = 2*1;// Sides of hysteresis loop in Wb per meter square
A = S1*S2;// Area of hysteresis loop in W-s per meter cube
ph_each = A;// Hysteresis loss in each cycle in Joule per meter cube
ph = ph_each*f/D;// Hysterseis loss in W per Kg
pe = %pi*%pi*f*f*Bm*Bm*t*t/(6*p*D);// Eddy current loss in W per Kg
pi = pe+ph;// Total iron loss in W per Kg
```



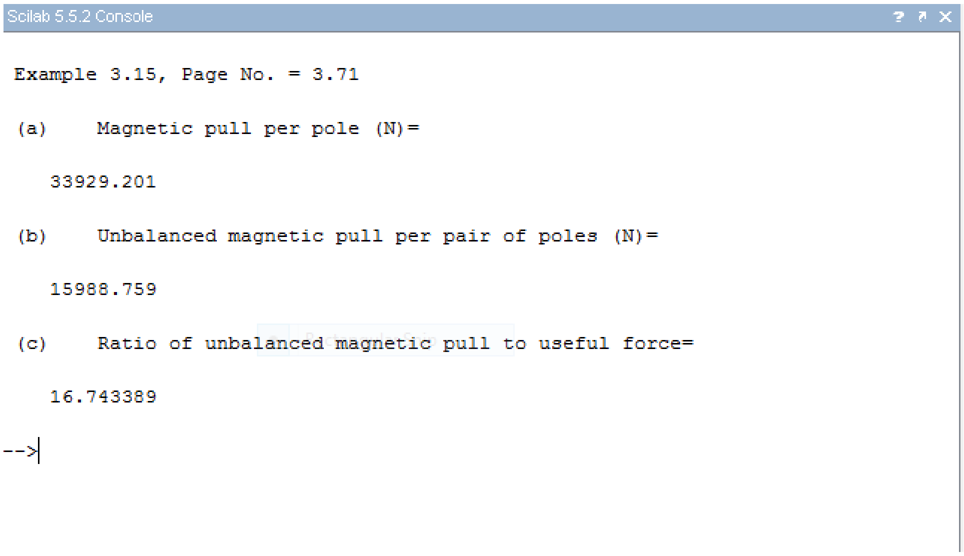
```
 Example 3.13, Page No. = 3.35

 (a)    co-efficient (n)=

    0.0000131

 (b)    Hysterseis loss(W per Kg)=

    6.6547132

-->
```

Figure 3.9: Calculating the hysteresis loss

```
disp(pi,'Specific iron loss(W per Kg)=');
disp('The calculated iron loss is smaller than the quoted.')
//in book answer is 1.014 W per Kg.  The answers vary due to round off error
```

Scilab code Exa 3.13 Calculating the hysteresis loss

```
// Calculating the hysteresis loss
clc;
disp('Example 3.13, Page No. = 3.35')
// Given Data
Bm = 1.0;// Maximum flux density in Wb per meter square
f = 50;// Frequency in Hz
SGi = 7.5;// Specific gravity of iron
ph = 4.9;// Hysterseis loss in W per Kg
```



```
Example 3.15, Page No. = 3.71

 (a)     Magnetic pull per pole (N)=

    33929.201

 (b)     Unbalanced magnetic pull per pair of poles (N)=

    15988.759

 (c)     Ratio of unbalanced magnetic pull to useful force=

    16.743389

-->
```

Figure 3.10: Calculating the magnetic pull and unbalanced magnetic pull and ratio of unbalanced magnetic pull to useful force

```
// Calculation of co-efficient 'n'
Di = 7500;// Density of iron
n = ph/(Di*f*(Bm^(1.7)));//
disp(n,'(a)    co-efficient (n)=');
//in book answer is 1307*10^(-6). The answers vary due to round off error
// Calculation of hysteresis loss
Bm = 1.8;// Maximum flux density in Wb per meter square
f = 25;// Frequency in Hz
ph = n*f*Di*Bm^(1.7);// Hysterseis loss in W per Kg
disp(ph,'(b)    Hysterseis loss(W per Kg)=');
//in book answer is 6.66 W per Kg. The answers vary due to round off error
```

Scilab code Exa 3.15 `Calculating the magnetic pull and unbalanced magnetic pull an`

```
// Calculating the magnetic pull, unbalanced magnetic pull and ratio of unbalanced magnetic pull to useful force
clc;
disp('Example 3.15, Page No. = 3.71')
// Given Data
Power = 75000;// Power rating in W
f = 50;// Frequency in Hz
p = 2;// Number of poles
D = 0.5;// Stator bore in meter
L = 0.2;// Axial length of core in meter
lg = 5;// Length of air gap
ATm = 4500;// Peak magnetizing mmf per pole
Bm = ATm*4*%pi*10^(-7)/(lg*10^(-3));// Peak value of flux density in Wb per meter square
// Calculation of magnetic pull per pole
MP = Bm*Bm*D*L/(3*4*%pi*10^(-7));// Magnetic pull per pole (Flux Distribution is sinusoidal)
disp(MP,'(a)    Magnetic pull per pole (N)=');
//in book answer is 33.9 in kN  The answers vary due to round off error
// Calculation of unbalanced magnetic pull
e = 1;// Displacement of rotor axis in mm
Pp = %pi*D*L*Bm*Bm*e/(lg*4*4*%pi*10^(-7));// Unbalanced magnetic pull per pair of poles
disp(Pp,'(b)    Unbalanced magnetic pull per pair of poles (N)=');
//in book answer is 16000 in N  The answers vary due to round off error
// Calculation of Ratio of unbalanced magnetic pull to useful force
Speed = 2*f/p;// Speed in r.p.s.
T = Power/(2*%pi*Speed);// Useful torque in Nm
F = T/(D/2);// Useful force in N
Ratio = Pp/F;// Ratio of unbalanced magnetic pull to useful force
```

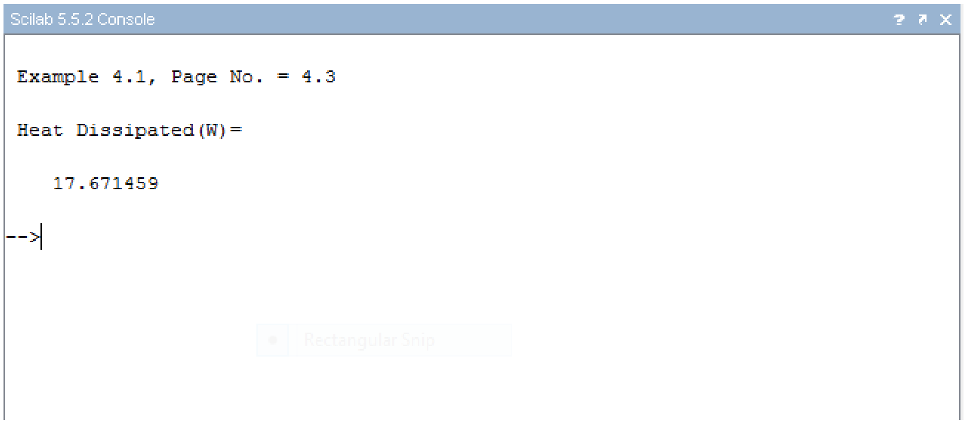
```
disp(Ratio,'(c)    Ratio of unbalanced magnetic pull to useful force=');
//in book answer is 16.8  The answers vary due to round off error
```

Chapter 4

Thermal Design Aspects of Electrical Machines

Scilab code Exa 4.1 `Calculating the loss that will pass through copper bar to iron`

```
// Calculating the loss that will pass through
   copper bar to iron
clc;
disp('Example 4.1, Page No. = 4.3')
// Given Data
D = 12;// Diameter of copper bar in mm
t = 1.5;// Thickness of micanite tube in mm
p = 8;// Resistivity of macanite tube in ohm*meter
T = 25;// Temperature difference in degree celsius
L = 0.2;// Length of copper bar
// Calculation of loss.that will pass through copper
    bar to iron
S = %pi*(D+t)*10^(-3)*L;//Area of insulation in the
   path of heat flow
R =( p*t*10^(-3))/S;// Thermal resistance of
   micanite tube
Q_con= T/R;// Heat Dissipated
```



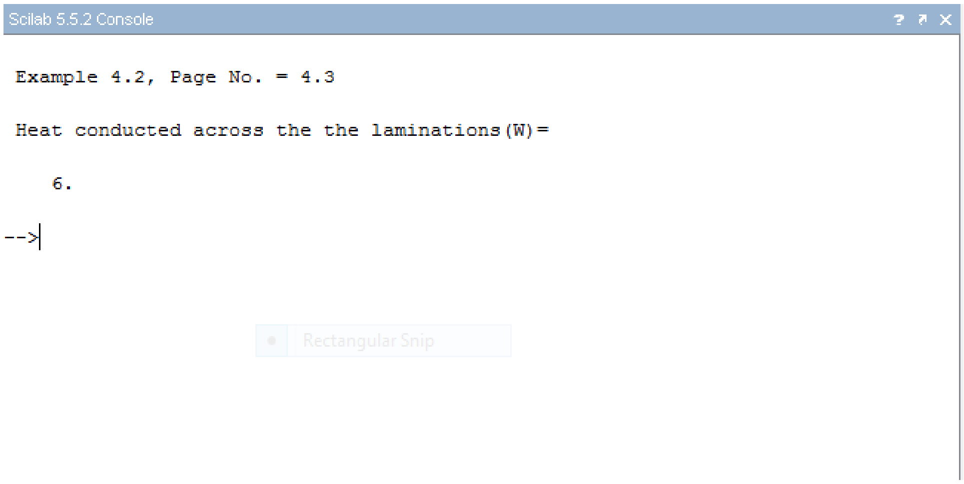
```
Example 4.1, Page No. = 4.3

Heat Dissipated(W)=

   17.671459

-->
```

Figure 4.1: Calculating the loss that will pass through copper bar to iron

```
disp(Q_con,'Heat Dissipated(W)=');
//in book answer is 17.67 W.  The answers vary due to round off error
```

Scilab code Exa 4.2 `Calculating the loss that will be conducted across the the lam`

```
// Calculating the loss that will be conducted across the the laminations
clc;
disp('Example 4.2, Page No. = 4.3')
// Given Data
Q_con_5 = 25;// Heat Dissipated
t_5 = 20;// Thickness of laminations in mm
S_5 = 2500;// Cross-section area of conduction in mm square
T_5 = 5;// Temperature difference in degree celsius
t_20 = 40;// Thickness of laminations in mm
S_20 = 6000;// Cross-section area of conduction in mm square
```

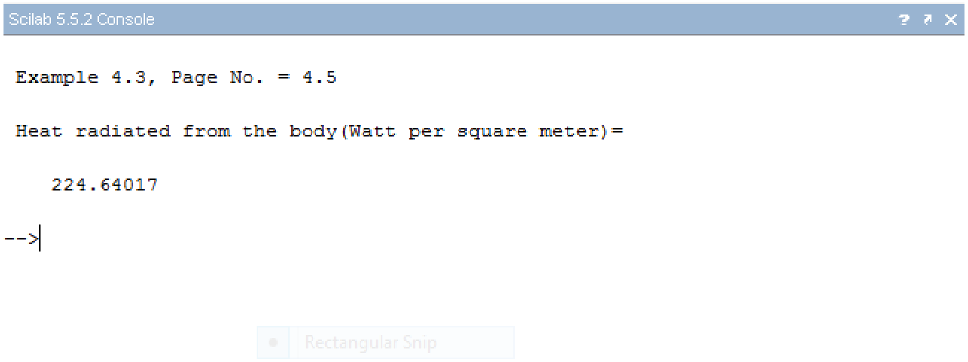


```
Example 4.2, Page No. = 4.3

Heat conducted across the the laminations(W)=

   6.

-->
```

Figure 4.2: Calculating the loss that will be conducted across the the laminations

```
T_20 = 20;// Temperature difference in degree
    celsius
// Calculation of heat conducted across the
    laminations
p_along = (T_5*S_5*10^(-6))/(Q_con_5*t_5*10^(-3));//
     Thermal resistivity along the direction of
    laminations
p_across = 20*p_along;// Thermal resistivity across
    the direction of laminations
Q_con_20 = S_20*10^(-6)*T_20/(p_across*t_20*10^(-3))
    ;// Heat conducted across the the laminations
disp(Q_con_20,'Heat conducted across the the
    laminations(W)=');
//in book answer is 6 W.  The answers vary due to
    round off error
```

Scilab code Exa 4.3 `Calculating the heat radiated from the body`



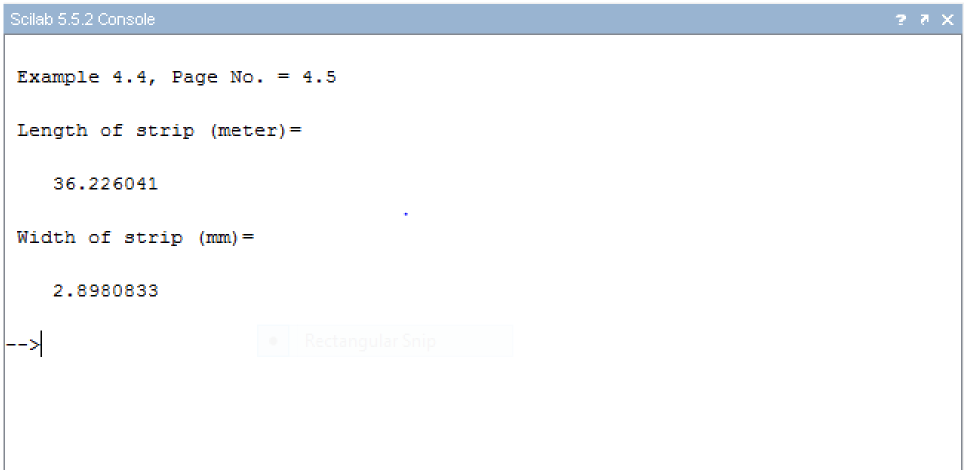
```
Example 4.3, Page No. = 4.5

Heat radiated from the body(Watt per square meter)=

   224.64017

-->
```

Figure 4.3: Calculating the heat radiated from the body

```
// Calculating the heat radiated from the body
clc;
disp('Example 4.3, Page No. = 4.5')
// Given Data
e = 0.8;// Co-efficient of emissivity
T1 = 273+60;// Temperature of body in degree kelvin
T0 = 273+20;// Temperature of walls in degree kelvin
// Calculation of the heat radiated from the body
q_rad = 5.7*10^(-8)*e*(T1^(4)-T0^(4));// Heat radiated from the body
disp(q_rad,'Heat radiated from the body(Watt per square meter)=');
//in book answer is 224.6 in Watt per square meter. The answers vary due to round off error
```

Scilab code Exa 4.4 `Calculating the length and width of strip`

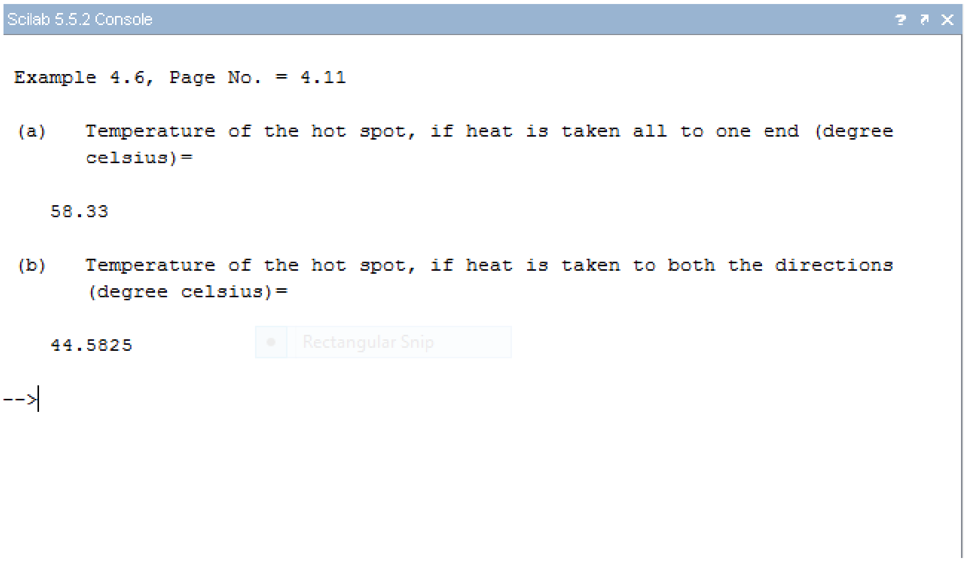
```
// Calculating the length and width of strip
clc;
```



```
Example 4.4, Page No. = 4.5

Length of strip (meter)=

   36.226041

Width of strip (mm)=

   2.8980833

-->
```

Figure 4.4: Calculating the length and width of strip

```
disp('Example 4.4, Page No. = 4.5')
// Given Data
e = 0.9;// Emissivity
Radiating_efficiency = 0.75;// Radiating efficiency
v = 250;// Voltage in volts
P = 1000;// Power in Watts
t = 0.2;// Thickness of nickel chrome strip
T1 = 273+(300+30);// Temperature of strip in degree kelvin
T0 = 273+30;// Temperature of ambient medium in degree kelvin
p = 1*10^(-6);// Resistivity of nickel chrome
// Calculation of length and width of strip
e = e*Radiating_efficiency;// Effective co-efficient of emissivity
q_rad = 5.7*10^(-8)*e*(T1^(4)-T0^(4));// Heat dissipated by radiation in Watt per meter square
R = v*v/P;// Resistance of strip in ohm
l_by_w = R*t*10^(-3)/p;// This is equal to l/w
lw = 1000/(q_rad*2);// This is equal to l*w
l = sqrt(lw*l_by_w);// Length of strip in meter
w = (lw/l)*10^(3);// Width of strip in mm
```



```
 Example 4.6, Page No. = 4.11

 (a)    Temperature of the hot spot, if heat is taken all to one end (degree
        celsius)=

    58.33

 (b)    Temperature of the hot spot, if heat is taken to both the directions
        (degree celsius)=

    44.5825

-->
```

Figure 4.5: Estimating the temperature of the hot spot

```
disp(l,'Length of strip (meter)=');
disp(w,'Width of strip (mm)=');
//in book Length is 36.2 meter and width is 2.9 mm. The answers vary due to round off error
```

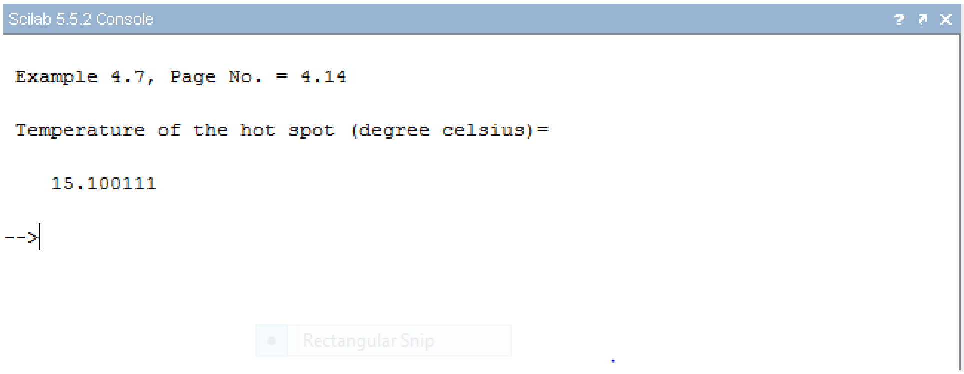
Scilab code Exa 4.6 `Estimating the temperature of the hot spot`

```
// Estimating the temperature of the hot spot
clc;
disp('Example 4.6, Page No. = 4.11')
// Given Data
t = 0.5;// Plate width of transformer core in meter
Ki = 0.94;// Stacking Factor
p_core = 3;// Core loss in Watt per kg
thermal_conductivity = 150;// Thermal conductivity in Watt per degree celsius
```

```
Ts = 40;// Surface temperature in degree celsius
D = 7800;// Density of steel plate in kg per meter cube
// Calculation of the temperature of the hot spot
q = p_core*Ki*D;// Core loss per unit volume (Watt per meter cube)
p = 1/thermal_conductivity;// thermal resistivity
x =t;// Since heat is taken all to one end
Tm = (q*p*x*x/2)+Ts;// Temperature of the hot spot, if heat is taken all to one end (degree celsius)
disp(Tm,'(a)   Temperature of the hot spot, if heat is taken all to one end (degree celsius)=');
//in book answers is 58.3 degree celsius.  The answers vary due to round off error
x =t/2;// Since heat is taken to both the directions
Tm = (q*p*x*x/2)+Ts;// Temperature of the hot spot, if heat is taken to both the directions (degree celsius)
disp(Tm,'(b)   Temperature of the hot spot, if heat is taken to both the directions (degree celsius)=');
//in book answers is 44.6 degree celsius.  The answers vary due to round off error
```

Scilab code Exa 4.7 Estimating the hot spot temperature

```
// Estimating the hot spot temperature
clc;
disp('Example 4.7, Page No. = 4.14')
// Given Data
l = 1;// Length of mean turn in meter
Sf = 0.56;// Space Factor
p = 120;// Total loss in the coil in Watt
```



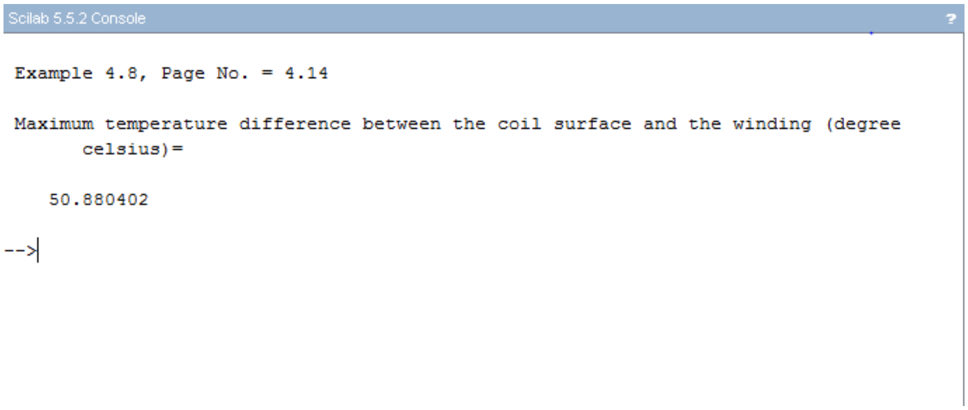
```
Example 4.7, Page No. = 4.14

Temperature of the hot spot (degree celsius)=

   15.100111

-->
```

Figure 4.6: Estimating the hot spot temperature

```
pi = 8;// Thermal resistivity in ohm*meter
A = 100*50;// Area of cross-section in mm square
t = 50*10^(-3);// Thickness of coil in meter
// Calculation of the temperature of the hot spot
pe = pi*(1-Sf^(1/2));// Effective thermal resistivity in ohm*meter
V = A*l*10^(-6);// Volume of coil(in meter cube)
q = p/V;// Heat dissipated in Watt per meter cube
T0 =q*pe*t*t/8;// Assuming equal inward and outward heat flows
disp(T0,'Temperature of the hot spot (degree celsius)=');
//in book answers is 15 degree celsius. The answers vary due to round off error
```

Scilab code Exa 4.8 Calculating the maximum temperature difference between the coi

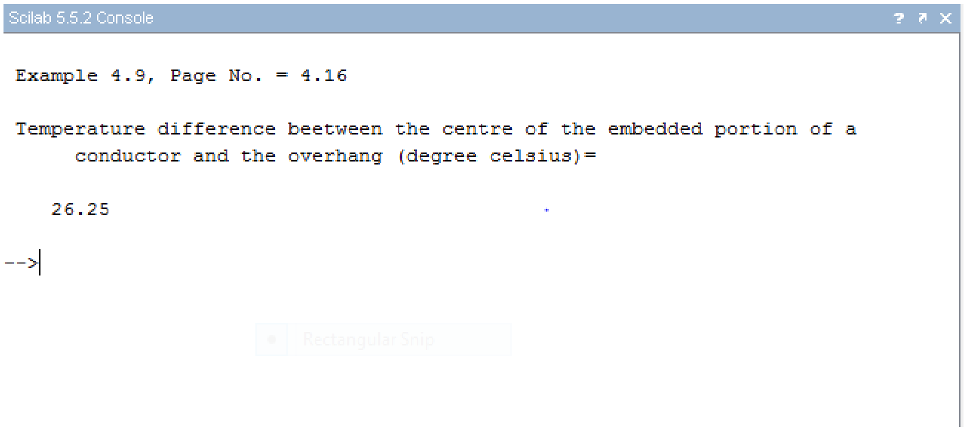
```
// Calculating the maximum temperature difference between the coil surface and the winding
clc;
disp('Example 4.8, Page No. = 4.14')
```



```
Example 4.8, Page No. = 4.14

Maximum temperature difference between the coil surface and the winding (degree
      celsius)=

   50.880402

-->
```

Figure 4.7: Calculating the maximum temperature difference between the coil surface and the winding

```
// Given Data
t = 25*10^(-3);// Thickness of coil (in meter)
Sf = 0.7;// Space Factor
Loss_cu = 20;// Copper losses (in Watt per kg)
pi = 8;// Thermal resistivity of paper insulation(in ohm*meter)
D_cu = 8900;// Density of copper (in kg per meter cube)
// Calculation of the maximum temperature difference between the coil surface and the winding
pe = pi*(1-Sf^(1/2));// Effective thermal resistivity in (ohm*meter)
q = Sf*Loss_cu*D_cu;// Losses(in Watt per meter cube)
T =q*pe*t^(2)/2;// Maximum temperature difference between the coil surface and the winding (in degree celsius)
disp(T,'Maximum temperature difference between the coil surface and the winding (degree celsius)=');
//in book answer is 51 degree celsius. The answers vary due to round off error
```

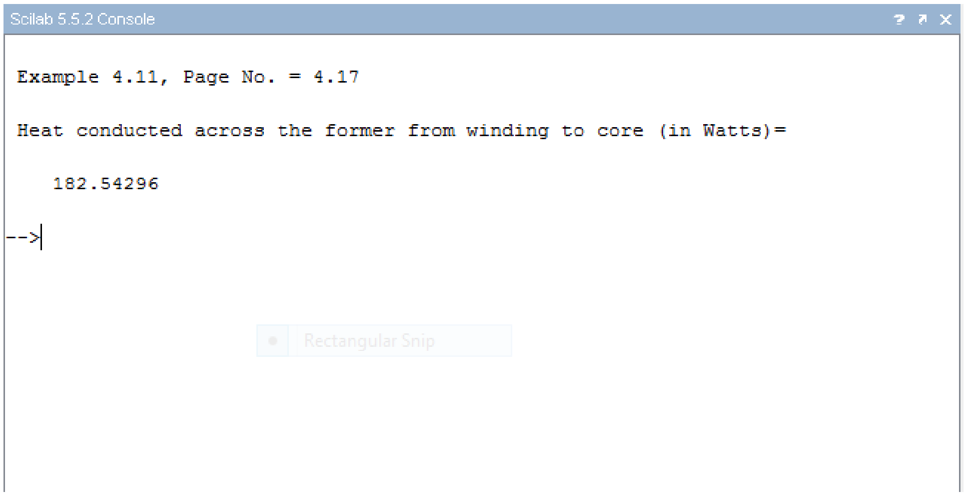


```
 Example 4.9, Page No. = 4.16

 Temperature difference beetween the centre of the embedded portion of a
      conductor and the overhang (degree celsius)=

    26.25

-->
```

Figure 4.8: Calculating the temperature difference beetween the centre of the embedded portion of a conductor and the overhang

Scilab code Exa 4.9 `Calculating the temperature difference beetween the centre of`

```
// Calculating the temperature difference beetween the centre of the embedded portion of a conductor and the overhang
clc;
disp('Example 4.9, Page No. = 4.16')
// Given Data
L = 0.5;// Length of the machine in meter
pc = 0.0025;// Thermal resistivity of conductor in ohm*meter
p = 0.021*10^(-6);// Electrical resistivity of conductor in ohm*meter
s = 4;// Current density in the conductors (in A per mm square)
// Calculation of the temperature difference beetween the centre of the embedded portion of a
```



```
Example 4.11, Page No. = 4.17

Heat conducted across the former from winding to core (in Watts)=

   182.54296

-->
```

Figure 4.9: Calculating the heat conducted across the former from winding to core

```
    conductor and the overhang
T = (s*10^(6))^(2)*(p*pc*L*L)/8;// Effective thermal resistivity in ohm*meter
disp(T,'Temperature difference beetween the centre of the embedded portion of a  conductor and the overhang (degree celsius)=');
//in book answers is 26.3 degree celsius.  The answers vary due to round off error
```

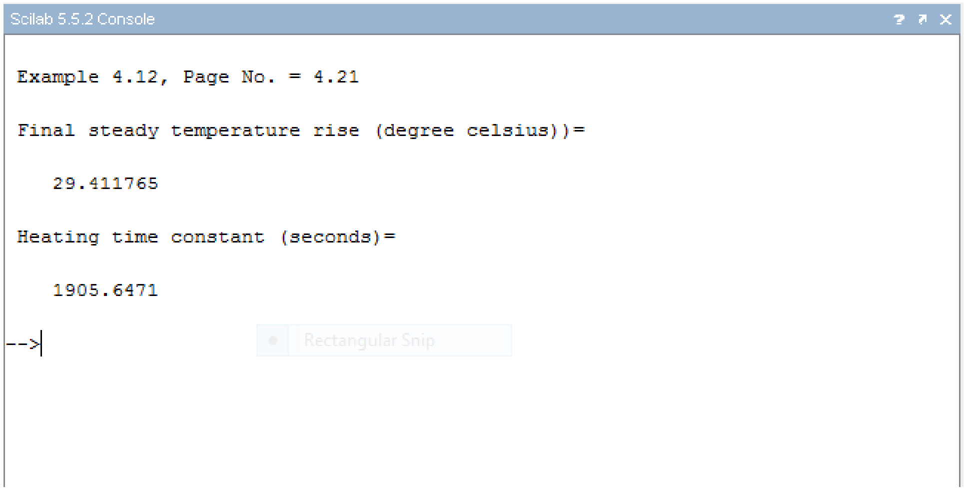
Scilab code Exa 4.11 `Calculating the heat conducted across the former from winding`

```
// Calculating the heat conducted across the former from winding to core
clc;
disp('Example 4.11, Page No. = 4.17')
// Given Data
t = 2.5;// Thickness of former (in mm)
```

```
t_air = 1;// Thickness of air space (in mm)
lw = 150*250;// The inner dimentions of the former of field coil (in mm square)
h = 200;// Winding height (in mm)
s_former = 0.166;// Thermal conductivity of former (in W per meter per degree celsius)
s_air = 0.05;// Thermal conductivity of air (in W per meter per degree celsius)
T = 40;// Temperature rise (in degree celsius)
// Calculation of the heat conducted across the former from winding to core
S = 2*(150+250)*h*10^(-6);// Area of path of heat flow (in meter square)
R_former = t*10^(-3)/(S*s_former);// Thermal resistance of former (in ohm)
R_air = t_air*10^(-3)/(S*s_air);// Thermal resistance of former (in ohm)
R0 = R_former+R_air;// Since R_former and R_air are in series. Total thermal resistance to heat flow (in ohm)
Q_con = T/R0;// Heat conducted (in Watts)
disp(Q_con,'Heat conducted across the former from winding to core (in Watts)=');
//in book answers is 182.6 Watts. The answers vary due to round off error
```

Scilab code Exa 4.12 Estimating the final steady temperature rise of coil and its

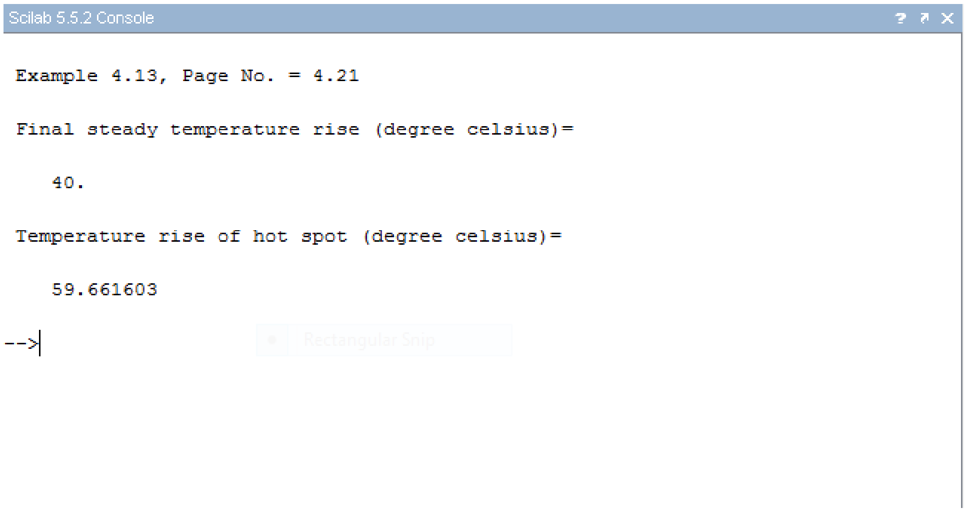
```
// Estimating the final steady temperature rise of coil and its time constant
clc;
disp('Example 4.12, Page No. = 4.21')
// Given Data
```



```
Example 4.12, Page No. = 4.21

Final steady temperature rise (degree celsius))=

   29.411765

Heating time constant (seconds)=

   1905.6471

-->
```

Figure 4.10: Estimating the final steady temperature rise of coil and its time constant

```
S = 0.15;// Heat dissipating surface (in meter square)
l = 1;// Length of mean turn in meter
Sf = 0.56;// Space Factor
A = 100*50;// Area of cross-section (in mm square)
Q = 150;// Dissipating loss (in Watts)
emissivity = 34;// Emissivity (in Watt per degree celsius per meter square)
h = 390;// Specific heat of copper (in J per kg per degree celsius)
// Calculation of the final steady temperature rise of coil and its time constant
V = l*A*Sf*10^(-6);// Volume of copper (in meter cube)
G = V*8900;// Since copper weighes 8900 kg per meter cube. Weight of copper(in kg)
Tm = Q/(S*emissivity);// Final steady temperature rise (in degree celsius)
Th = G*h/(S*emissivity);// Heating time constant (in seconds)
disp(Tm,'Final steady temperature rise (degree
```



```
Example 4.13, Page No. = 4.21

Final steady temperature rise (degree celsius)=

   40.

Temperature rise of hot spot (degree celsius)=

   59.661603

-->
```

Figure 4.11: Calculating the final steady temperature rise of coil surface and hot spot temperature rise

```
    celsius))=');
disp(Th,'Heating time constant (seconds)=');
//in book final steady temperature rise (in degree celsius) is equal to 29.4 and heating time constant (in seconds) is equal to 1906. The answers vary due to round off error
```

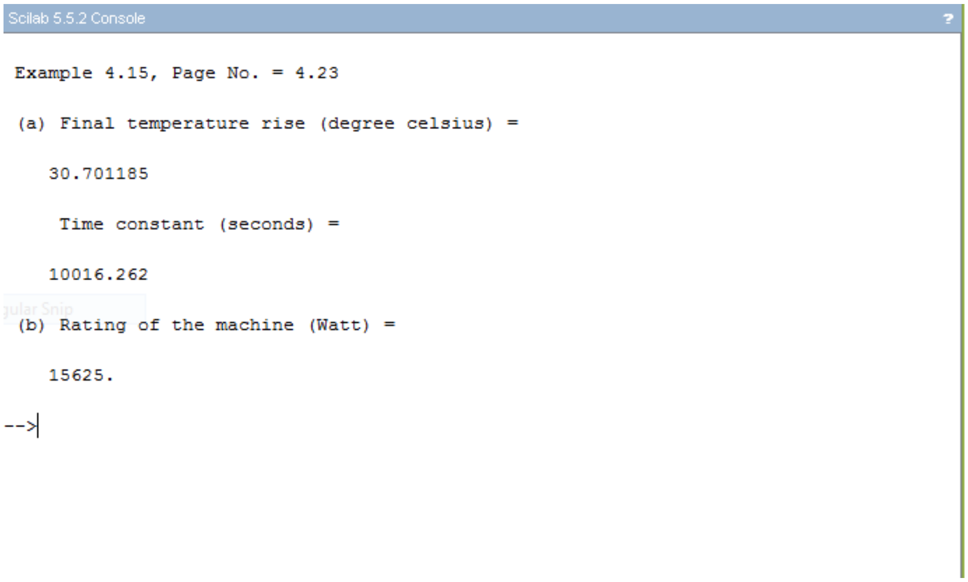
Scilab code Exa 4.13 `Calculating the final steady temperature rise of coil surface`

```
// Calculating the final steady temperature rise of coil surface and hot spot temperature rise
clc;
disp('Example 4.13, Page No. = 4.21')
// Given Data
S = 0.125;// Cooling surface (in meter square)
l = 0.8;// Length of mean turn in meter
```

```
Sf = 0.56;// Space Factor
A = 120*50;// Area of cross-section (in mm square)
Q = 150;// Dissipating loss (in Watts)
emissivity = 30;// Specific heat dissipation (in Watt per degree celsius per meter square)
pi = 8;// Thermal resistivity of insulating material (in ohm*meter)
// Calculation of the final steady temperature rise of coil surface and hot spot temperature rise
Tm = Q/(S*emissivity);// Final steady temperature rise (in degree celsius)
p0 = pi*(1-Sf^(1/2));// Effective thermal resistivity (in ohm*meter)
q = Q/(l*A*10^(-6));// Loss (in Watts per meter cube)
T0 = q*p0*(50*10^(-3))^(2)/8;// Temperature difference between coil surtface and hot spot (in degree celsius)
disp(Tm,'Final steady temperature rise (degree celsius)=');
disp(Tm+T0,'Temperature rise of hot spot (degree celsius)=');
//in book final steady temperature rise (in degree celsius) is equal to 40 and hot spot temperature rise(in degree celsius) is equal to 59.5. The answers vary due to round off error
```

Scilab code Exa 4.15 Calculating the temperature rise and thermal time constant an

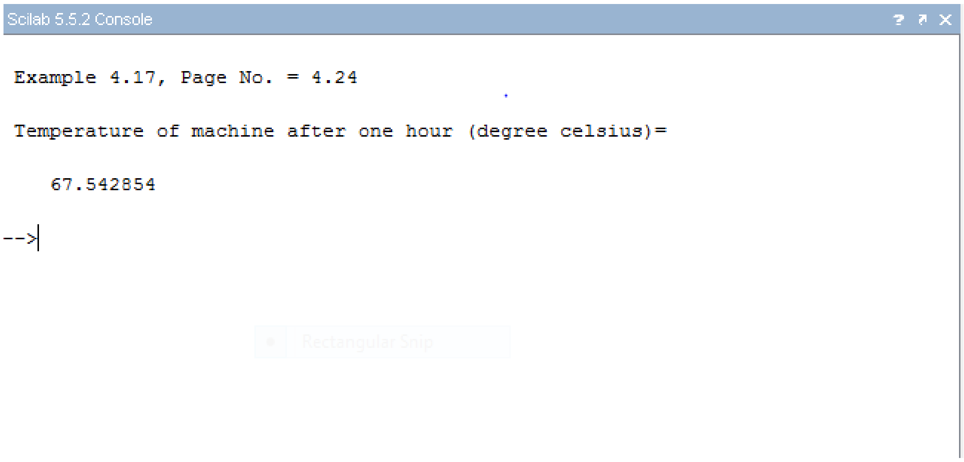
```
// Calculating the temperature rise and thermal time constant and rating of the machine
clc;
disp('Example 4.15, Page No. = 4.23')
```



```
 Example 4.15, Page No. = 4.23

 (a) Final temperature rise (degree celsius) =

    30.701185

     Time constant (seconds) =

    10016.262

 (b) Rating of the machine (Watt) =

    15625.

-->
```

Figure 4.12: Calculating the temperature rise and thermal time constant and rating of the machine

```
// Given Data
D = 0.6;// Diameter of induction motor (in meter)
L = 0.9;// Length of induction motor (in meter)
out = 7500;// Output of induction motor (in W)
e = 0.9;// Efficiency
G = 375;// Weight of material (in kg)
h = 725;// Specific heat (in J/kg degree celsius)
Lem = 12;// Specific heat dissipation (in Watt per meter square degree celsius)
// Calculation of the temperature rise and thermal time constant of the machine
S = (%pi*D*L)+(2*%pi/4*D^(2));// Total heat dissipating surface (in meter square)
Q = (out/e)-out;// Losses (in Watts)
Tm = Q/(S*Lem);// Final temperature rise (in degree celsius)
Th = G*h/(S*Lem);// Time constant (in seconds)
disp(Tm,'(a) Final temperature rise (degree celsius)
```



```
 Example 4.17, Page No. = 4.24

 Temperature of machine after one hour (degree celsius)=

    67.542854

-->
```

Figure 4.13: Calculating the temperature of machine after one hour of its final steady temperature rise

```
    =');
disp(Th,'    Time constant (seconds) =');
// Calculation of the rating of the machine
Lem_new = 25;// Specific heat dissipation (in Watt per meter square degree celsius)
Q = Tm*S*Lem_new;// Losses (in Watts)
out = (e*Q)/(1-e);// Output of induction motor (in W)
disp(out,'(b) Rating of the machine (Watt) =');
//in book answers are 30.85 degree celsius, 10025 seconds and 15687 watts. The answers vary due to round off error
```

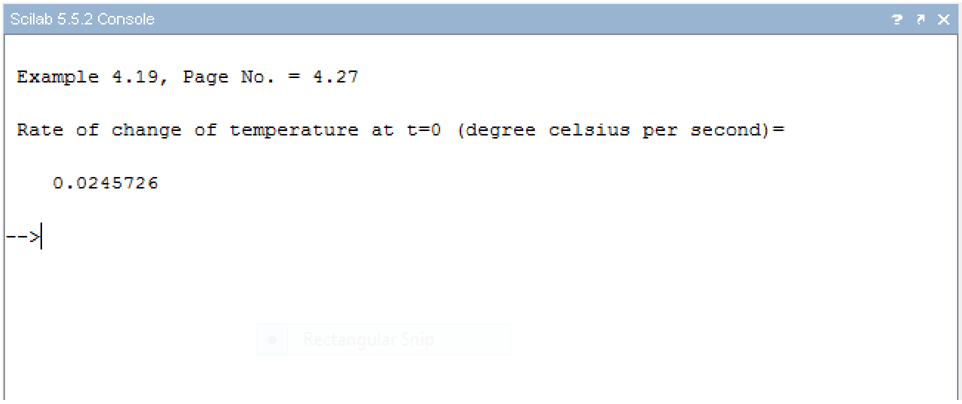
Scilab code Exa 4.17 Calculating the temperature of machine after one hour of its

```
// Calculating the temperature of machine after one hour of its final steady temperature rise
```

```
clc;
disp('Example 4.17, Page No. = 4.24')
// Given Data
Ti = 40;// Initial temperature (in degree celsius)
T_ambient = 30;// Ambient temperature (in degree celsius)
Tm = 80;// Final steady temperature rise (in degree celsius)
Th = 2;// Heating time constant (in hours)
t = 1;// Since we have to calculate temperature of machine after one hour of its final steady temperture rise (in hours)
// Calculation of the final steady temperature rise of coil surface and hot spot temperature rise
Ti_rise = Ti-T_ambient;// Initial temperature rise (in degree celsius)
T = Tm*(1-%e^(-t/Th))+(Ti_rise*%e^(-t/Th));// Temperature rise after one hour (in degree celsius)
disp(T+T_ambient,'Temperature of machine after one hour (degree celsius)=');
//in book answer is 67.54 (degree celsius). The answers vary due to round off error
```

Scilab code Exa 4.19 `Calculating the rate of change of temperature`

```
// Calculating the rate of change of temperature at t=0
clc;
disp('Example 4.19, Page No. = 4.27')
// Given Data
I = 2.5;// Current (in Amperes)
V = 230;// Voltage (in volts)
```



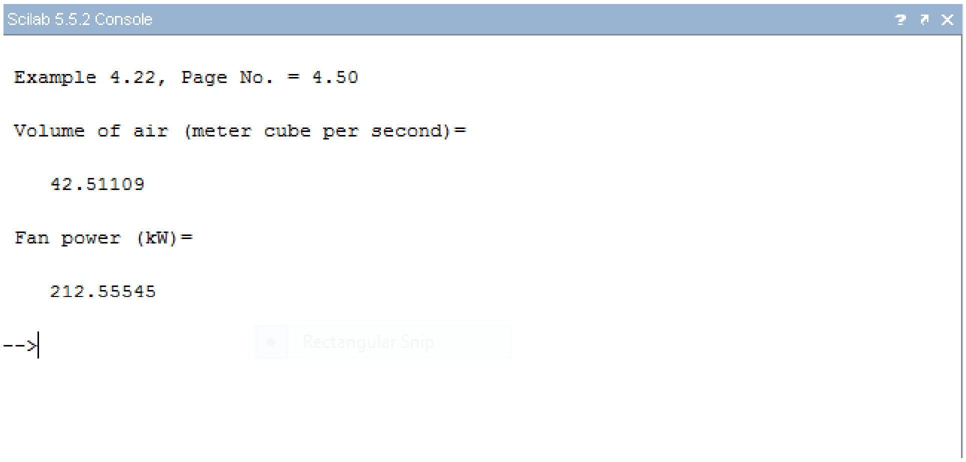
```
Example 4.19, Page No. = 4.27

Rate of change of temperature at t=0 (degree celsius per second)=

   0.0245726

-->
```

Figure 4.14: Calculating the rate of change of temperature

```
G = 60;// Weight of copper (in kg)
h = 390;// Specific heat of copper (in J per kg per degree celsius)
// Calculation of the rate of change of temperature at t=0
Q = I*V;// Loss (in Watts)
T_rate = Q/(G*h);// Rate of change of temperature at t=0 (in degree celsius per second)
disp(T_rate,'Rate of change of temperature at t=0 (degree celsius per second)=');
//in book answer is 0.0246 (in degree celsius per second). The answers vary due to round off error
```

Scilab code Exa 4.22 Calculating the volume of air required per second and fan pow

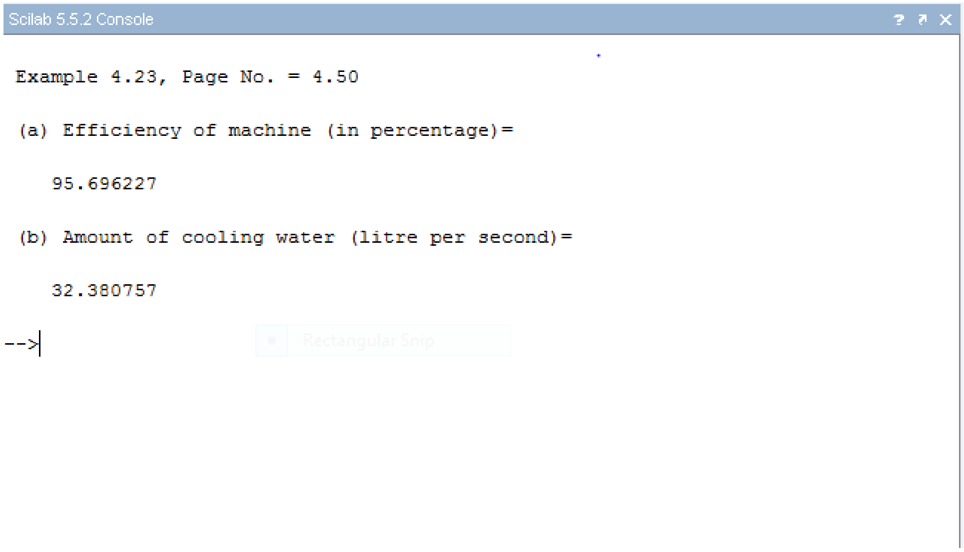
```
// Calculating the volume of air required per second and fan power
clc;
disp('Example 4.22, Page No. = 4.50')
// Given Data
```



```
Example 4.22, Page No. = 4.50

Volume of air (meter cube per second)=

   42.51109

Fan power (kW)=

   212.55545

-->
```

Figure 4.15: Calculating the volume of air required per second and fan power

```
MVA = 50;// MVA rating of turbo-alternator
Q = 1500;// Total loss (in kW)
Ti = 25;// Inlet temperature of air (in degree celsius)
T = 30;// Temperature limit (in degree celsius)
H = 760;// Barometric height (in mm of mercury)
P = 2000;// Pressure (in N per meter square)
nf = 0.4;// Fan efficiency
// Assumption
cp = 995;// Specific heat of air at constant pressure (in J per kg per degree celsius)
V = 0.775;// Volume of 1 kg of air at N.T.P. (in meter cube)
// Calculation of the volume of air required per second and fan power
Va = (V*Q*10^(3)/(cp*T))*((Ti+273)/273)*(760/H);// Volume of air (in meter cube per second)
Pf = (P*Va/nf)*10^(-3);// Fan power (in kW)
disp(Va,'Volume of air (meter cube per second)=');
disp(Pf,'Fan power (kW)=');
//in book Va is equal to 42.6 (meter cube per second) and Pf is equal to 212.5 (kW). The answers vary due to round off error
```



```
 Example 4.23, Page No. = 4.50

 (a) Efficiency of machine (in percentage)=

    95.696227

 (b) Amount of cooling water (litre per second)=

    32.380757

-->
```

Figure 4.16: Calculating the efficiency of machine and amount of cooling water

---

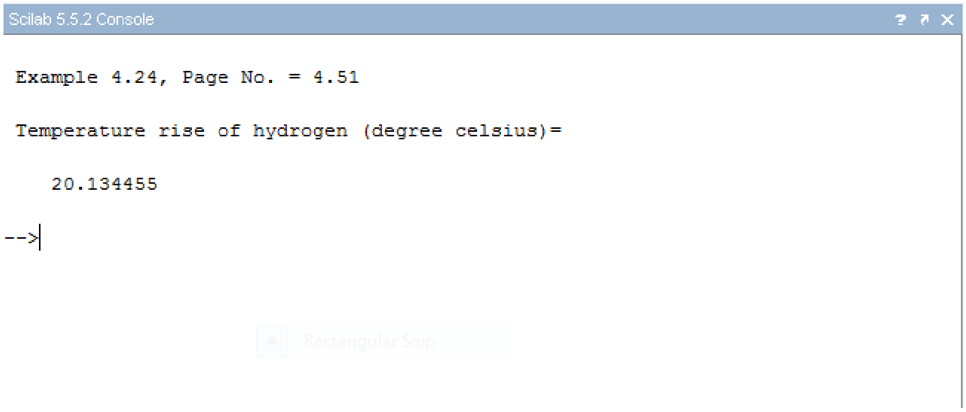
Scilab code Exa 4.23 Calculating the efficiency of machine and amount of cooling w

```
// Calculating the efficiency of machine and amount of cooling water
clc;
disp('Example 4.23, Page No. = 4.50')
// Given Data
MVA = 30;// MVA rating of turbo-alternator
Ti = 15;// Inlet temperature of air (in degree celsius)
To = 45;// Outlet temperature of air (in degree celsius)
H = 750;// Barometric height (in mm of mercury)
Va = 30;// Volume of air (in meter cube per second)
```

```
nf = 0.4;// Fan efficiency
cp = 1000;// Specific heat of air at constant pressure (in J per kg per degree celsius)
V = 0.78;// Volume of 1 kg of air at N.T.P. (in meter cube)
pf = 0.8;// Power factor
// Calculation of the efficiency of machine
T = To-Ti;// Temperature rise limit (in degree celsius)
Q = Va/((V*10^(3)/(cp*T))*((Ti+273)/273)*(760/H));// Total losses (in kW)
P_out = 30*10^(3)*pf;// Output power (in kW)
n = P_out/(P_out+Q)*100;// Fan power (in kW)
disp(n,'(a) Efficiency of machine (in percentage)=');
// Calculation of the amount of cooling water
T = 8;// Temperature rise of water (in degree celsius)
Vw = 0.24*Q/T;// Amount of cooling water (in litre per second)
disp(Vw,'(b) Amount of cooling water (litre per second)=');
//in book efficiency is equal to 95.7% and amount of cooling water 32.4 (litre per second).  The answers vary due to round off error
```

Scilab code Exa 4.24 Calculating the temperature rise of hydrogen

```
// Calculating the temperature rise of hydrogen
clc;
disp('Example 4.24, Page No. = 4.51')
// Given Data
Q = 750;// Losses (in kW)
```

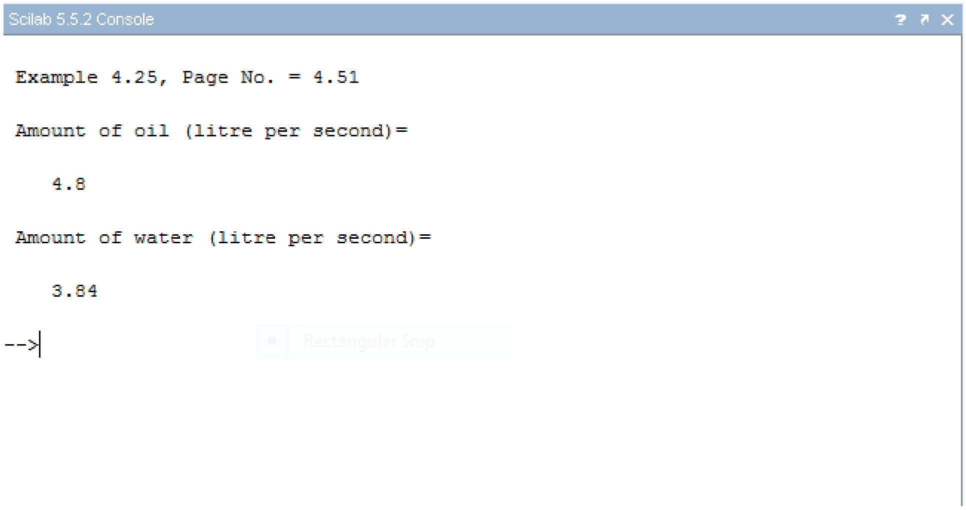


```
Example 4.24, Page No. = 4.51

Temperature rise of hydrogen (degree celsius)=

   20.134455

-->
```

Figure 4.17: Calculating the temperature rise of hydrogen

```
Ti = 25;// Inlet temperature of air (in degree celsius)
H = (2000+760);// Barometric height (in mm of mercury)
VH = 10;// Volume of hydrogen leaving the coolers (in meter cube per second)
cp = 12540;// Specific heat of air at constant pressure (in J per kg per degree celsius)
V = 11.2;// Volume of 1 kg of air at N.T.P. (in meter cube)
// Calculation of the temperature rise of hydrogen
T = (V*Q*10^(3)/(cp*VH))*((Ti+273)/273)*(760/H);// Temperature rise of hydrogen(in degree celsius)
disp(T,'Temperature rise of hydrogen (degree celsius)=');
//in book ans is 20 (degree celsius).  The answers vary due to round off error
```

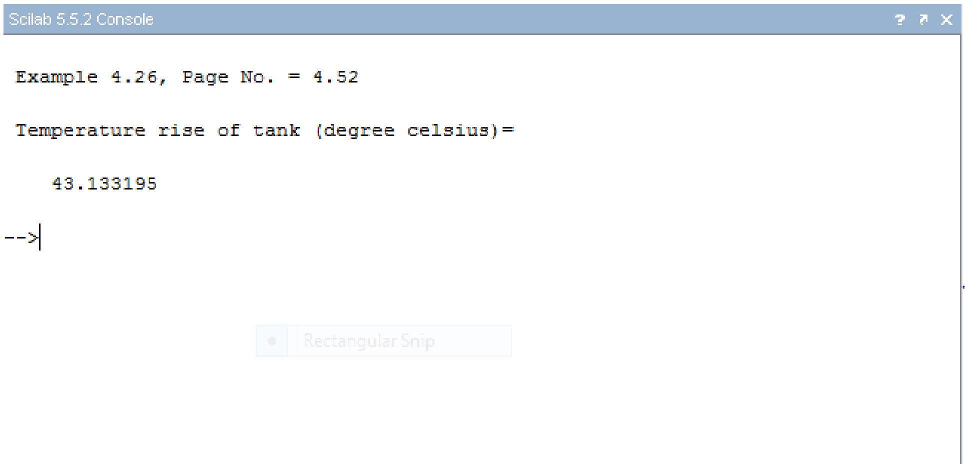
Scilab code Exa 4.25 `Calculating the amount of oil and amount of water`



```
 Example 4.25, Page No. = 4.51

 Amount of oil (litre per second)=

    4.8

 Amount of water (litre per second)=

    3.84

-->
```

Figure 4.18: Calculating the amount of oil and amount of water

```
// Calculating the amount of oil and amount of water
clc;
disp('Example 4.25, Page No. = 4.51')
// Given Data
MVA = 40;// MVA rating of transformer
Q = 200;// Total losses (in kW)
Q_oil = 0.8*Q;// Since 20% of losses are dissipated by tank walls  Heat taken up by oil (in kW)
// Calculation of the amount of oil
T = 20;// Temperature rise of oil (in degree celsius)
cp = 0.4;// by assuming
Vo = 0.24*Q_oil/(cp*T);// Amount of oil (in litre per second)
disp(Vo,'Amount of oil (litre per second)=');
// Calculation of the amount of water
T = 10;// Temperature rise of water (in degree celsius)
Vw = 0.24*Q_oil/T;// Amount of water (in litre per second)
```



```
 Example 4.26, Page No. = 4.52

 Temperature rise of tank (degree celsius)=

    43.133195

-->
```

Figure 4.19: Calculating the temperature rise of tank

```
disp(Vw,'Amount of water (litre per second)=');
//in book Vo is equal to 4.8 (litre per second) and Vw is equal to 3.84 (litre per second). The answers vary due to round off error
```

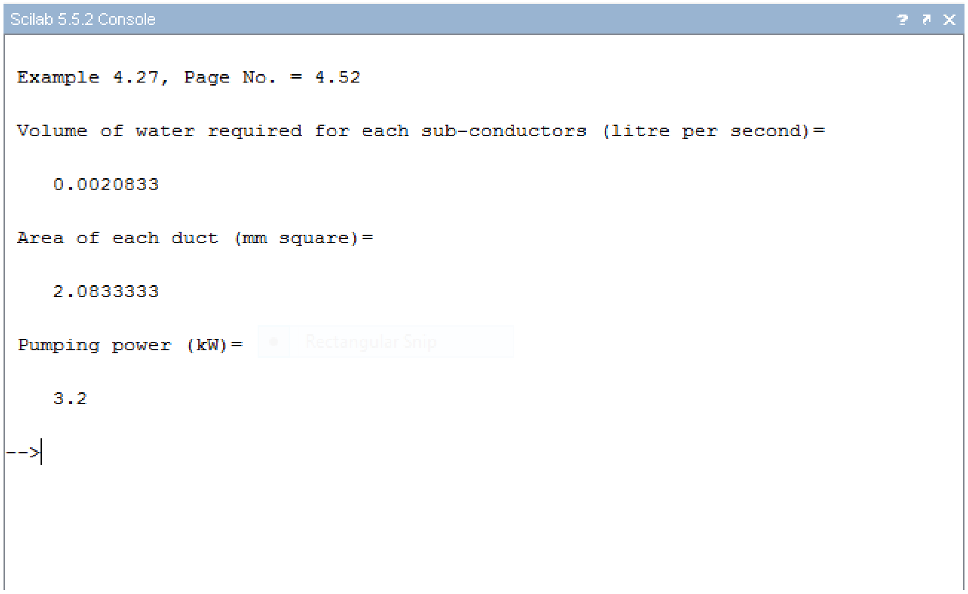
Scilab code Exa 4.26 `Calculating the temperature rise of tank`

```
// Calculating the temperature rise of tank
clc;
disp('Example 4.26, Page No. = 4.52')
// Given Data
MVA = 15;// MVA rating of transformer
Q_iron = 80;// Iron losses (in kW)
Q_copper = 120;// Copper losses (in kW)
T_water = 15;// Temperature rise of water (in degree celsius)
Vw = 3;// Amount of water (in litre per second)
Dimensions = 3.5*3.0*1.4;// Tank dimensions (in
```

```
meter)
l = 10;// Specific loss dissipation from tank walls (in Watt per degree celsius per meter square)
// Calculation of the temperature rise of tank
Q_total = Q_iron+Q_copper;// Total losses (in kW)
Q = Vw*T_water/0.24;// Heat taken away by water (in kW)
Q_walls = Q_total-Q;// Loss dissipated by walls (in kW)
S = 2*3.5*(3+1.14);// Area of tank walls by neglecting top and bottom surfaces
T = Q_walls*10^(3)/(S*l);// Temperature rise of tank (in degree celsius)
disp(T,'Temperature rise of tank (degree celsius)=');
//in book answer is 40.6 (degree celsius). The provided in the textbook is wrong
```

Scilab code Exa 4.27 Calculating the amount of water required and area of water du

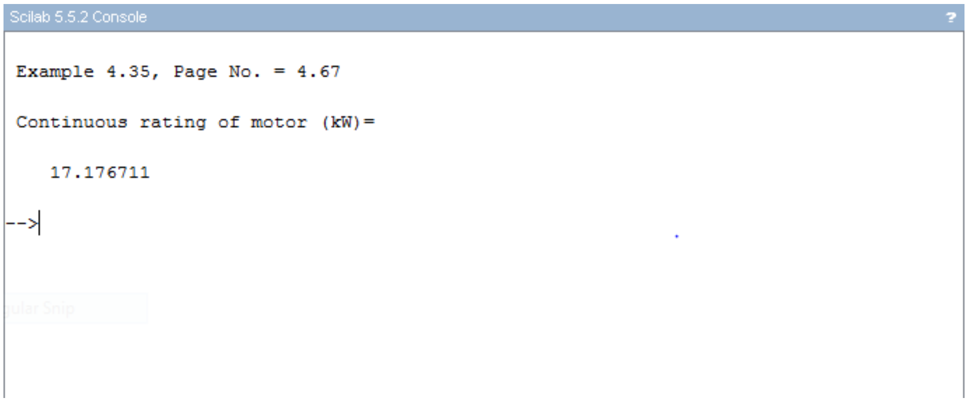
```
// Calculating the amount of water required per second, area of water duct and pumping power
clc;
disp('Example 4.27, Page No. = 4.52')
// Given Data
Q = 800;// Stator copper losses (in kW)
Ti = 38;// Temperature of water inlet (in degree celsius)
To = 68;// Temperature of water outlet (in degree celsius)
Ns = 48;// Number of slots
v = 1;// velocity (in meter per second)
p = 300*10^(3);// Pumping pressure (in N per meter
```



```
Example 4.27, Page No. = 4.52

Volume of water required for each sub-conductors (litre per second)=

   0.0020833

Area of each duct (mm square)=

   2.0833333

Pumping power (kW)=

   3.2

-->
```

Figure 4.20: Calculating the amount of water required and area of water duct and pumping power

```
square)
n = 0.6;// Efficiency
// Calculation of the volume of water required per second
T = To-Ti;// Temperature rise of water (in degree celsius)
Vwl = 0.24*Q/T;// Amount of water (in litre per second)
Vwm = Vwl*10^(-3);// Amount of water (in meter cube per second)
N_cond = 2*Ns;// Since each slot has two conductors  Total number of stator conductors
N_sub_cond = 32*N_cond;// Since each conductor is subdivided into 32 sub-conductors
Vw_sub_cond = Vwl/N_sub_cond;// Volume of water required for each sub-conductors (in litre per second)
disp(Vw_sub_cond,'Volume of water required for each
```



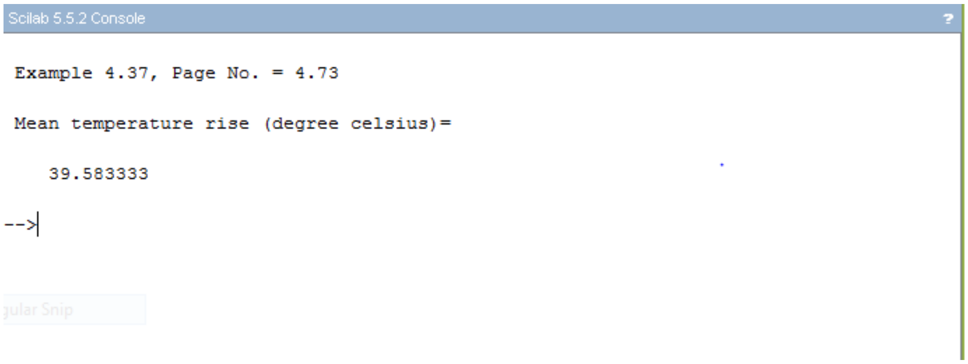
```
Example 4.35, Page No. = 4.67

Continuous rating of motor (kW)=

   17.176711

-->
```

Figure 4.21: Calculating the continuous rating of motor

```
    sub-conductors (litre per second)=');
A = Vw_sub_cond*10^(-3)/v;// Area of each duct (in meter square)
A = A*10^(6);// Area of each duct (in mm square)
disp(A,'Area of each duct (mm square)=');
Q = 800-500;// Since it ia a 500 KW direct cooled turbo-alternator (in kW)
P = (Q*10^(3)*Vwm/n)*10^(-3);// Pumping power (in kW)
disp(P,'Pumping power (kW)=');
//in book Vwl is equal to 0.00208 (litre per second), A is 2 (mm square) and pumping power is 3.2 (kW). The answers vary due to round off error
```

Scilab code Exa 4.35 `Calculating the continuous rating of motor`

```
// Calculating the continuous rating of motor
clc;
disp('Example 4.35, Page No. = 4.67')
// Given Data
```



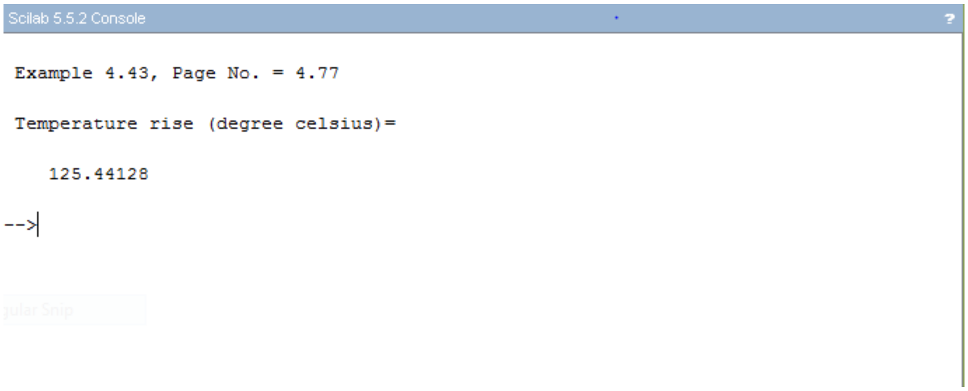
```
Example 4.37, Page No. = 4.73

Mean temperature rise (degree celsius)=

   39.583333

-->
```

Figure 4.22: Calculating the mean temperature rise

```
Psh = 37.5;// Power rating of motor (in kW)
th = 30;// Time (in minuts)
Th = 90;// Heating time constant (in minuts)
// Calculation of the continuous rating of motor
ph = 1/(1-%e^(-th/Th));// Heating overload ratio
K = 0.7^(2);// Maximum efficiency occurs at 70% full load
pm = ((K+1)*ph-K)^(1/2);// Mechanical overload ratio
Pnom = Psh/pm;// Continuous rating of motor (in kW)
disp(Pnom,'Continuous rating of motor (kW)=');
//in book answer is 17.2 kW. The answers vary due to round off error
```

Scilab code Exa 4.37 `Calculating the mean temperature rise`

```
// Calculating the mean temperature rise
clc;
disp('Example 4.37, Page No. = 4.73')
// Given Data
th = 20;// Heating time (in minuts)
Th = 120;// Heating time constant (in minuts)
```



```
Example 4.43, Page No. = 4.77

Temperature rise (degree celsius)=

   125.44128

-->
```

Figure 4.23: Calculating the temperature rise

```
tc = 15;// Cooling time (in minuts)
Tc = 180;// Cooling time constant (in minuts)
Tm = 50;// Final temperature rise on the continuous full load (in degree celsius)
Loss_fl = 500;// Copper loss at full load (in Watt)
Loss_nl = 300;// Copper loss at no load (in Watt)
// Calculation of the mean temperature rise
Total_Loss_fl = Loss_fl+Loss_nl;// Total loss at full load (in Watt)
Total_Loss_nl = Loss_nl;// Total loss at no load (in Watt)
Tn = Total_Loss_nl/Total_Loss_fl*Tm;// Final temperature rise when running on no load (in degree celsius)
T = ((Tm*th/Th)+(Tn*tc/Tc))/(th/Th+tc/Tc);// Mean temperature rise (in degree celsius)
disp(T,'Mean temperature rise (degree celsius)=');
//in book answer is 39.58 degree celsius. The answers vary due to round off error
```

Scilab code Exa 4.43 Calculating the temperature rise

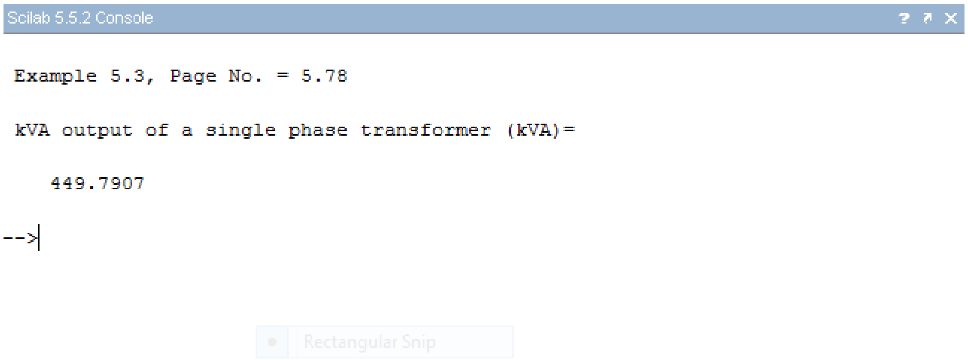
```
// Calculating the temperature rise
clc;
disp('Example 4.43, Page No. = 4.77')
// Given Data
az = 30*10^(-6);// Cross-sectional area (in meter square)
Iz = 20*10^(3);// Current (in Ampere)
t = 50;// Time (in mili second)
p = 0.021*10^(-6);// Resistivity of conductor (in ohm*meter)
h = 418;// Specific heat (in J/kg degree celsius)
g = 8900;// Density (in kg per meter cube)
// Calculation of the temperature rise
T = Iz^(2)*p*t*10^(-3)/(g*az^(2)*h);// Temperature rise (in degree celsius)
disp(T,'Temperature rise (degree celsius)=');
//in book answer is 125 degree celsius. The answers vary due to round off error
```

Chapter 5

Design of Transformers

Scilab code Exa 5.3 `Calculating the kVA output of a single phase transformer`

```
// Calculating the kVA output of a single phase transformer
clc;
disp('Example 5.3, Page No. = 5.78')
// Given Data
D = 0.4;// Distance between core centres (in meter)
f = 50;// Frequency (in Hz)
Bm = 1.2;// Flux density of core (in Wb per meter square)
Kw = 0.27;// Window space factor
s = 2.3;// Current density (in Ampere per mm square)
R1 = 2.8;// Ratio of core height and distance between core centres
R2 = 0.56;// Ratio of circumscribing circle and distance between core centres
R3 = 0.7;// Ratio of net iron area and area of circumscribing circle
// Calculation of the kVA output of a single phase transformer
```



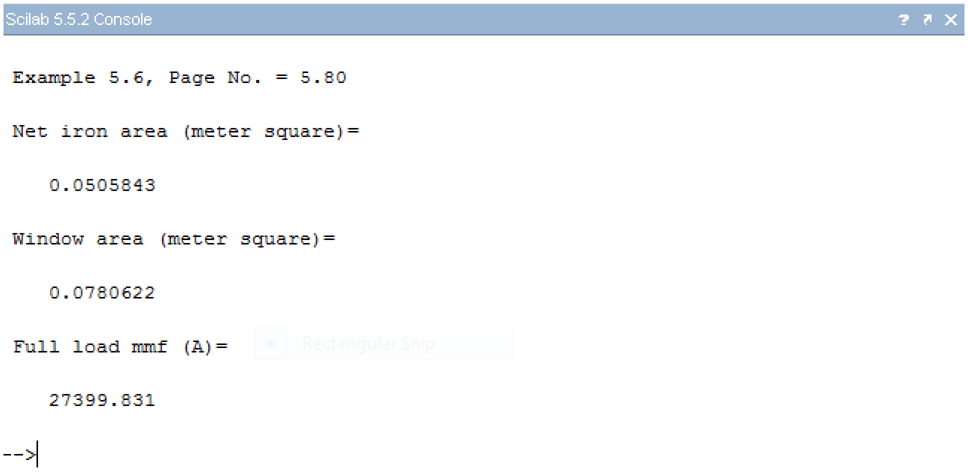
```
Example 5.3, Page No. = 5.78

kVA output of a single phase transformer (kVA)=

   449.7907

-->
```

Figure 5.1: Calculating the kVA output of a single phase transformer

```
Hw = R1*D;// Core heightor window height (in meter)
d = R2*D;// Diameter of circumscribing circle (in meter)
Ww = D-d;// Width of window (in meter)
Aw = Hw*Ww;// Area of window (in meter square)
A = (%pi/4)*d*d;// Area of circumscribing circle (in meter square)
Ai = R3*A;// Net iron area (in meter square)
Q = 2.22*f*Bm*Kw*s*10^(6)*Aw*Ai*10^(-3);// kVA output of a single phase transformer
disp(Q,'kVA output of a single phase transformer (kVA)=');
//in book answer is 450 kVA. The answers vary due to round off error
```

Scilab code Exa 5.6 Calculating the net iron area and window area and full load mm

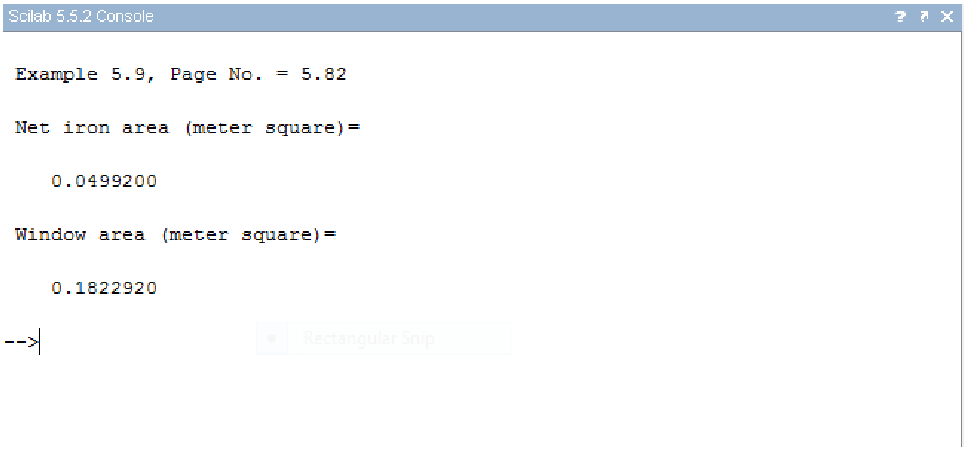
```
// Calculating the net iron area and window area and full load mmf
```



```
Example 5.6, Page No. = 5.80

Net iron area (meter square)=

   0.0505843

Window area (meter square)=

   0.0780622

Full load mmf (A)=

   27399.831

-->
```

Figure 5.2: Calculating the net iron area and window area and full load mmf

```
clc;
disp('Example 5.6, Page No. = 5.80')
// Given Data
Q = 400;// kVA rating
R = 2.4*10^(-6);// Ratio of flux to full load mmf
f = 50;// Frequency (in Hz)
Bm = 1.3;// Maximum flux density of core (in Wb per
    meter square)
Kw = 0.26;// Window space factor
s = 2.7;// Current density (in Ampere per mm square)
// Calculation of the net iron area
K = (4.44*f*R*10^(3))^(1/2);
Et = K*Q^(1/2);// Voltage per turn (in Volts)
Flux = Et/(4.44*f);// Flux (in Wb)
Ai = Flux/Bm;// Net iron area (in meter square)
disp(Ai,'Net iron area (meter square)=');
// Calculation of the net window area
Aw = Q/(2.22*f*Bm*Kw*s*10^(6)*Ai*10^(-3));// Window
```



```
 Example 5.9, Page No. = 5.82

 Net iron area (meter square)=

    0.0499200

 Window area (meter square)=

    0.1822920

-->
```

Figure 5.3: Calculating the net iron area and window area

```
area (in meter square)
disp(Aw,'Window area (meter square)=');
// Calculation of the full load mmf
AT = Flux/R;// Full load mmf (in A)
disp(AT,'Full load mmf (A)=');
//in book answers are 0.0507 (meter square), 0.0777 (meter square) and 27500 (A) respectively. The answers vary due to round off error
```

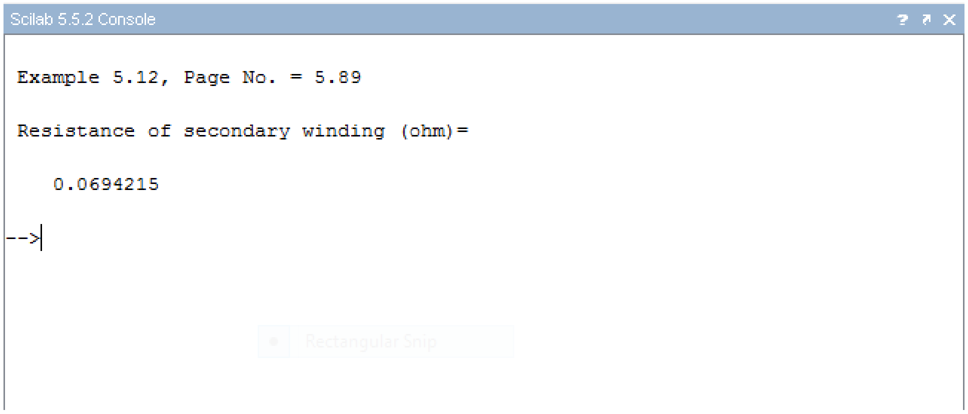
Scilab code Exa 5.9 `Calculating the net iron area and window area`

```
// Calculating the net iron area and window area
clc;
disp('Example 5.9, Page No. = 5.82')
// Given Data
Q = 400;// kVA rating
f = 50;// Frequency (in Hz)
Bm = 1.5;// Maximum flux density of core (in Wb per meter square)
```

```
Kw = 0.12;// Copper space factor
s = 2.2;// Current density (in Ampere per mm square)
gc = 8.9*10^(3);// Density of copper (in kg per meter cube)
gi = 7.8*10^(3);// Density of iron (in kg per meter cube)
R1 = 0.5;// Ratio of length of mean turn of copper to length of mean flux path
R2 = 4;// Ratio of weight of iron to weight of copper
// Calculation of the net iron area
C = (1/2.22*R1*gc/gi*10^(3))^(1/2);// Flux (in Wb)
Ai = C*(Q*R2/(f*Bm*s*10^(6)))^(1/2);// Net iron area (in meter square)
disp(Ai,'Net iron area (meter square)=');
// Calculation of the net window area
Aw = Q/(2.22*f*Bm*Kw*s*10^(6)*Ai*10^(-3));// Window area (in meter square)
disp(Aw,'Window area (meter square)=');
//in book answers are 0.0478 (meter square) and 0.183 (meter square) respectively. The answers vary due to round off error
```

Scilab code Exa 5.12 Calculating the resistance of secondary winding

```
// Calculating the resistance of secondary winding
clc;
disp('Example 5.12, Page No. = 5.89')
// Given Data
sp = 2.2;// Current density of primary winding(in Ampere per mm square)
ss = 2.1;// Current density of secondary winding(in Ampere per mm square)
```



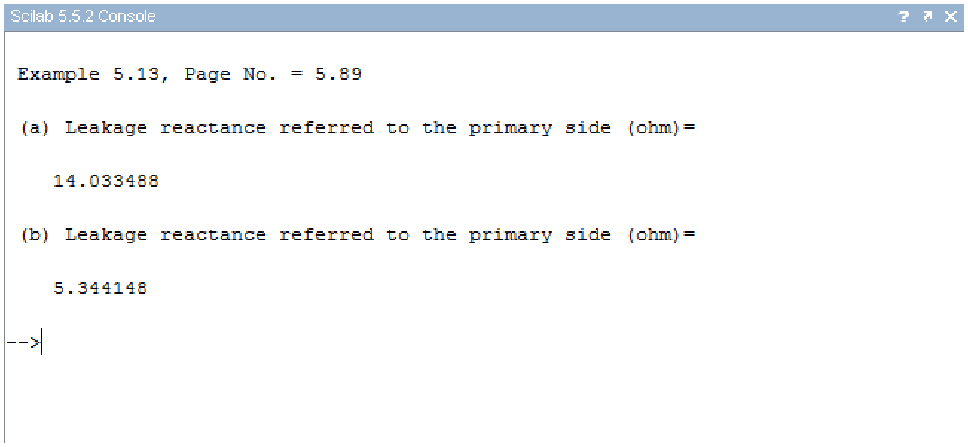
```
Example 5.12, Page No. = 5.89

Resistance of secondary winding (ohm)=

   0.0694215

-->
```

Figure 5.4: Calculating the resistance of secondary winding

```
rp = 8;// Resistance of primary inding (in ohm)
R1 = 1/1.1;// Since length of mean turn of primary is 10% than that of the secondary
R2 = 1/10;// Since ratio of transformation is 10:1
// Calculation of the resistance of secondary winding
rs = R2*R2*(ss/sp)*R1*rp;// Resistance of secondary winding (ohm)
disp(rs,'Resistance of secondary winding (ohm)=');
//in book answer is 0.0694 ohm.  The answers vary due to round off error
```

Scilab code Exa 5.13 `Calculating the leakage reactance of the transformer referred`

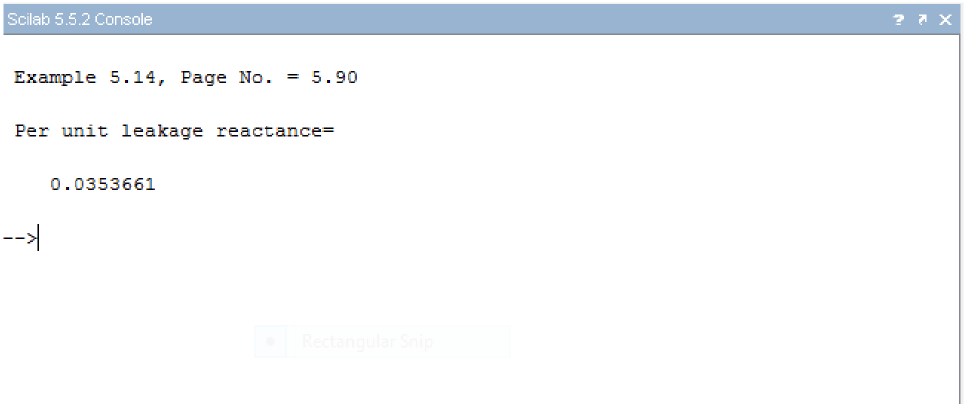
```
// Calculating the leakage reactance of the transformer referred to the h.v. side
clc;
disp('Example 5.13, Page No. = 5.89')
// Given Data
```



```
Example 5.13, Page No. = 5.89

 (a) Leakage reactance referred to the primary side (ohm)=

    14.033488

 (b) Leakage reactance referred to the primary side (ohm)=

    5.344148

-->
```

Figure 5.5: Calculating the leakage reactance of the transformer referred to the HV side

```
// 6600/400 V, delta/star 3-phase core type transformer
Q = 300;// kVA rating
f = 50;// Frequency (in Hz)
u0 = 4*%pi*10^(-7);
Tp = 830;// h.v winding turns
Lmt = 0.9;// Length of mean turn (in meter)
Lc = 0.5;// Height of coils (in meter)
a = 0.015;// Width of duct between h.v and l.v. windings (in meter)
bp = 0.025;// Width of h.v. winding (in meter)
bs = 0.016;// Width of l.v. winding (in meter)
// Calculation of the leakage reactance of the transformer referred to the h.v. side
Xp = 2*%pi*f*u0*Tp*Tp*Lmt/Lc*(a+(bp+bs)/3);// Leakage reactance referred to the primary side (ohm)
disp(Xp,'(a) Leakage reactance referred to the primary side (ohm)=');
// If the l.v. winding divided into two parts, one on each side of h.v. winding
Xp = %pi*f*u0*Tp*Tp*Lmt/Lc*(a+(bp+bs)/6);// Leakage
```



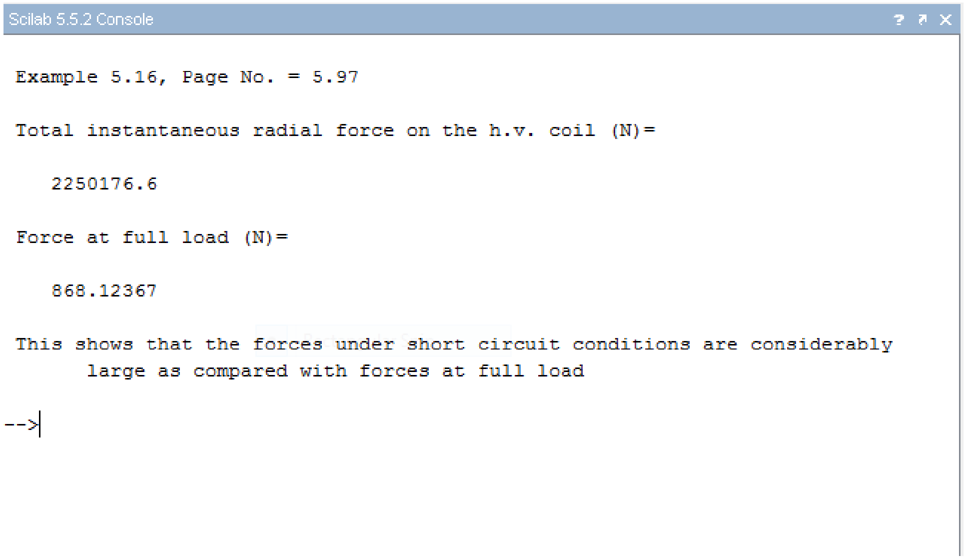
```
 Example 5.14, Page No. = 5.90

 Per unit leakage reactance=

    0.0353661

-->
```

Figure 5.6: Calculating the per unit leakage reactance

```
    reactance referred to the primary side (ohm)
disp(Xp,'(b) Leakage reactance referred to the primary side (ohm)=');
//in book answers are 14 ohm and 5.36 ohm respectively. The answers vary due to round off error
```

Scilab code Exa 5.14 `Calculating the per unit leakage reactance`

```
// Calculating the per unit leakage reactance
clc;
disp('Example 5.14, Page No. = 5.90')
// Given Data
// 2000/400 V, single phase shell type transformer
Q = 100;// kVA rating
f = 50;// Frequency (in Hz)
u0 = 4*%pi*10^(-7);
Tp = 200;// h.v winding turns
Lmt = 1.5;// Length of mean turn (in meter)
W = 0.12;// Width of winding (in meter)
```



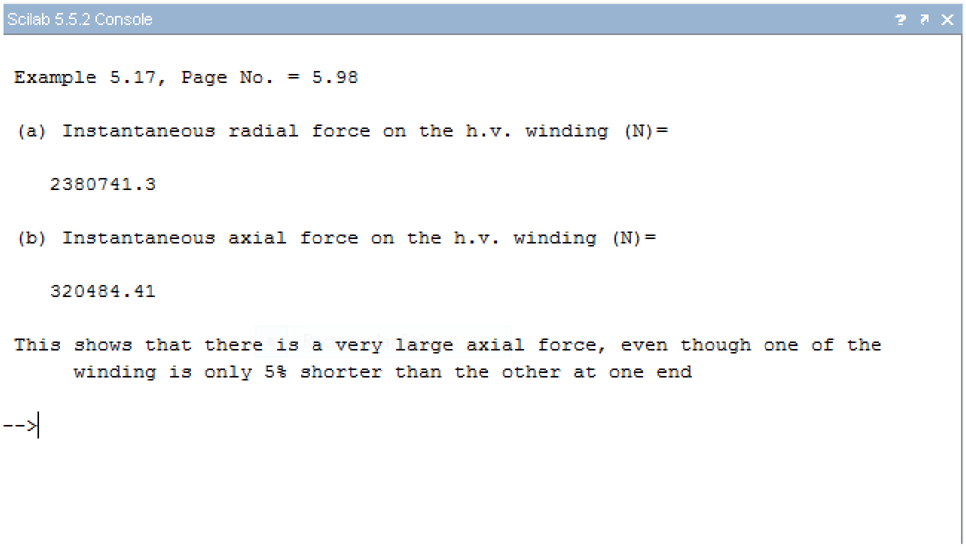
```
Example 5.16, Page No. = 5.97

Total instantaneous radial force on the h.v. coil (N)=

   2250176.6

Force at full load (N)=

   868.12367

This shows that the forces under short circuit conditions are considerably
      large as compared with forces at full load

-->
```

Figure 5.7: Calculating the instantaneous radial force on the HV winding if a short circuit occurs at the terminals of the LV winding with HV energised and the force at full load

```
a = 0.016;// Width of duct between h.v and l.v. windings (in meter)
bp = 0.04;// Width of h.v. winding (in meter)
bs = 0.036;// Width of l.v. winding (in meter)
// Calculation of the per unit leakage reactance
Xp = %pi*f*u0*Tp*Tp/2*Lmt/W*(a+(bp+bs)/6);// Leakage reactance referred to the primary side (ohm)
I_hv = Q*10^(3)/2000;// H.V. winding current at full load (in ampere)
Xp_pu = Xp*I_hv/2000;// Per unit leakage reactance
disp(Xp_pu,'Per unit leakage reactance=');
//in book answer is 0.0353. The answers vary due to round off error
```

Scilab code Exa 5.16 `Calculating the instantaneous radial force on the HV winding`

```
// Calculating the instantaneous radial force on the h.v. winding if a short circuit occurs at the terminals of the l.v. winding with h.v. energised and the force at full load
clc;
disp('Example 5.16, Page No. = 5.97')
// Given Data
// 6600/400 V, delta/star 3-phase core type transformer
Q = 1000;// kVA rating
f = 50;// Frequency (in Hz)
u0 = 4*%pi*10^(-7);
T = 500;// h.v winding turns
Lmt = 1.3;// Length of mean turn (in meter)
Lc = 0.6;// Height of winding (in meter)
m = 1.8;// Doubling effect multiplier
// Calculation of the per unit leakage reactance
I_fl = Q*1000/(3*6600);// Full load current per phase on h.v. side (in Ampere)
i = m*2^(1/2)*(1/0.05)*I_fl;// Instantaneous peak value of short circuit current (in Ampere)
Fr = u0/2*(i*T)^(2)*Lmt/Lc;// Total instantaneous radial force on the h.v. coil (in N)
disp(Fr,'Total instantaneous radial force on the h.v. coil (N)=');
Fr = u0/2*(I_fl*T)^(2)*Lmt/Lc;// Force at full load (in N)
disp(Fr,'Force at full load (N)=');
disp('This shows that the forces under short circuit conditions are considerably large as compared with forces at full load')
//in book answers are 2330000 (N) and 866 (N). The answers vary due to round off error
```



```
Example 5.17, Page No. = 5.98

 (a) Instantaneous radial force on the h.v. winding (N)=

    2380741.3

 (b) Instantaneous axial force on the h.v. winding (N)=

    320484.41

 This shows that there is a very large axial force, even though one of the
      winding is only 5% shorter than the other at one end

-->
```

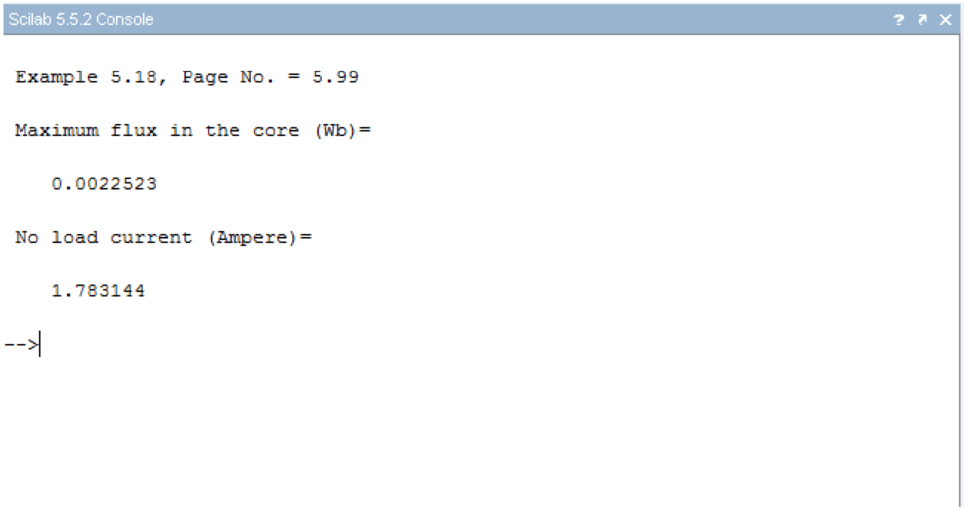
Figure 5.8: Calculating the instantaneous radial force and instantaneous axial force on the HV winding under short circuit conditions

Scilab code Exa 5.17 `Calculating the instantaneous radial force and instantaneous`

```
// Calculating the instantaneous radial force and instantaneous axial force on the h.v. winding under short circuit conditions
clc;
disp('Example 5.17, Page No. = 5.98')
// Given Data
// 7500/435 V, single phase core type transformer
Q = 575;// kVA rating
f = 50;// Frequency (in Hz)
u0 = 4*%pi*10^(-7);
Z_pu = 0.036;// Per unit impedance
T = 190;// h.v winding turns
```

```
Lmt = 1.25;// Length of mean turn (in meter)
Lc = 0.35;// Height of coils (in meter)
m = 1.8;// Doubling effect multiplier
a = 0.015;// Width of duct (in meter)
bp = 0.027;// Width of h.v. winding (in meter)
bs = 0.023;// Width of l.v. winding (in meter)
k = 0.05;// Since the h.v. winding is 5% shorter than the l.v. winding at one end
// Calculation of the instantaneous radial force
I_fl = Q*1000/7500;// Rms value of full load current (in Ampere)
i = m*2^(1/2)*(1/Z_pu)*I_fl;// Instantaneous peak value of short circuit current (in Ampere)
Fr = u0/2*(i*T)^(2)*Lmt/Lc;// Instantaneous radial force on the h.v. coil (in N)
disp(Fr,'(a) Instantaneous radial force on the h.v. winding (N)=');//in book answer is 2380000 (N). The answers vary due to round off error
// Calculation of the instantaneous axial force
Fa = u0/2*k*(i*T)^(2)*Lmt/(2*(a+bp+bs));// Total instantaneous radial force on the h.v. coil (in N)
disp(Fa,'(b) Instantaneous axial force on the h.v. winding (N)=');
//in book answer is 3200000 (N). The provided in the textbook is wrong
disp('This shows that there is a very large axial force, even though one of the winding is only 5% shorter than the other at one end')
```

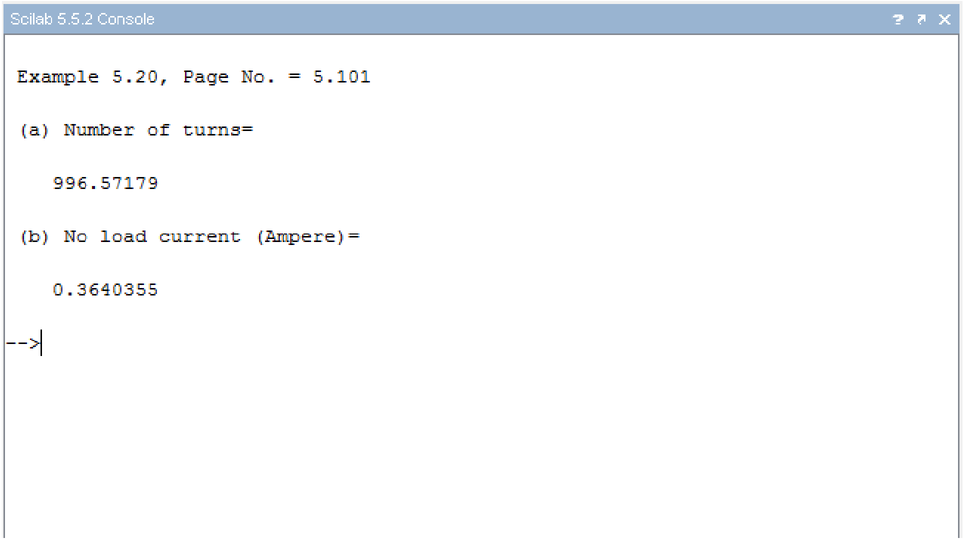
Scilab code Exa 5.18 Calculating the maximum flux and no load current of the trans



```
 Example 5.18, Page No. = 5.99

 Maximum flux in the core (Wb)=

    0.0022523

 No load current (Ampere)=

    1.783144

-->
```

Figure 5.9: Calculating the maximum flux and no load current of the transformer

```
// Calculating the maximum flux and no load current of the transformer
clc;
disp('Example 5.18, Page No. = 5.99')
// Given Data
Ep = 400;// Primary winding voltage (in volts)
f = 50;// Frequency (in Hz)
A = 2.5*10^(-3);// Area of cross section (in meter square)
Sf = 0.9;// Stacking factor
Tp = 800;// Primary winding turns
li = 2.5;// Length of the flux path (in meter)
u0 = 4*%pi*10^(-7);// Permeability of free space
ur = 1000;// Relative ermeability
D = 7.8*10^(3);// Density of iron (in kg per meter cube)
FD_w = 2.6;// Working flux density (in W per kg)
// Calculation of the maximum flux
Ai = Sf*A;// Net iron area (in meter square)
Bm = Ep/(4.44*f*Ai*Tp);// Maximum flux density of
```



```
Example 5.20, Page No. = 5.101

 (a) Number of turns=

    996.57179

 (b) No load current (Ampere)=

    0.3640355

-->
```

Figure 5.10: Calculating the number of turns and no load current

```
    core (in Wb per meter square)
Fm = Bm*Ai;// Maximum flux in the core (in Wb)
disp(Fm,'Maximum flux in the core (Wb)=');
// Calculation of the no load current
AT0 = li/(ur*u0)*Bm;// Magnetic mmf (in A)
Im = AT0/(2^(1/2)*Tp);// Magnetising current (in A)
V = Ai*li;// Volume of the core (in meter cube)
W = V*D;// Weight of core (in kg)
Pi = W*FD_w;// Iron loss (in W)
Il = Pi/Ep;// Loss component of no load current (in A)
I0 =(Im*Im+Il*Il)^(1/2);// No load current (in A)
disp(I0,'No load current (Ampere)=');
//in book answers are 0.00225 (Wb) and 1.77 (Ampere) respectively. The answers vary due to round off error
```

Scilab code Exa 5.20 Calculating the number of turns and no load current

```
// Calculating the number of turns and no load current
clc;
disp('Example 5.20, Page No. = 5.101')
// Given Data
E = 6600;// Primary winding voltage (in volts)
f = 60;// Frequency (in Hz)
Ai = 22.6*10^(-3);// Area of cross section (in meter square)
Bm = 1.1;// Maximum flux density of core (in Wb per meter square)
Af = 1.52;// Amplitude factor
Tp = 800;// Primary winding turns
l = 2.23;// Mean length (in meter)
mmf =232;// mmf per meter (in A per meter)
n = 4;// Number of lap joints
Gs = 7.5*10^(3);// Specific gravity of plates
Ls = 1.76;// Specific loss (in W per kg)
// Calculation of the number of turns
Tp = E/(4.44*f*Ai*Bm);// Number of turns
disp(Tp,'(a) Number of turns=');
// Calculation of the no load current
mmf_iron = mmf*l;// Mmf required for iron parts
mmf_joints = 4*(1/4)*mmf;// Mmf required for joints. Since lap joints takes 1/4 times reactive mmf as required per meter of core
AT0 = mmf_iron+mmf_joints;// Total magnetising mmf (in A)
Kpk = Af*2^(1/2);// Peak factor
Im = AT0/(Kpk*Tp);// Magnetising current (in A)
W = Ai*l*Gs;// Weight of core (in kg)
Pi = Ls*W;// Iron loss (in W)
```

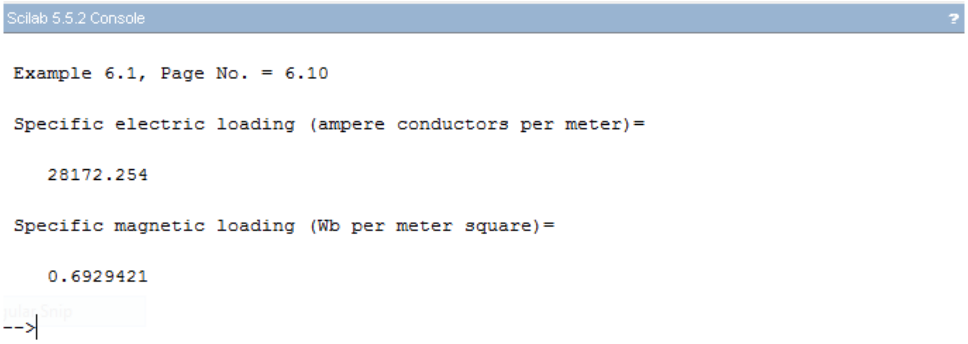
```
Il = Pi/E;// Loss component of no load current (in A)
I0 =(Im*Im+Il*Il)^(1/2);// No load current (in A)
disp(I0,'(b) No load current (Ampere)=');
//in book answers are 1100 and 0.333 (A) respectively. The provided in the textbook is wrong
```

Chapter 6

General Concepts and Constraints in Design of Rotating Machines

Scilab code Exa 6.1 `Calculating the specific electric and specific magnetic loadin`

```
// Calculating the specific electric and specific magnetic loading
clc;
disp('Example 6.1, Page No. = 6.10')
// Given Data
P = 350;// Power rating (in kW)
E = 500;// Voltage (in V)
rpm = 450;
p = 6;// Number of poles
a = 6;// Since a=p for lap winding
Z = 660;// Number of conductors
L = 0.32;// Core length (in meter)
D = 0.87;// Armature diameter (in meter)
// Calculation of the specific electric loading
Ia = P*1000/E;// Armature current (in A)
```

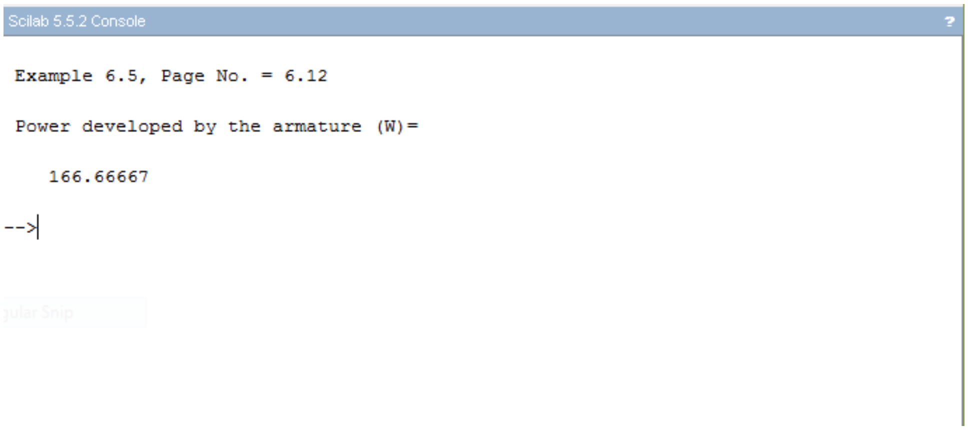


```
Example 6.1, Page No. = 6.10

Specific electric loading (ampere conductors per meter)=

   28172.254

Specific magnetic loading (Wb per meter square)=

   0.6929421

-->
```

Figure 6.1: Calculating the specific electric and specific magnetic loading

```
Iz = Ia/a;// Current in each conductor (in A)
ac = Iz*Z/(%pi*D);// Specific electric loading
disp(ac,'Specific electric loading (ampere conductors per meter)=');
// Calculation of the specific magnetic loading
F = E*a/(Z*rpm/60*p);// Flux per pole (in Wb)
Bac = p*F/(%pi*D*L);// specific magnetic loading
disp(Bac,'Specific magnetic loading (Wb per meter square)=');
//in book answers are 28200 (ampere conductors per meter) and 0.693 (Wb per meter square) respectively. The answers vary due to round off error
```

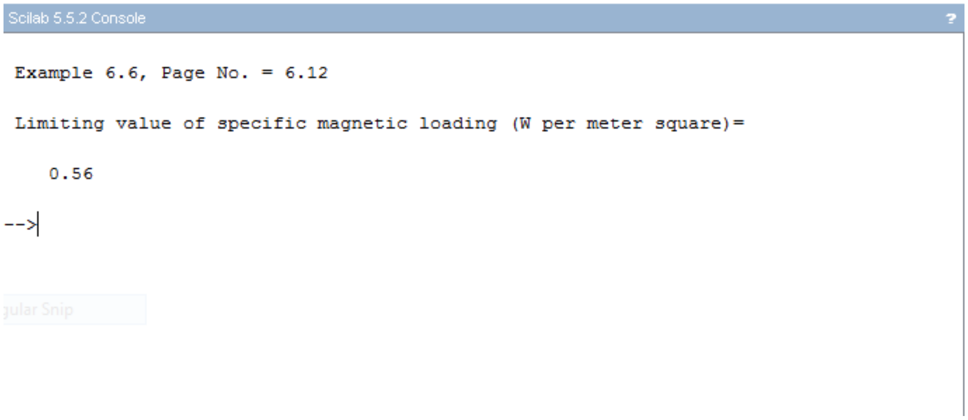
Scilab code Exa 6.5 `Calculating the power developed by the armature of motor`



```
 Example 6.5, Page No. = 6.12

 Power developed by the armature (W)=

    166.66667

-->
```

Figure 6.2: Calculating the power developed by the armature of motor

```
// Calculating the power developed by the armature of motor
clc;
disp('Example 6.5, Page No. = 6.12')
// Given Data
P = 125;// Power rating (in W)
E = 230;// Voltage (in V)
rpm = 5000;
// Calculation of the power developed by the armature
Losses_total = P;// Total losses (in W)
Losses_constant = P/3;// Constant losses (in W). Since the sum of iron, friction and windage losses is approximately 1/3 of total losses
Pa = Losses_total+Losses_constant;// Power developed by the armature (in W)
disp(Pa,'Power developed by the armature (W)=');
//in book answer is 167 (W). The answers vary due to round off error
```

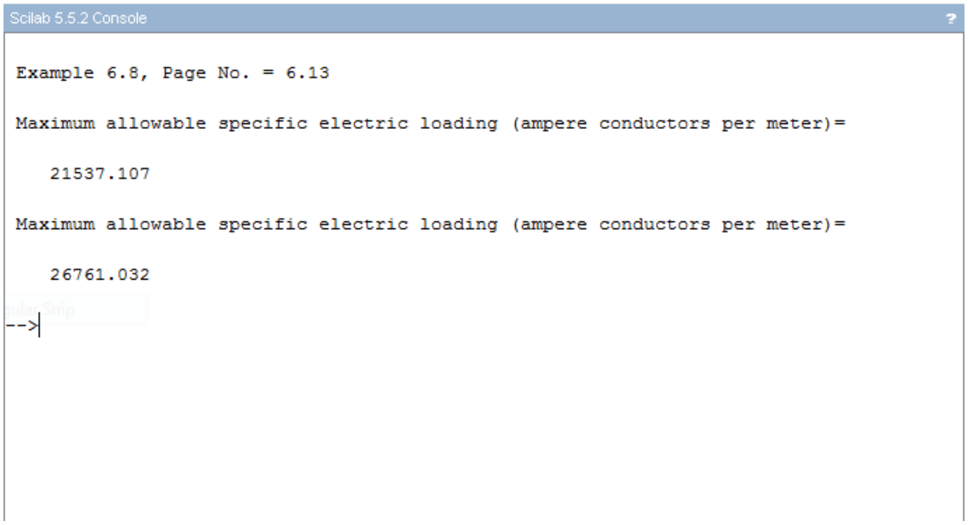


```
 Example 6.6, Page No. = 6.12

 Limiting value of specific magnetic loading (W per meter square)=

    0.56

-->
```

Figure 6.3: Calculating the limiting value of specific magnetic loading

Scilab code Exa 6.6 `Calculating the limiting value of specific magnetic loading`

```
// Calculating the limiting value of specific magnetic loading
clc;
disp('Example 6.6, Page No. = 6.12')
// Given Data
Bt = 2.0;// Maximum flux density in the armature (in Wb per meter square)
R = 0.7;// Ratio of pole arc to pole pitch
Wt_ys = 0.4;// Ratio of minimum width of tooth to slot pitch
// Calculation of the limiting value of specific magnetic loading
Bav = R*Wt_ys*Bt;// Limiting value of specific magnetic loading (in W per meter square)
disp(Bav,'Limiting value of specific magnetic loading (W per meter square)=');
```



```
Example 6.8, Page No. = 6.13

Maximum allowable specific electric loading (ampere conductors per meter)=

   21537.107

Maximum allowable specific electric loading (ampere conductors per meter)=

   26761.032

-->
```

Figure 6.4: Calculating the maximum permissible specific electric loading

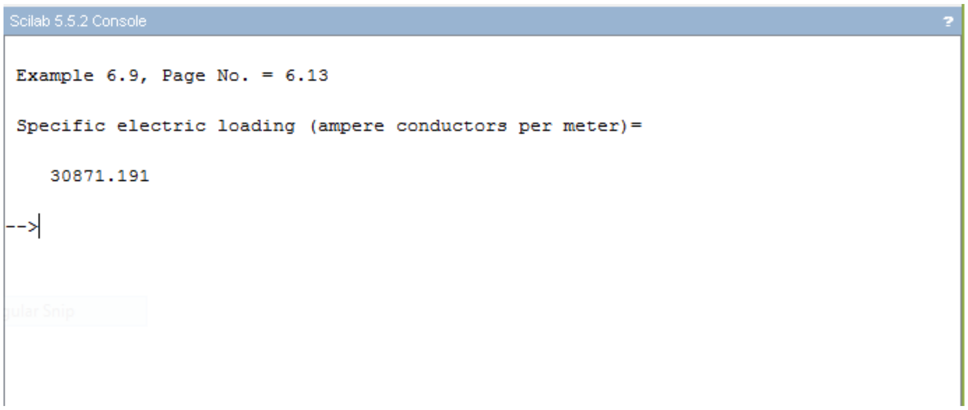
```
//in book answer is 0.56 (W per meter square).  The answers vary due to round off error
```

Scilab code Exa 6.8 `Calculating the maximum permissible specific electric loading`

```
// Calculating the maximum permissible specific electric loading
clc;
disp('Example 6.8, Page No. = 6.13')
// Given Data
p_20 = 1.734*10^(-8);// Resistivity of copper at 20 degree celsius (in ohm*meter)
alpha = 0.00393;// Resistance temperature co-efficient of copper at 20 degree celsius (in per degree celsius)
s = 3.5;// Current density (in A per mm square)
```

```
c = 0.03;// Cooling co-efficient
Tm_ambient = 40;// Maximum ambient temperature (in degree celsius)
Tm_rise_A = 50;// Maximum temperature rise for Class A insulation (in degree celsius)
Tm_rise_E = 65;// Maximum temperature rise for Class E insulation (in degree celsius)
// Calculation of the maximum permissible specific electric loading
//for Class A insulation
T_A = Tm_ambient+Tm_rise_A;// Operating temperature of copper conductors (in degree celsius)
p = p_20*(1+alpha*(T_A-20));// Resistivity at operating temperature (in ohm*meter)
ac = Tm_rise_A/(p*s*10^(6)*c);// Maximum permissible specific electric loading
disp(ac,'Maximum allowable specific electric loading (ampere conductors per meter)=');
T_E = Tm_ambient+Tm_rise_E;// Operating temperature of copper conductors (in degree celsius)
//for Class E insulation
p = p_20*(1+alpha*(T_E-20));// Resistivity at operating temperature (in ohm*meter)
ac = Tm_rise_E/(p*s*10^(6)*c);// Maximum permissible specific electric loading
disp(ac,'Maximum allowable specific electric loading (ampere conductors per meter)=');
//in book answers are 21600 (ampere conductors per meter) and 26700 (ampere conductors per meter) respectively. The answers vary due to round off error
```

Scilab code Exa 6.9 `Calculating the specific electric loading`



```
Example 6.9, Page No. = 6.13

Specific electric loading (ampere conductors per meter)=

   30871.191

-->
```

Figure 6.5: Calculating the specific electric loading

```
// Calculating the specific electric loading
clc;
disp('Example 6.9, Page No. = 6.13')
// Given Data
Pc = 1000;// Core loss (in W)
R = 0.025;// Armature resistance (in ohm)
l = 230;// Specific loss dissipation (in W per degree celsius per meter square)
a = 2;// Since a=z for lap winding
Z = 270;// Number of conductors
L = 0.25;// Core length (in meter)
D = 0.25;// Armature diameter (in meter)
T = 40;// Temperature rise (degree celsius)
// Calculation of the specific electric loading
c = 1/l;// Cooling co-efficient
S = %pi*D*L;// Dissipation surface (in meter square)
Q = S*T/c;// Maximum allowable pwer dissipation from armature surface
Ia = ((Q-Pc)/R)^(1/2);// Armature current (in Ampere)
Iz = Ia/a;// Current in each conductor (in A)
ac = Iz*Z/(%pi*D);// Specific electric loading
disp(ac,'Specific electric loading (ampere conductors per meter)=');
```

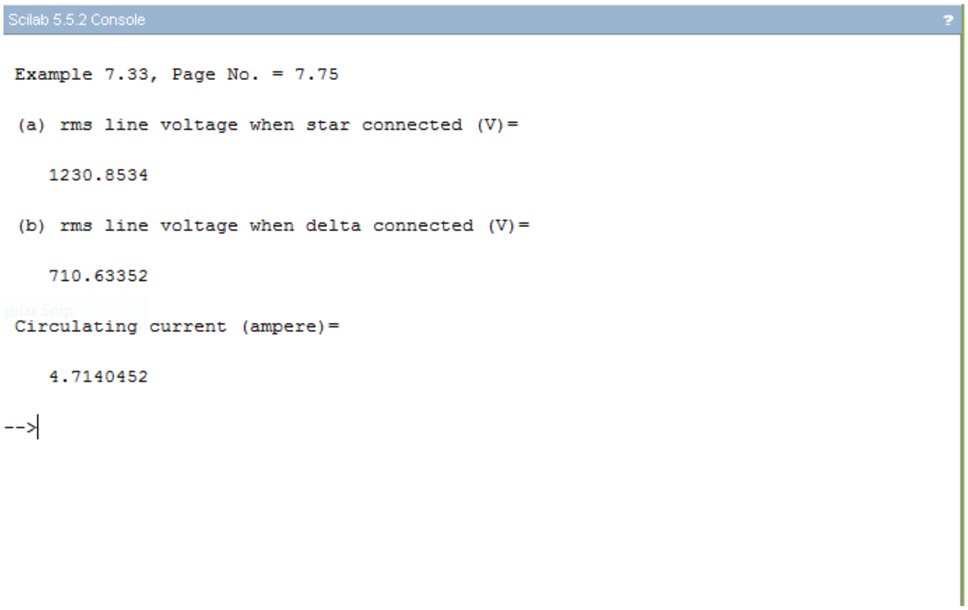
```
//in book answer is 31000 (ampere conductors per meter). The answers vary due to round off error
```

Chapter 7

Armature Windings

Scilab code Exa 7.33 `Calculating the rms line voltage and circulating current`

```
// Calculating the rms line voltage and circulating
   current
clc;
disp('Example 7.33, Page No. = 7.75')
// Given Data
E = 1000;// Amplitude of fundamental emf (in V)
R = 10;// Reactance per phase (in ohm)
// Calculation of the rms line voltage and
   circulating current
Eph1 = E/2^(1/2);// Rms value of fundamental emf per
    phase
Eph3 = 0.2*Eph1;// Rms value of 3rd harmonic
   component of phase voltage (in V)  Given 20%
Eph5 = 0.1*Eph1;// Rms value of 5th harmonic
   component of phase voltage (in V)  Given 10%
Eph = (Eph1*Eph1+Eph5*Eph5)^(1/2);// Phase voltage
   considering no 3rd harmonic
disp(3^(1/2)*Eph,'(a) rms line voltage when star
   connected (V)=');
```



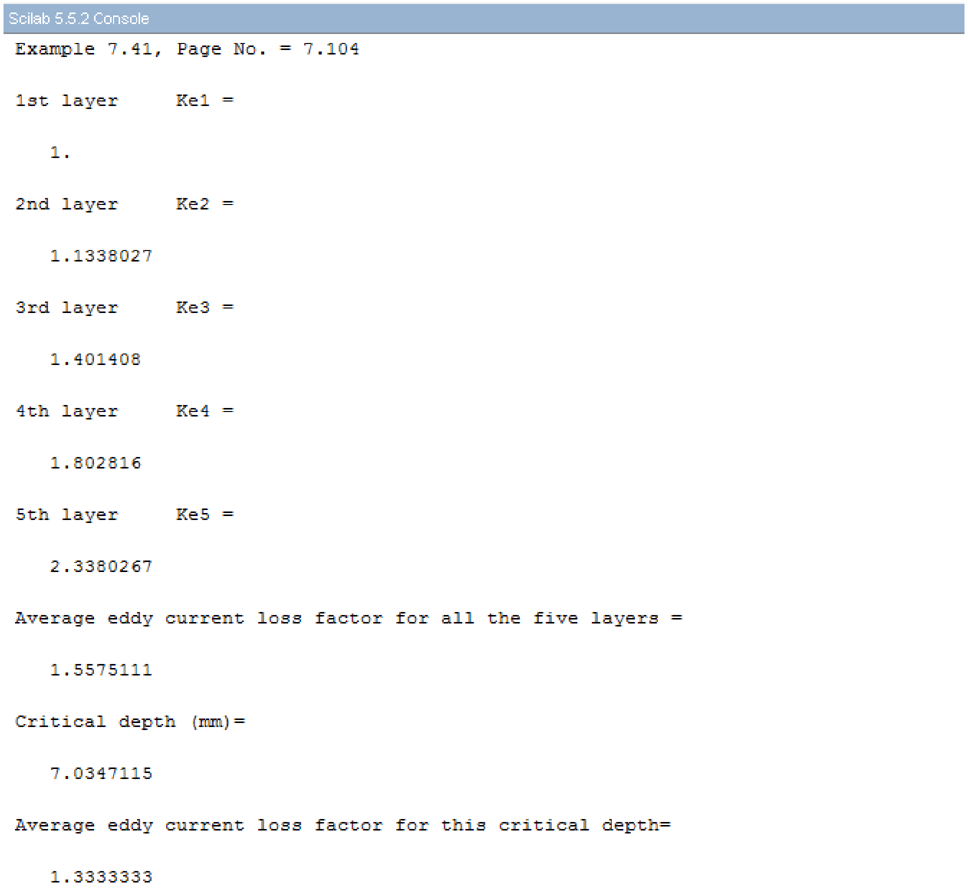
```
Example 7.33, Page No. = 7.75

 (a) rms line voltage when star connected (V)=

    1230.8534

 (b) rms line voltage when delta connected (V)=

    710.63352

Circulating current (ampere)=

    4.7140452

-->
```

Figure 7.1: Calculating the rms line voltage and circulating current

```
disp(Eph,'(b) rms line voltage when delta connected (V)=');
I_circulating = 3*Eph3/(3*3*10);// Circulating current taking reactance corresponding to 3rd harmonic
disp(I_circulating,'Circulating current (ampere)=');
//in book answers are 1230.8 V, 710.6 v and 4.71 ampere respectively. The answers vary due to round off error
```

Scilab code Exa 7.41 `Calculating the eddy current loss ratio and average loss rati`

```
// Calculating the eddy current loss ratio and average loss ratio and critical depth for minimum
```



```
Example 7.41, Page No. = 7.104

1st layer     Ke1 =

   1.

2nd layer     Ke2 =

   1.1338027

3rd layer     Ke3 =

   1.401408

4th layer     Ke4 =

   1.802816

5th layer     Ke5 =

   2.3380267

Average eddy current loss factor for all the five layers =

   1.5575111

Critical depth (mm)=

   7.0347115

Average eddy current loss factor for this critical depth=

   1.3333333
```

Figure 7.2: Calculating the eddy current loss ratio and average loss ratio and critical depth for minimum loss

```
loss
clc;
disp('Example 7.41, Page No. = 7.104')
// Given Data
Ws = 20;// Slot width (in mm)
b = 14;// Width of copper conductors (in mm)
h = 8;// Depth of copper conductors (in mm)
f = 50// Frequency (in Hz)
N = 5;// Number of layers
// Calculation of eddy loss factor for different layers
a = 100*(b/Ws)^(1/2);
ah = a*h*10^(-3);
ah4 = ah^(4);
Ke1 = 1;// 1st layer
Ke2 = 1+ah4*2*(2-1)/3;// 2nd layer
Ke3 = 1+ah4*3*(3-1)/3;// 3rd layer
Ke4 = 1+ah4*4*(4-1)/3;// 4th layer
Ke5 = 1+ah4*5*(5-1)/3;// 5th layer
disp(Ke1,'1st layer     Ke1 =');
disp(Ke2,'2nd layer     Ke2 =');
disp(Ke3,'3rd layer     Ke3 =');
disp(Ke4,'4th layer     Ke4 =');
disp(Ke5,'5th layer     Ke5 =');
// Calculation of average eddy current loss factor for all the five layers
Ke_av = 1+ah4*N*N/9;
disp(Ke_av,'Average eddy current loss factor for all the five layers =');
// Calculation of critical depth for minimum loss
hc = 1/(a*(3*N*N/9)^(1/4))*1000;// Critical depth (in mm)
disp(hc,'Critical depth (mm)=');
// Calculation of average eddy current loss factor for all the five layers for this critical depth
ahc = a*hc*10^(-3);
ahc4 = ahc^(4);
Ke_av = 1+ahc4*N*N/9;
```

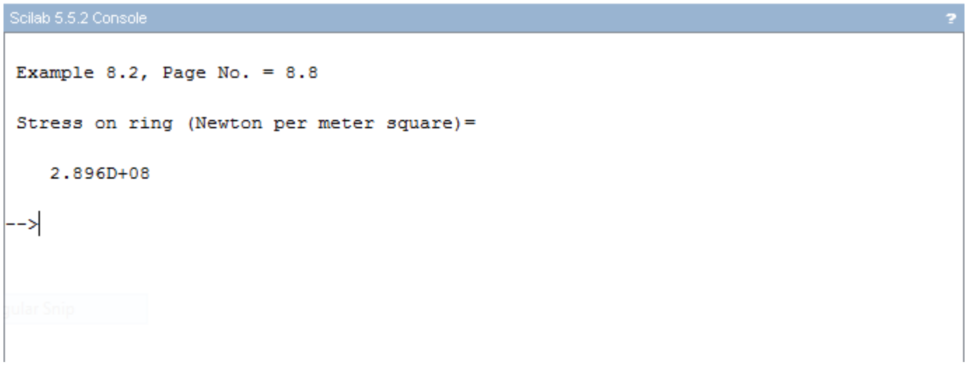
```
disp(Ke_av,'Average eddy current loss factor for
    this critical depth=');
//in book answers are 1, 1.13, 1.4, 1.8, 2.33, 1.55,
     7 mm and 1.33 respectively.  The answers vary
    due to round off error
```

Chapter 8

Aspects of Design of Mechanical Parts

Scilab code Exa 8.2 `Calculating the stress on the ring`

```
// Calculating the stress on the ring
clc;
disp('Example 8.2, Page No. = 8.8')
// Given Data
rpm = 3000;// Speed in r.p.m.
Rm = 0.35;// Radius of overhang (in meter)
Rmr = 0.49;// Radius of ring (in meter)
G = 300;// Weight of copper winding (in kg)
gr = 7800;// Density of ring material (in kg per
    meter cube)
tb = 350*45*10^(-6);// Area of retaining ring
// Calculation of the stress on the ring
n = rpm/60;// Speed in r.p.s
Dm = 2*Rm;// Diameter of overhang (in meter)
Dmr = 2*Rmr;// Diameter of ring (in meter)
ft = (%pi*n*n*G*Dm/tb)+(%pi*%pi*n*n*gr*Dmr*Dmr);//
    Stress on ring (in Newton per meter square)
```



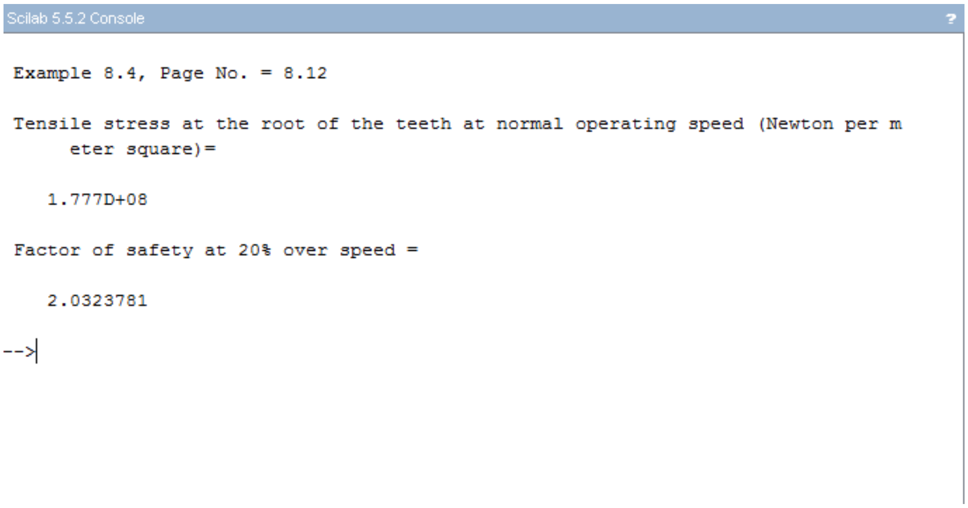
```
Example 8.2, Page No. = 8.8

Stress on ring (Newton per meter square)=

   2.896D+08

-->
```

Figure 8.1: Calculating the stress on the ring

```
disp(ft,'Stress on ring (Newton per meter square)=');
//in book answer is 289.5 (MN per meter square). The answers vary due to round off error
```

Scilab code Exa 8.4 Calculating the tensile stress and factor of safety

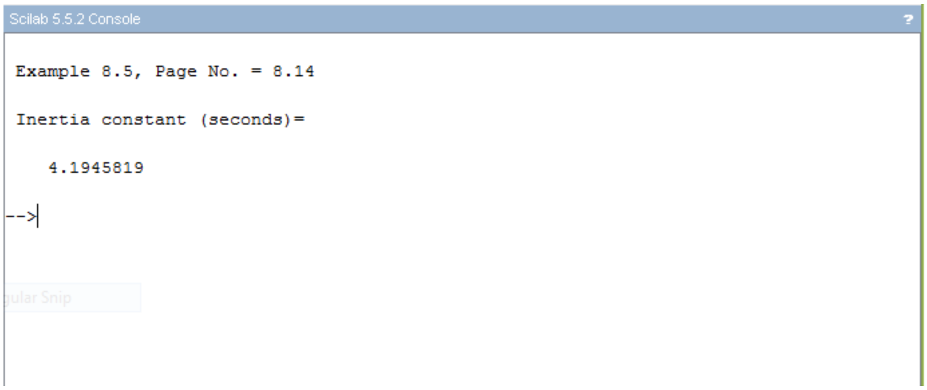
```
// Calculating the tensile stress and factor of safety
clc;
disp('Example 8.4, Page No. = 8.12')
// Given Data
rpm = 3000;// Speed in r.p.m.
Dr1 = 1.15;// Outer diameter  of rotor (in meter)
Nrs = 39;// Number of rotor slot
Drs = 140;// Depth of rotor slot (in mm)
Wrs = 45;// Width of rotor slot (in mm)
gs = 7800;// Density of steel (in kg per meter cube)
yield_stress = 520*10^(6);// Yield stress of rotor steel (in Newton per meter square)
```



```
Example 8.4, Page No. = 8.12

Tensile stress at the root of the teeth at normal operating speed (Newton per m
     eter square)=

   1.777D+08

Factor of safety at 20% over speed =

   2.0323781

-->
```

Figure 8.2: Calculating the tensile stress and factor of safety

```
// Calculation of the tensile stress and factor of safety
n = rpm/60;// Speed in r.p.s
Dr2 = Dr1-2*Drs*10^(-3);// Diameter of rotor at the bottom of slots (in meter)
t = (%pi*Dr2*10^(3)/Nrs)-Wrs;// Width of tooth at the bottom of slot (in mm)
alpha = 360/Nrs;// Angle subtended by each slot (in degree)
f = %pi^(3)/(3*t*10^(-3))*gs*n*n*(alpha/360)*(Dr1^(3)-Dr2^(3));// Tensile stress (in Newton per meter square)
disp(f,'Tensile stress at the root of the teeth at normal operating speed (Newton per meter square)=');
f_20 = 1.2^(2)*f;// Tensile stress at 20% over speed. Since centrifugal force is propartional of square of speed
disp(yield_stress/f_20,'Factor of safety at 20% over speed =');
//in book answers are 178 (Mega Newton per meter
```



```
Example 8.5, Page No. = 8.14

Inertia constant (seconds)=

   4.1945819

-->
```

Figure 8.3: Calculating the inertia constant of the generator

```
    square) and 2.03 respectively.  The answers vary
    due to round off error
```

Scilab code Exa 8.5 `Calculating the inertia constant of the generator`

```
// Calculating the inertia constant of the generator
clc;
disp('Example 8.5, Page No. = 8.14')
// Given Data
P = 500;// Power rating (in MW)
f = 50;// Frequency (in Hz)
J = 50*10^(3);// Moment of inertia (in kg-meter
    square)
pf = 0.85;// Power factor
// Calculation of the inertia constant of the
    generator
w = 2*%pi*f;// Angular speed (in rad/s)
Q = 500*10^(3)/pf;// kVA rating
H = (1/2)*J*w*w/(Q*10^(3));// Inertia constant (in
    seconds)
```

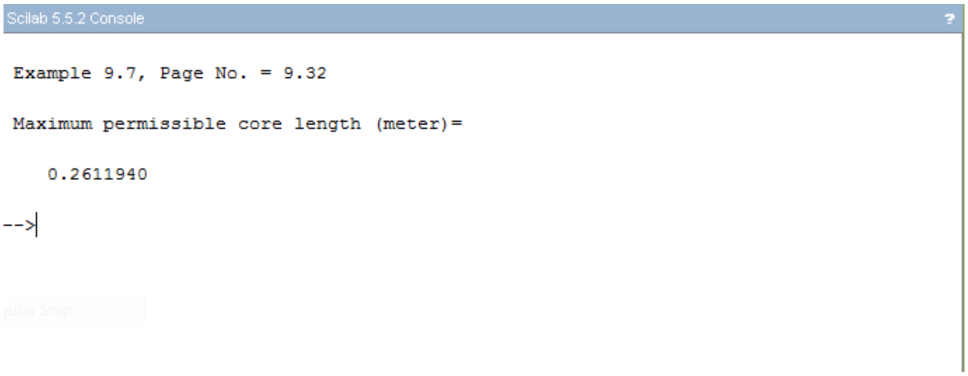
```
disp(H,'Inertia constant (seconds)=');
//in book answer is 4.2 seconds. The answers vary due to round off error
```

Chapter 9

DC Machines

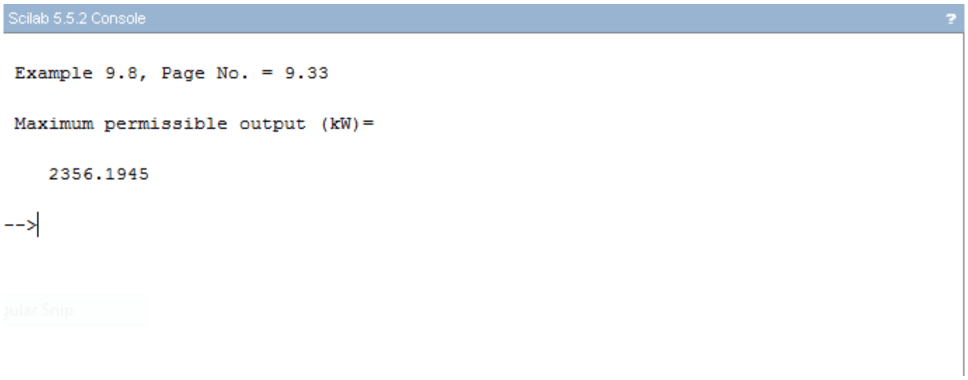
Scilab code Exa 9.7 `Calculating the maximum permissible core length for the machin`

```
// Calculating the maximum permissible core length for the machine
clc;
disp('Example 9.7, Page No. = 9.32')
// Given Data
Kf = 0.67;// Form factor
Bg = 1;// Maximum gap density (in Wb per meter square)
Va = 40;// Armature peripheral speed (in meter)
E = 7;// Maximum permissible value of emf induced in a conductor at no load (in Volts)
// Calculation of the maximum permissible core length for the machine
Bav = Kf*Bg;// Average gap density (in Wb per meter square)
L = E/(Bav*Va);// Maximum permissible core length (in meter)
disp(L,'Maximum permissible core length (meter)=');
//in book answer is 0.26 (meter). The answers vary
```



```
Example 9.7, Page No. = 9.32

Maximum permissible core length (meter)=

   0.2611940

-->
```

Figure 9.1: Calculating the maximum permissible core length for the machine



```
Example 9.8, Page No. = 9.33

Maximum permissible output (kW)=

   2356.1945

-->
```

Figure 9.2: Calculating the maximum permissible output from a machine

```
   due to round off error
```

Scilab code Exa 9.8 `Calculating the maximum permissible output from a machine`

```
// Calculating the maximum permissible output from a
    machine
clc;
disp('Example 9.8, Page No. = 9.33')
```

```
Example 9.9, Page No. = 9.38

 (a) Wave connected

 Extra turns required on the shunt field =

    100.

 (b) Lap connected

 Extra turns required on the shunt field =

    50.

-->
```

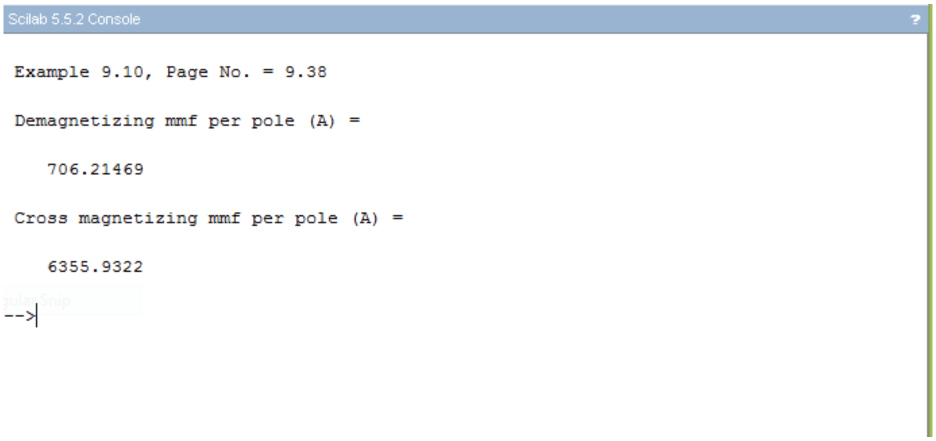
Figure 9.3: Calculating the number of extra shunt field turns to neutralize the demagnetization

```
// Given Data
D = 2;// Diameter (in meter)
ac = 50000;// Specific electric loading
ez = 7.5;// emf generated in a conductor at no load (in Volts)
// Calculation of the maximum permissible output from a machine
P = %pi*D*ac*ez*10^(-3);// Maximum permissible output (in kW)
disp(P,'Maximum permissible output (kW)=');
//in book answer is 2350 (kW).  The answers vary due to round off error
```

Scilab code Exa 9.9 Calculating the number of extra shunt field turns to neutraliz

```
// Calculating the number of extra shunt field turns to neutralize the demagnetization
```

```
clc;
disp('Example 9.9, Page No. = 9.38')
// Given Data
p = 4;// Number of poles
Is = 140;// Current supplied by generator (in ampere)
Z = 480;// Number of armature conductors
mech_degree = 10;// Since brushes are given an actual lead of 10 degree
// Calculation of the extra shunt field turns to neutralize the demagnetization
Ia = Is+10;// Armature current (A). Since field winding is shunt connected and takes a current of 10 ampere
alpha = p/2*mech_degree;// Angle of lead (in electrical degree)
disp('(a) Wave connected')
a= 2 // With wave winding number of parallel paths
ATa = Ia*Z/(a*2*p);// Armature mmf per pole (A)
ATad = ATa*2*alpha/180;;// Demagnetizing mmf per pole (A)
ATaq = ATa-ATad;// Cross magnetizing mmf per pole (A)
Extra_turns = ATad/10;// Extra turns required on the shunt field. Since field winding is shunt connected and takes a current of 10 ampere
disp(Extra_turns,'Extra turns required on the shunt field =');
disp('(b) Lap connected')
a= p // With lap winding number of parallel paths
ATa = Ia*Z/(a*2*p);// Armature mmf per pole (A)
ATad = ATa*2*alpha/180;;// Demagnetizing mmf per pole (A)
ATaq = ATa-ATad;// Cross magnetizing mmf per pole (A)
Extra_turns = ATad/10;// Extra turns required on the shunt field. Since field winding is shunt connected and takes a current of 10 ampere
```



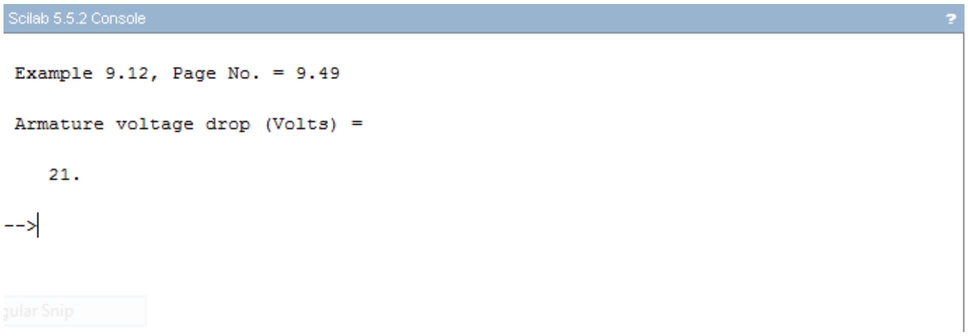
```
Example 9.10, Page No. = 9.38

Demagnetizing mmf per pole (A) =

   706.21469

Cross magnetizing mmf per pole (A) =

   6355.9322

-->
```

Figure 9.4: Calculating the demagnetizing and cross magnetizing mmf per pole

```
disp(Extra_turns,'Extra turns required on the shunt field =');
//in book answers are 100 and 50 respectively. The answers vary due to round off error
```

Scilab code Exa 9.10 `Calculating the demagnetizing and cross magnetizing mmf per p`

```
// Calculating the demagnetizing and cross magnetizing mmf per pole
clc;
disp('Example 9.10, Page No. = 9.38')
// Given Data
P = 500;// Power rating (in kW)
rpm = 375;// Speed in r.p.m.
p = 8;// Number of poles
flux = 0.0885;// Flux per pole (in Wb per meter)
// Calculation of the demagnetizing and cross magnetizing mmf per pole
```



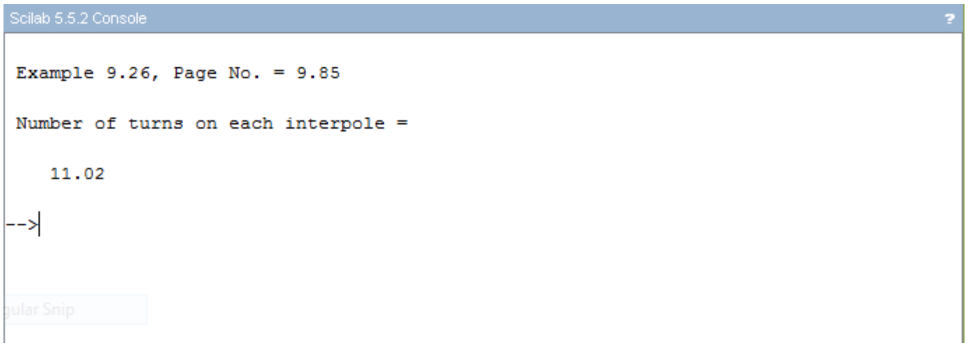
```
 Example 9.12, Page No. = 9.49

 Armature voltage drop (Volts) =

    21.

-->
```

Figure 9.5: Calculating the armature voltage drop

```
n = rpm/60;// Speed in r.p.s.
alpha = 5/100*180;// Brush shift (in electrical degree). Since the brushes are given a lead by of 5% of pole pitch
ATa = P/(2*flux*n*p*p*10^(-3));// Armature mmf per pole (A)
ATad = ATa*2*alpha/180;;// Demagnetizing mmf per pole (A)
ATaq = ATa-ATad;// Cross magnetizing mmf per pole (A)
disp(ATad,'Demagnetizing mmf per pole (A) =');
disp(ATaq,'Cross magnetizing mmf per pole (A) =');
//in book answers are 706 (A) and 6354 (A) respectively. The answers vary due to round off error
```

Scilab code Exa 9.12 `Calculating the armature voltage drop`

```
// Calculating the armature voltage drop
clc;
disp('Example 9.12, Page No. = 9.49')
// Given Data
```



```
Example 9.26, Page No. = 9.85

Number of turns on each interpole =

   11.02

-->
```

Figure 9.6: Calculating the number of turns on each commutating pole

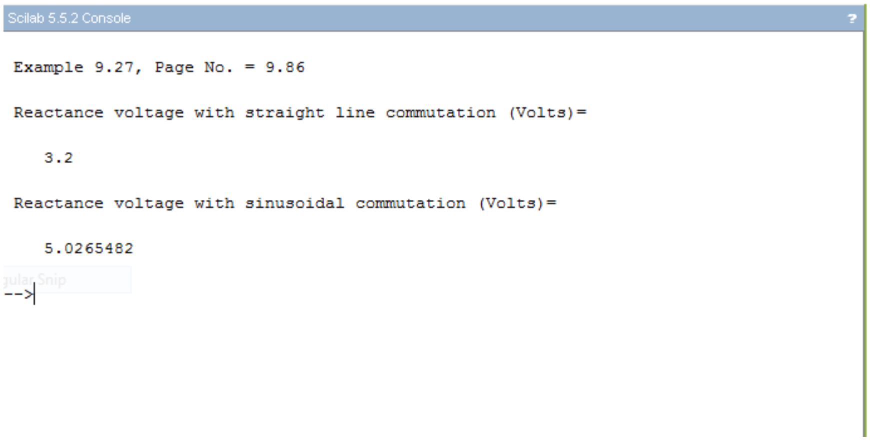
```
P = 300;// Power rating (in kW)
V = 500;// Voltage rating (in volts)
a = 6;// Number of parallel paths (Since lap winding)
p = 0.021;// resistivity (in ohm mm square)
Ns = 150;// Number of slots
Lmt = 2.5;// Length of mean turn (in meter)
az = 25;// Area of each conductror (in mm square)
// Calculation of the armature voltage drop
Z = Ns*8;// Number of armature conductors. Since 8 conductors per slot
ra = Z*p*Lmt/(2*a*a*az);// Resistance of armature (in ohm)
Ia = P*10^(3)/V;// Armature current
disp(Ia*ra,’Armature voltage drop (Volts) =’);
//in book answer is 21 (Volt). The answers vary due to round off error
```

Scilab code Exa 9.26 `Calculating the number of turns on each commutating pole`

```
// Calculating the number of turns on each commutating pole
clc;
disp('Example 9.26, Page No. = 9.85')
// Given Data
p = 6;// Number of poles
Bgi = 0.5;// Flux density (in Wb per meter square)
Ia = 500;// Armature full load current (in ampere)
Z = 540;// Number of conductors
Kgi = 1;// Inerpole interaction factor
lgi = 4;// Effective length of air gap
// Calculation of the number of turns on each commutating pole
a = p;// Number of parallel paths.  Since armature is lap wound
ATa = Ia/a*Z/(2*p);// Armature mmf per pole
mmf_airgap = 800000*Bgi*Kgi*lgi*10^(-3);// Mmf required for air gap (in A)
mmf_iron = 0.1*mmf_airgap;// Mmf required for iron parts (in A).  Since mmf required is one-tenth that for air gap
ATi = ATa+mmf_airgap+mmf_iron;// Total mmf per pole on each interpole (in A)
Ti = ATi/Ia;// Number of turns on each interpole
disp(Ti,'Number of turns on each interpole =');
//in book answer is 11.  The answers vary due to round off error
```

Scilab code Exa 9.27 `Calculating the reactance voltage for a machine with straight`

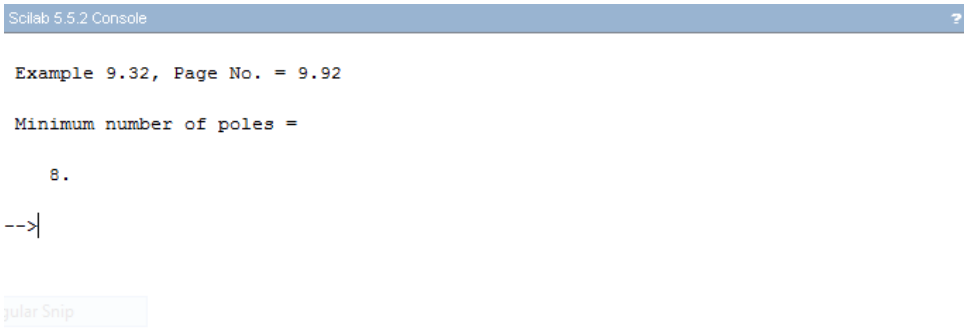
```
// Calculating the reactance voltage for a machine with straight line and sinusoidal commutation
clc;
```



```
Example 9.27, Page No. = 9.86

Reactance voltage with straight line commutation (Volts)=

   3.2

Reactance voltage with sinusoidal commutation (Volts)=

   5.0265482

-->
```

Figure 9.7: Calculating the reactance voltage for a machine with straight line and sinusoidal commutation

```
disp('Example 9.27, Page No. = 9.86')
// Given Data
Ns = 60;// Number of segments
rev = 10;// Number of revolution per second
W = 1.5;// Brush width in segments
L = 0.2;// Co-efficient of self-induction (in mH)
I = 20;// Current per coil
// Calculation of the reactance voltage for a machine with straight line and sinusoidal commutation
Tc = W/(Ns*rev);// Time of commutation
Erav = L*10^(-3)*2*I/Tc;// Average reactance voltage
disp(Erav,'Reactance voltage with straight line commutation (Volts)=');
disp(%pi/2*Erav,'Reactance voltage with sinusoidal commutation (Volts)=');
//in book answers are 3.2 Volts and 5 Volts respectively. The answers vary due to round off error
```

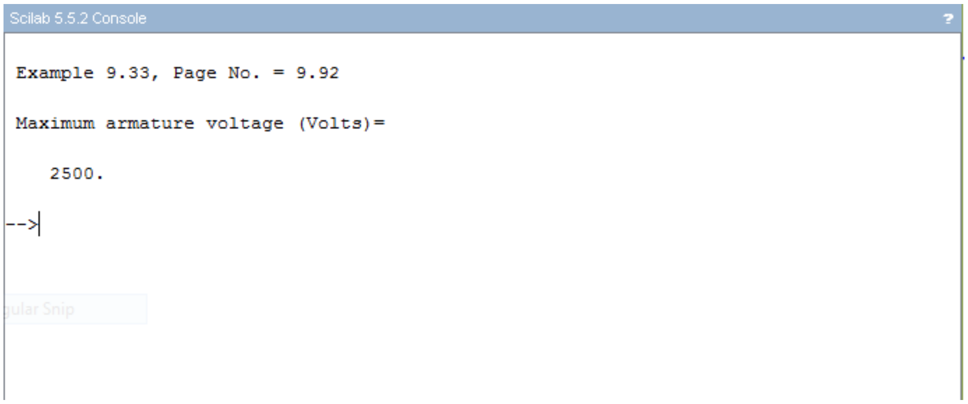


```
 Example 9.32, Page No. = 9.92

 Minimum number of poles =

    8.

-->
```

Figure 9.8: Calculating the minimum number of poles

Scilab code Exa 9.32 `Calculating the minimum number of poles`

```
// Calculating the minimum number of poles
clc;
disp('Example 9.32, Page No. = 9.92')
// Given Data
P = 1200;// Power rating (in kW)
Ec = 15;// Average voltage between commutator segments (in Volts)
ATa = 10000;// Armature mmf per pole
// Calculation of the minimum number of poles
a = P*10^(3)/(ATa*Ec);// Minimum number of parallel paths
p = a;// Minimum number of poles. Since these parallel paths can be obtained by using a simplex winding
disp(p,'Minimum number of poles =');
//in book answer is 8 poles. The answers vary due to round off error
```



```
Example 9.33, Page No. = 9.92

Maximum armature voltage (Volts)=

   2500.

-->
```

Figure 9.9: Calculating the maximum armature voltage

Scilab code Exa 9.33 `Calculating the maximum armature voltage`

```
// Calculating the maximum armature voltage
clc;
disp('Example 9.33, Page No. = 9.92')
// Given Data
Vc = 40;// Peripheral speed of commutator (in meter
    per second)
Ec = 20;// Average emf between adjacent segments (in
     Volts)
Bc = 4;// Minimum pitch of commutator segments (in
    mm)
f = 40;// Frequency (in Hz)
// Calculation of the maximum armature voltage
E = Vc*Ec/(2*f*Bc*10^(-3));// Maximum armature
    voltage (in Volts)
disp(E,'Maximum armature voltage (Volts)=');
//in book answer is 2500 Volts. The answers vary
    due to round off error
```

```
 Example 9.34, Page No. = 9.92

 Total commutator losses (Watts)=

    7232.4599

-->
```

Figure 9.10: Calculating the total commutator losses

Scilab code Exa 9.34 `Calculating the total commutator losses`

```
// Calculating the total commutator losses
clc;
disp('Example 9.34, Page No. = 9.92')
// Given Data
P = 800;// Power rating (in kW)
V = 400;// Voltage rating (in Volts)
rpm = 300;// r.p.m.
p = 10;// Number of poles
Dc = 1;// Commutator diameter (in meter). Since 100 cm = 1 meter
u = 0.23;// Co-efficient of friction
Pb = 14.7;// Brush pressure (in kN per meter square)
J = 0.075;// Current density in brushes (in A per mm square)
Vcb = 2.2;// Total brush contact drop (in Volts)
// Calculation of the total commutator losses
n = rpm/60;// r.p.s.
```

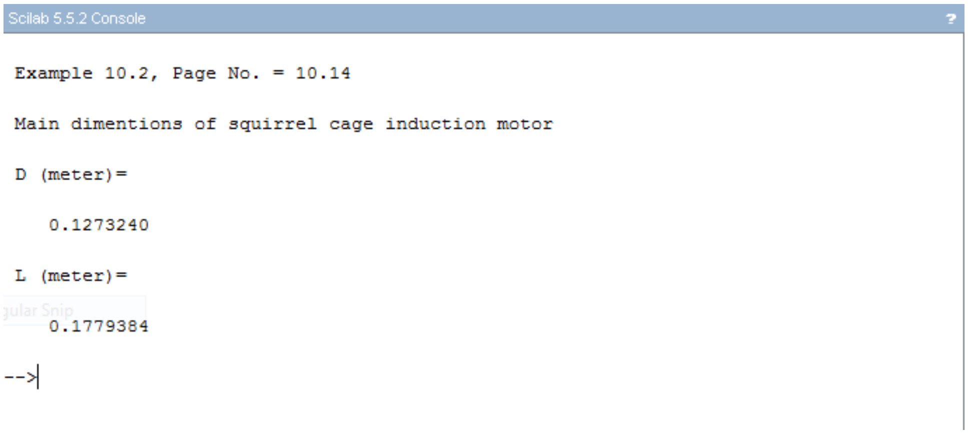
```
Ia = P*10^(3)/V;//  Armature current (in Ampere)
Ib = 2*Ia/p;// Current per brush arm (in Ampere)
Ab = Ib/J;// Brush area per brush arm (in mm square)
AB = p*Ab*10^(-6);// Total brush area on the commutator (in meter square)
Vc = %pi*Dc*n;// Peripheral speed (in meter per second)
Wcf = u*Pb*10^(3)*AB*Vc;// Brush friction loss (in Watts)
Wcb = Ia*Vcb;// Brush contact loss (in Watts)
disp(Wcf+Wcb,'Total commutator losses (Watts)=');
//in book answer is 7230 Watts.  The answers vary due to round off error
```

Chapter 10

Three Phase Induction Motors

Scilab code Exa 10.2 `Calculating the main dimentions of squirrel cage induction mo`

```
// Calculating the main dimentions of squirrel cage induction motor
clc;
disp('Example 10.2, Page No. = 10.14')
// Given Data
P = 15;// Power rating (in kW)
V = 400;// Voltage rating (in Volts)
rpm = 2810;// r.p.m.
f = 50;// Frequency (in Hz)
e = 0.88;// Efficiency
pf = 0.9;// Full load power factor
ac = 25000;// Specific electrical loading (in A per meter)
Bav = 0.5;// Specific magnetic loading (in Wb per meter square)
Kw = 0.955;
// the rotor peripheral speed is approximately 20 meter per second at synchronous speed
// Calculation of the main dimentions of squirrel
```

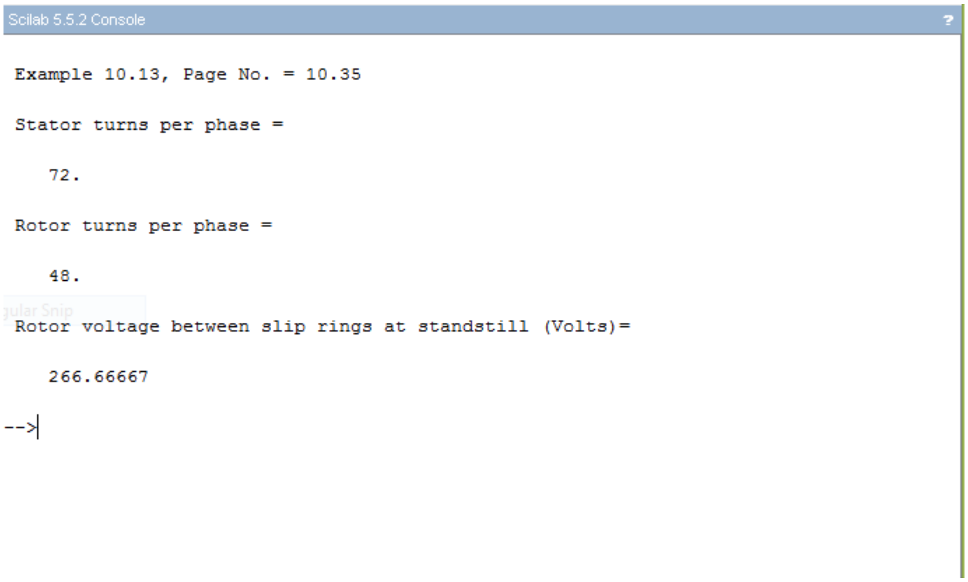


```
Example 10.2, Page No. = 10.14

Main dimentions of squirrel cage induction motor

D (meter)=

   0.1273240

L (meter)=

   0.1779384

-->
```

Figure 10.1: Calculating the main dimentions of squirrel cage induction motor

```
cage induction motor
Q = P/(e*pf);// kVA input
Co = 11*Kw*Bav*ac*10^(-3);// Output co-efficient
ns = 3000/60;// Synchronous speed corresponding to 50 Hz (in r.p.s.)
D2L = Q/(Co*ns);// Product of D^(2)*L
D = 20/(%pi*ns);// Since the rotor diameter in an induction motor is almost equal to stator bore
L = D2L/(D*D);
disp('Main dimentions of squirrel cage induction motor')
disp(D,'D (meter)=');
disp(L,'L (meter)=');
//in book answers are 0.1257 meter and 0.177 meter respectively. The answers vary due to round off error
```

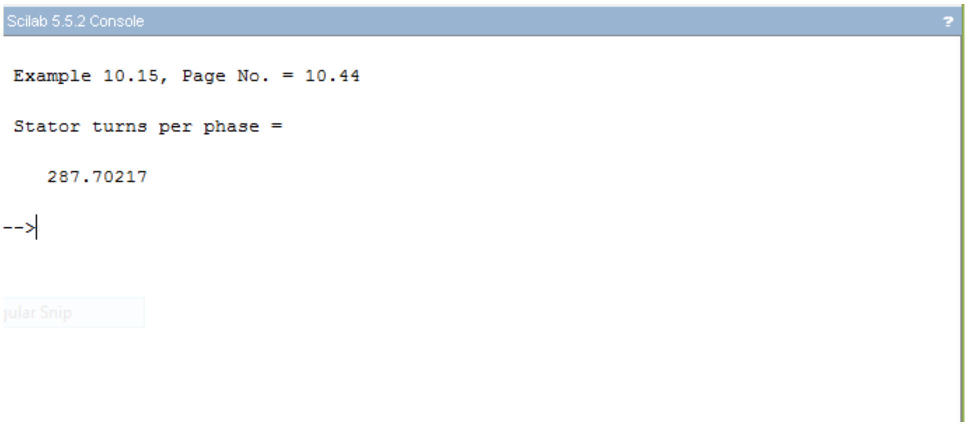
Scilab code Exa 10.13 `Calculating the number of stator and rotor turns and rotor v`



```
 Example 10.13, Page No. = 10.35

 Stator turns per phase =

    72.

 Rotor turns per phase =

    48.

 Rotor voltage between slip rings at standstill (Volts)=

    266.66667

-->
```

Figure 10.2: Calculating the number of stator and rotor turns and rotor voltage between slip rings at standstill

```
// Calculating the number of stator and rotor turns and rotor voltage between slip rings at standstill
clc;
disp('Example 10.13, Page No. = 10.35')
// Given Data
// 3 phase induction motor
Nss = 54;// Number of stator slots
Nrs = 72;// Number of rotor slots
V = 400;// Applied voltage across the stator terminals
// Calculation of the number of stator and rotor turns and rotor voltage between slip rings at standstill
Ts = Nss*8/6;// Stator turns per phase. Since 8 conductors per slot
Tr = Nrs*4/6;// Rotor turns per phase. Since 4 conductors per slot
```



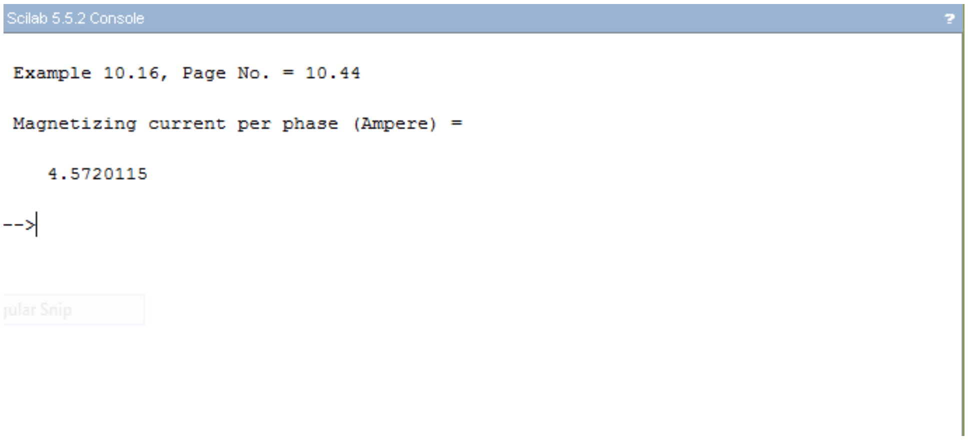
```
 Example 10.15, Page No. = 10.44

 Stator turns per phase =

    287.70217

-->
```

Figure 10.3: Calculating the number of stator turns per phase

```
Es = 400/3^(1/2);// Stator voltage per phase
Er = Es*Tr/Ts;// Rotor voltage per phase at standstill
disp(Ts,'Stator turns per phase =');
disp(Tr,'Rotor turns per phase =');
disp(3^(1/2)*Er,'Rotor voltage between slip rings at standstill (Volts)=');
//in book answers are 72, 48 and 266.7 Volts respectively. The answers vary due to round off error
```

Scilab code Exa 10.15 `Calculating the number of stator turns per phase`

```
// Calculating the number of stator turns per phase
clc;
disp('Example 10.15, Page No. = 10.44')
// Given Data
// 3 phase star connected induction motor
P = 75;// Power rating (in kw)
```



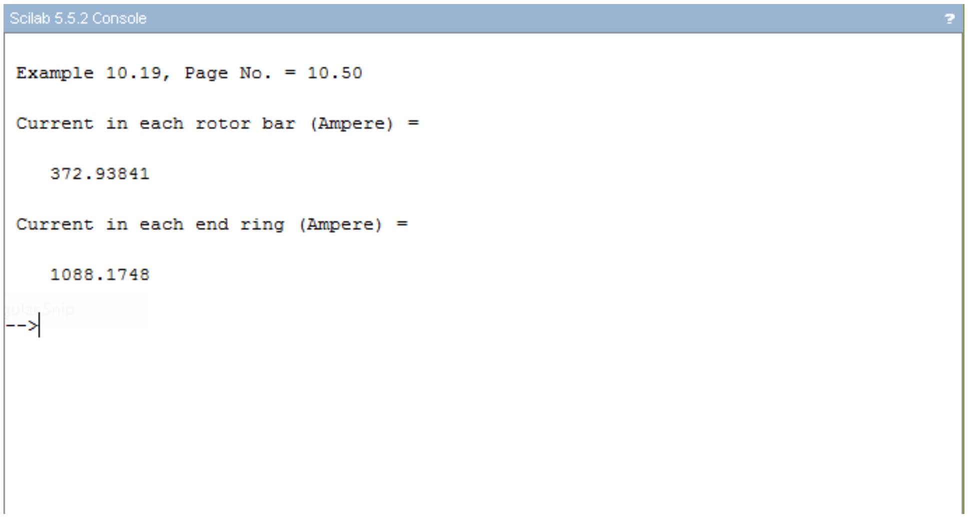
```
 Example 10.16, Page No. = 10.44

 Magnetizing current per phase (Ampere) =

    4.5720115

-->
```

Figure 10.4: Calculating the magnetizing current per phase

```
V = 3000;// Voltage rating
f = 50;// Frequency (in Hz)
p = 8;// Number of poles
AT60 = 500;// mmf required for flux density at 30
    degree from pole axis
Kws = 0.95;// Winding factor
e = 0.94;// Full load efficiency
pf = 0.86;// Full load power factor
// Calculation of the number of stator turns per
    phase
I = P*10^(3)/(3^(1/2)*V*e*pf);// Full load current (
    in ampere)
Im = 0.35*I;// Magnetizing current (in Ampere).
    Since magnetizing current is 35% of full load
    current
Ts = 0.427*p*AT60/(Kws*Im);// Stator turns per phase
disp(Ts,'Stator turns per phase =');
//in book answer is 288.  The answers vary due to
    round off error
```

Scilab code Exa 10.16 Calculating the magnetizing current per phase

```
// Calculating the magnetizing current per phase
clc;
disp('Example 10.16, Page No. = 10.44')
// Given Data
// 3 phase delta connected induction motor
P = 75;// Power rating (in kw)
V = 400;// Voltage rating
f = 50;// Frequency (in Hz)
p = 6;// Number of poles
D = 0.3;// Diameter of motor core (in meter)
L = 0.12;// Length of motor core (in meter)
Nss = 72;// Number of stator slots
Nc = 20;// Number of conductors per slot
lg = 0.55;// Length of air gap (in meter)
Kg = 1.2// Gap constraction factor
Coil_Span = 11;// Coil span (slots)
// Calculation of the magnetizing current per phase
q = Nss/(3*p);// Slots per pole per phase
Kd = sin(60/2*%pi/180)/(q*sin(60/(2*4)*%pi/180));// Distribution factor
Ns_pole = Nss/p;// Slots per pole
alpha = 1/Ns_pole*180;// Angle of chording (in degree). Since the winding is chorded by 1 slot pitch
Kp = cos(alpha/2*%pi/180);// Pitch factor
Kws = Kd*Kp;// Stator winding factor
Ns = Nss*Nc;// Total stator conductors
Ts = Ns/(3*2);// Stator turns per phase
Eb = V;// Stator voltage per phase. Since machine is delta connected
Fm = Eb/(4.44*f*Ts*Kws);// Flux per pole (in Wb)
A = %pi*D*L/p;// Area per pole (in meter square)
```



```
Example 10.19, Page No. = 10.50

Current in each rotor bar (Ampere) =

   372.93841

Current in each end ring (Ampere) =

   1088.1748

-->
```

Figure 10.5: Calculating the current in rotor bars and in end rings

```
Bav = Fm/A;// Average air gap density (in Wb per meter square)
Bg60 = 1.36*Bav;// Gap flux density at 30 degree from pole axis
ATg = 800000*Bg60*Kg*lg*10^(-3);// Mmf required for air gap (in A)
ATi = 0.35*ATg;// Mmf for iron parts (in A).  Since mmf required for iron parts is 35% of air gap mmf
AT60 = ATg+ATi;// Total mmf (in A)
Im = 0.427*p*AT60/(Kws*Ts);// Magnetizing current per phase (in ampere)
disp(Im,'Magnetizing current per phase (Ampere) =');
//in book answer is 4.56 Ampere.  The answers vary due to round off error
```

Scilab code Exa 10.19 `Calculating the current in rotor bars and in end rings`

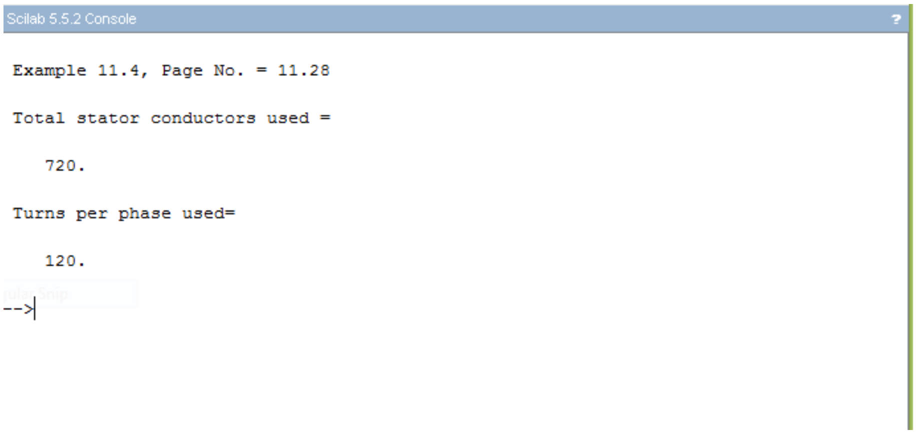
```
// Calculating the current in rotor bars and in end rings
clc;
disp('Example 10.19, Page No. = 10.50')
// Given Data
p = 6;// Number of poles
ms = 3;// Number of phases of stator
Nss = 72;// Number of stator slots
Nc = 15;// Number of conductors per slot
Sr = 55;// Number of stator slots
Is = 24.1;// Stator current (in Ampere)
Coil_Span = 11;// Coil span (slots)
pf = 0.83;// Power factor
// Calculation of the current in rotor bars and in end rings
q = Nss/(ms*p);// Stator slots per pole per phase
Kd = sin(60/2*%pi/180)/(q*sin(60/(2*4)*%pi/180));// Distribution factor
Ns_pole = Nss/p;// Slots per pole
alpha = 1/Ns_pole*180;// Angle of chording (in degree).  Since the winding is chorded by 1 slot pitch
Kp = cos(alpha/2*%pi/180);// Pitch factor
Kws = Kd*Kp;// Stator winding factor
Ir_ = Is*pf;// Stator current equivalent to rotor current (in Ampere)
Ns = Nss*Nc;// Total stator conductors
Ts = Ns/(ms*2);// Stator turns per phase
Ib = 2*ms*Kws*Ts*Ir_/Sr;// Current in each rotor bar (in Ampere)
Ie = Sr*Ib/(%pi*p);// Current in each end ring (in Ampere)
disp(Ib,'Current in each rotor bar (Ampere) =');
disp(Ie,'Current in each end ring (Ampere) =');
//in book answers are 375.4 Ampere and 1095.3 Ampere respectively.  The answers vary due to round off error
```

Chapter 11

Design of Synchronous Machines

Scilab code Exa 11.4 `Calculating the suitable number of slots and conductors per s`

```
// Calculating the suitable number of slots and conductors per slot
clc;
disp('Example 11.4, Page No. = 11.28')
// Given Data
// 3 phase star connected alterator (Single layer winding)
rpm = 300;// R.p.m.
E = 3300;// Voltage rating (in volts)
f = 50;// Frequency (in Hz)
D = 2.3;// Diameter of core (in meter)
L = 0.35;// Length of core (in meter)
Bm = 0.9;// Maximum flux density in the air gap (in Wb per meter square)
// Calculation of the suitable number of slots and conductors per slot
ns = rpm/60;// Synchronous speed (r.p.s)
```

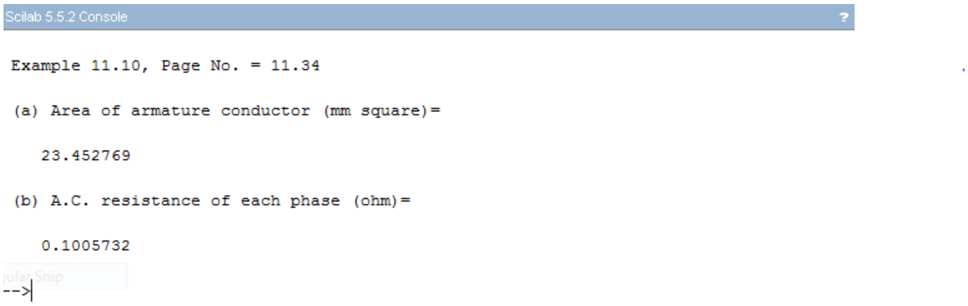


```
Example 11.4, Page No. = 11.28

Total stator conductors used =

   720.

Turns per phase used=

   120.

-->
```

Figure 11.1: Calculating the suitable number of slots and conductors per slot

```
p = 2*f/ns;// Number of poles
Bav = 2/%pi*Bm;// Average flux density in the air gap (in Wb per meter square)
Flux_pole = Bav*%pi*D*L/p;// Flux per pole (in Wb)
Eph = E/3^(1/2);// Voltage per phase (in volts)
ys = 40;// Slot pitch (in mm). The slot pitch should be nearly 40 mm for 3.3 kV machines
Kw = 0.955;// Taking winding factor
Tph = int(Eph/(4.44*f*Flux_pole*Kw));// Turns per phase
q = int(%pi*D/(3*p*ys*10^(-3)));// Slots per pole per phase
S = 3*p*q;// Total number of stator slots
Tph6 = 6*Tph;// Total number of stator conductors
Zs = int(Tph6/S);// Conductors per slot
disp(Zs*S,'Total stator conductors used =');
disp(Zs*S/6,'Turns per phase used=');
```

Scilab code Exa 11.10 Calculating the size of armature wire and the ac resistance



```
Example 11.10, Page No. = 11.34

(a) Area of armature conductor (mm square)=

   23.452769

(b) A.C. resistance of each phase (ohm)=

   0.1005732

-->
```

Figure 11.2: Calculating the size of armature wire and the ac resistance of each pahase

```
// Calculating the size of armature wire and the a.c. resistance of each pahase
clc;
disp('Example 11.10, Page No. = 11.34')
// Given Data
// 3 phase star connected synchronous generator
p = 8;// Number of poles
f = 50;// Frequency (in Hz)
ys = 0.3;// Pole pitch (in meter)
Iz = 100;// Line current (in Ampere)
L = 0.3;// Gross axial length (in meter)
Spp =3;// Slots per pole per phase
Cs = 6;// Conductors per slot
Kc_av = 1.3;// Average eddy current loss factor
// Calculation of the suitable number of slots and conductors per slot
D = ys*p/%pi;// Armature diameter (in meter)
ns = 2*f/p;// Synchronous speed (in r.p.s.)
Va = %pi*D*ns;// Peripheral speed (in meter per second)
S = Spp*3*p;// Total number of slots
```

```
Z = S*Cs;// Total number of conductors
Tph = Z/6;// Turns per phase
ac = Iz*Z/(%pi*D);// (in Ampere per meter)
J = (43000/ac)+(Va/16);// Current density (in Ampere per mm square)
as = 100/J;// Area of armature conductor
disp(as,'(a) Area of armature conductor (mm square)=');
L_active = 2*L;// Active length of each turn (in meter)
Lmt = 2*L_active;// Since Total length of a turn is twice the active length (in meter)
resistivity = 0.021;// Resistivity of copper at 75 degree celsius (in ohm per meter)
r_dc = resistivity*Tph*Lmt/as;// D.C. resistance of each phase at 75 degree celsius (in ohm)
r_ac = Kc_av*r_dc;// A.C. resistance of each phase
disp(r_ac,'(b) A.C. resistance of each phase (ohm)=');
//in book answers are 23.8 mm square and 0.099 ohm respectively. The answers vary due to round off error
```

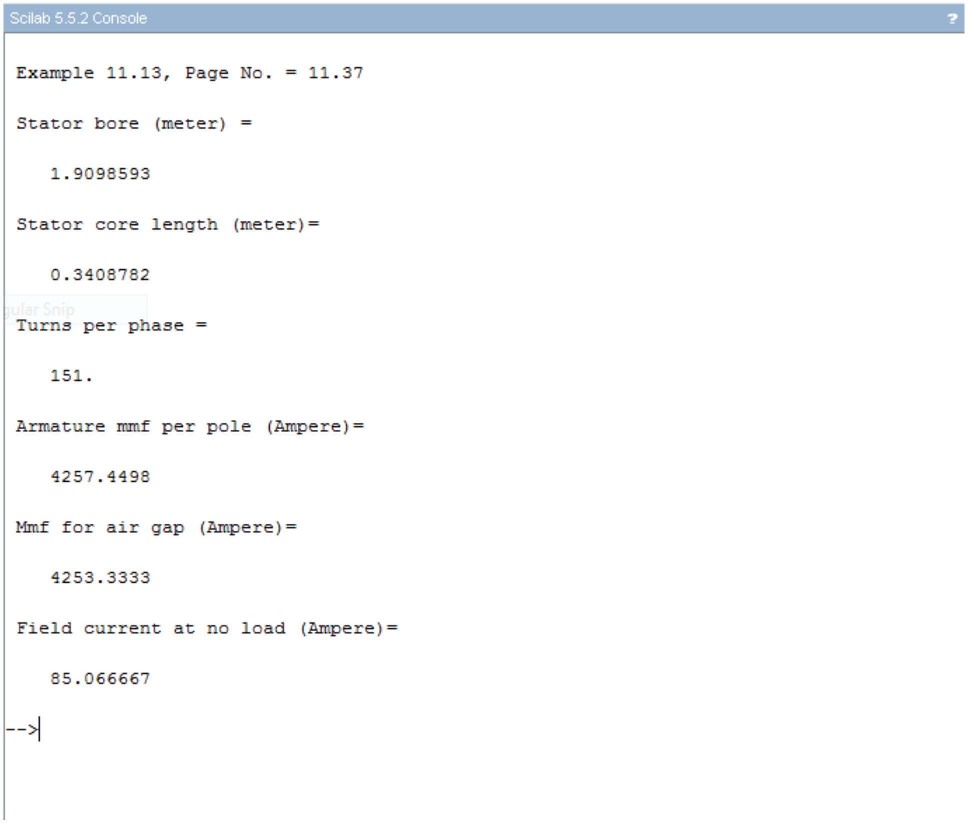
Scilab code Exa 11.11 `Calculating the length of air gap`

```
// Calculating the length of air gap
clc;
disp('Example 11.11, Page No. = 11.35')
// Given Data
// 3 phase silient pole alternator
kVA = 500;// kVA rating
V = 3.3;// Voltage rating (in kV)
f = 50;// Frequency (in Hz)
```

```
Example 11.11, Page No. = 11.35

Length of air gap (mm)=

   5.0996231

-->
```

Figure 11.3: Calculating the length of air gap

```
rpm = 600;// R.p.m.
Tph = 180;// Turns per phase
Bav = 0.54;// Average flux density (in Wb per meter square)
SCR = 1.2;// Short circuit ratio
Kw = 0.955;// Winding factor
Kg = 1.15;// Gap constraction factor
Kf = 0.65;// Since field form factor is equal to the ratio of pole arc to pole pitch
// Calculation of the length of air gap
ns = rpm/60;// Synchronous speed (in r.p.s.)
p = 2*f/ns;// Number of poles
Iph = kVA*1000/(3^(1/2)*V*1000);// Armature diameter (in meter)
ATa = 2.7*Iph*Tph*Kw/p;// Armature mmf per pole (in A)
AT_f0 = SCR*ATa;// No load field mmf per pole
Bg = Bav/Kf;// Maximum flux density in air gap (in Wb per meter square)
lg = 0.8*AT_f0/(800000*Bg*Kg);// Length of air gap
//  Since mmf required for gap is 80% of no load field mmf
disp(lg*1000,'Length of air gap (mm)=');
```



```
Example 11.13, Page No. = 11.37

Stator bore (meter) =

   1.9098593

Stator core length (meter)=

   0.3408782

Turns per phase =

   151.

Armature mmf per pole (Ampere)=

   4257.4498

Mmf for air gap (Ampere)=

   4253.3333

Field current at no load (Ampere)=

   85.066667

-->
```

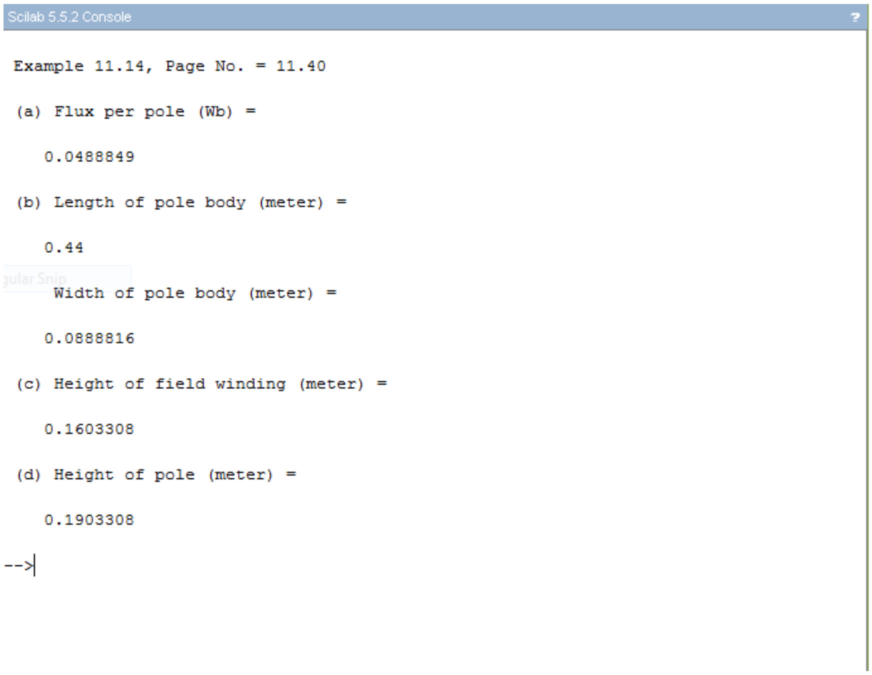
Figure 11.4: Calculating the stator bore and stator core length and turns per phase and armature mmf per pole and mmf for air gap and field current

```
//in book answer is 5.2 mm.  The answers vary due to
    round off error
```

Scilab code Exa 11.13 Calculating the stator bore and stator core length and turns

```
// Calculating the stator bore and stator core
   length and turns per phase and armature mmf per
   pole and mmf for air gap and field current
```

```
clc;
disp('Example 11.13, Page No. = 11.37')
// Given Data
// 3 phase synchronous generator
Q = 1250;// kVA rating
E = 3300;// Voltage rating (in kV)
f = 50;// Frequency (in Hz)
rpm = 300;// R.p.m.
Bav = 0.58;// Specific magnetic loading (in Wb per meter square)
ac = 33000;// Specific electric loading (in Ampere per meter)
lg = 5.5;// Gap length (in mm)
T_field = 60;// Field turns per pole
SCR = 1.2;// Short circuit ratio
Kw = 0.955;// Winding factor
Va = 30;// Peripheral speed (in meter per second)
// Calculation of the stator bore and stator core length and turns per phase and armature mmf per pole and mmf for air gap and field current
ns = rpm/60;// Synchronous speed (in r.p.s.)
p = 2*f/ns;// Number of poles
Co = 11*Kw*Bav*ac*10^(-3);// Output co-efficient
D2L = Q/(Co*ns);// Product of D*D*L
D = Va/(%pi*ns);// Stator bore (in meter)
disp(D,'Stator bore (meter) =');
L = D2L/D^(2);// Stator core length (in meter)
disp(L,'Stator core length (meter)=');
A_pole = %pi*D*L/p;// Area per pole
F_pole = Bav*A_pole;// Flux per pole
Eph = E/3^(1/2);// Voltage per phase
Tph = int(Eph/(4.44*f*F_pole*Kw));// Turns per phase
disp(Tph,'Turns per phase =');
Iph = Q*1000/(3^(1/2)*E);// Current per phase
ATa = 2.7*Iph*Tph*Kw/p;// Armature mmf per pole (in A)
disp(ATa,'Armature mmf per pole (Ampere)=');
A_effective = 0.6*A_pole;// Effective gap area is
```



```
Example 11.14, Page No. = 11.40

(a) Flux per pole (Wb) =

   0.0488849

(b) Length of pole body (meter) =

   0.44

    Width of pole body (meter) =

   0.0888816

(c) Height of field winding (meter) =

   0.1603308

(d) Height of pole (meter) =

   0.1903308

-->
```

Figure 11.5: Calculating the flux per pole and length and width of pole and winding height and pole height

```
    0.6 times the actual area
KgBg = F_pole/A_effective;// Effective gap density (in Wb per meter square)
mmf_airgap = 800000*KgBg*lg*10^(-3);// Mmf for air gap (in A)
disp(mmf_airgap,'Mmf for air gap (Ampere)=');
AT_f0 = SCR*mmf_airgap;// No load field mmf per pole
If = AT_f0 /T_field;// Field current at no load
disp(If,'Field current at no load (Ampere)=');
//in book answers are 1.9 meter, 0.345 meter, 150, 4240 ampere, 4250 ampere and 85 ampere respectively. The answers vary due to round off error
```

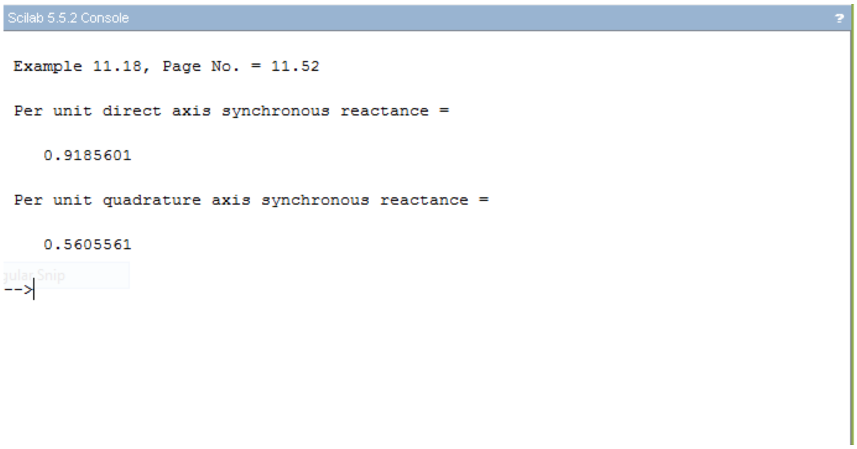
Scilab code Exa 11.14 Calculating the flux per pole and length and width of pole a

```
// Calculating the flux per pole and length and width of pole and winding height and pole height
clc;
disp('Example 11.14, Page No. = 11.40')
// Given Data
// 3 phase star connected selient pole alternator
Q = 2500;// kVA rating
E = 2400;// Voltage rating (in kV)
f = 60;// Frequency (in Hz)
rpm = 225;// R.p.m.
D = 2.5;// Stator bore (in meter)
L = 0.44;// Core length (in meter)
Nspp = 3;// Number of slot per pole per phase
Ncs = 4;// Number of conductors per slot
a = 2;// Circuits per phase
Bp = 1.5;// Flux density in pole core (in Wb per meter square)
df = 30;// Depth of winding (in mm)
Sf = 0.84;// Field widind space factor
Cl = 1.2;// Leakage factor
Kw = 0.95;// Winding factor
qf =1800;// Loss dissipated by field winding
h_insulation = 30;// Height of insulation
// Calculation of the flux per pole and length and width of pole and winding height and pole height
ns = rpm/60;// Synchronous speed (in r.p.s.)
p = 2*f/ns;// Number of poles
S = 3*p*3.5;// Total number of slots
Z = Ncs*S;// Total number of conductors
Tph = int(Z/6);// Turns per phase
Eph =E/3^(1/2);// Voltage per phase
F_pole = Eph*a/(4.44*Tph*f*Kw);// Flux per pole (in
```

```
Wb)
disp(F_pole,'(a) Flux per pole (Wb) =');
Fp = Cl*F_pole;// Flux in pole body (in Wb)
Ap = Fp/Bp;// Area of pole body (in meter square)
Lp = L;// Length of pole body = Length of armature core
bp = Ap/Lp;// Width of pole body
disp(Lp,'(b) Length of pole body (meter) =');
disp(bp,'    Width of pole body (meter) =');
Iph = Q*1000/(3^(1/2)*E);// Current in each phase
Iz = Iph/a;// Current in each conductor
ATa = 2.7*Iz*Tph*Kw/p;// Armature mmf per pole (in A)
AT_fl = 2*ATa;// Field mmf at full load (in A)
hf = AT_fl/(10^(4)*(Sf*df*10^(-3)*qf)^(1/2));// Height of field winding (in meter)
disp(hf,'(c) Height of field winding (meter) =');
disp(hf+h_insulation*10^(-3),'(d) Height of pole (meter) =');
//in book answers are 0.049 Wb, 0.44 meter, 0.089 meter, 0.16 meter and 0.19 meter respectively. The answers vary due to round off error
```

Scilab code Exa 11.18 Calculating the direct and quadrature axis synchronous react

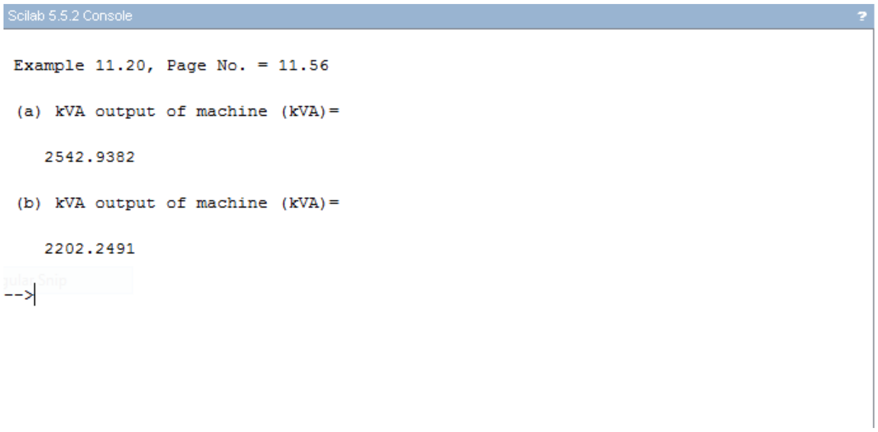
```
// Calculating the direct and quadrature axis synchronous reactances
clc;
disp('Example 11.18, Page No. = 11.52')
// Given Data
// 3 phase star connected selient pole alternator
Q = 2500;// kVA rating
E = 2400;// Voltage rating (in kV)
```



```
Example 11.18, Page No. = 11.52

Per unit direct axis synchronous reactance =

   0.9185601

Per unit quadrature axis synchronous reactance =

   0.5605561

-->
```

Figure 11.6: Calculating the direct and quadrature axis synchronous reactances

```
f = 60;// Frequency (in Hz)
p = 32;// Number of poles
D = 2.5;// Stator bore (in meter)
L = 0.44;// Core length (in meter)
Tph = 224;// Turns per phase
lg = 10;// Air gap length (in meter)
Kg = 1.11;// Air gap constraction factor
Kw = 0.95;// Winding factor
R = 0.69;// Ratio of pole arc to pole pitch
A1 = 1.068;// Ratio of amplitude of fundamental of gap flux density to maximum gap density
Xl = 0.14;// Per unit leakage reactance
// Calculation of the direct and quadrature axis synchronous reactances
xm = 7.54*f*Tph*Tph*Kw*Kw*D*L/(p*p*lg*10^(-3)*Kg)*10^(-6);// Magnetic reactance per phase (in ohm)
Eph =E/3^(1/2);// Voltage per phase
Iph = Q*1000/(3^(1/2)*E);// Current in each phase
Xm = Iph*xm/Eph;// Per unit magnetising reactance
a = R*%pi;// Angle embraced by pole arc (in rad)
pd = (a+sin(a))/(4*sin(a/2));// Reduction factor for direct axis armature mmf
```



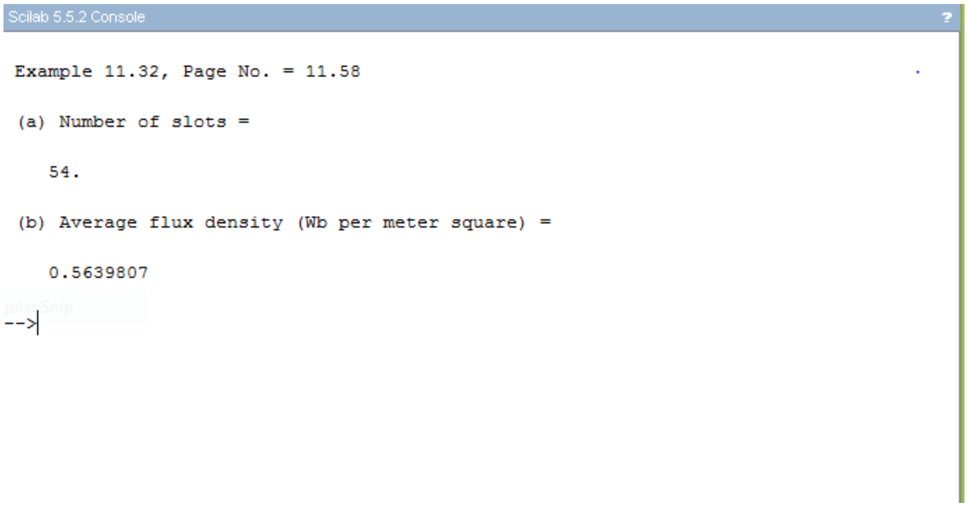
```
Example 11.20, Page No. = 11.56

(a) kVA output of machine (kVA)=

   2542.9382

(b) kVA output of machine (kVA)=

   2202.2491

-->
```

Figure 11.7: Calculating the kVA output of the machine

```
Ad1 = pd*A1;// Flux distribution factor for direct axis
Xad = Ad1*Xm;// Per unit direct axis armature reaction reactance
Aq1 = ((4*R+1)/5)-(sin(R*%pi)/%pi);// Flux distribution co-efficient for quadrature axis
Xaq = Aq1*Xm;// Per unit quadrature axis armature reaction reactance
Xd = Xl+Xad;// Per unit direct axis synchronous reactance
Xq = Xl+Xaq;// Per unit quadrature axis synchronous reactance
disp(Xd,'Per unit direct axis synchronous reactance =');
disp(Xq,'Per unit quadrature axis synchronous reactance =');
//in book answers are 0.916 and 0.533 respectively. The answers vary due to round off error
```

Scilab code Exa 11.20 `Calculating the kVA output of the machine`

```
// Calculating the kVA output of the machine
clc;
disp('Example 11.20, Page No. = 11.56')
// Given Data
// 3 phase turbo-alternator
rpm = 3000;// R.p.m.
f = 50;// Frequency (in Hz)
L = 0.94;// Core length (in meter)
Bav = 0.45;// Average gap density (in Wb per meter
    sqaure)
ac = 25000;// Ampere conductors per meter
Va = 100;// Peripheral speed of rotor (in meter per
    second)
lg = 20;// Length of air gap (in mm)
Kw = 0.95;// Winding factor
// Winding is infinitely distributed with a phase
    spread of 60 degree
// Calculation of the kVA output of the machine
ns = rpm/60;// R.p.s
Dr = Va/(%pi*ns);// Diameter of rotor (in meter)
D = Dr+(2*lg*10^(-3));// Stator bore (in meter)
// for full pitch
Kd = 0.955;// Distribution factor
Kp = 1;// Pitch factor
Kw = Kd*Kp;// Winding factor
Q = 11*Kw*Bav*ac*D*D*L*ns*10^(-3);// kVA output
disp(Q,'(a) kVA output of machine (kVA)=');
// for chorded by 1/3 pole pitch
alpha = 180/3;// Angle of chording
Kp = cos(alpha*%pi/180/2);// Pitch factor
Kd = 0.955;// Distribution factor
Kw = Kd*Kp;// Winding factor
Q = 11*Kw*Bav*ac*D*D*L*ns*10^(-3);// kVA output
disp(Q,'(b) kVA output of machine (kVA)=');
//in book answers are 2480 kVA and 2147 kVA
    respectively.  The provided in the textbook is
```



```
 Example 11.32, Page No. = 11.58

 (a) Number of slots =

    54.

 (b) Average flux density (Wb per meter square) =

    0.5639807

-->
```

Figure 11.8: Calculating the number of stator slots and average flux density

wrong

Scilab code Exa 11.32 `Calculating the number of stator slots and average flux dens`

```
// Calculating the number of stator slots and average flux density
clc;
disp('Example 11.32, Page No. = 11.58')
// Given Data
// 3 phase star connected direct watercooled generator
Q = 588;// MVA rating
E = 22000;// Voltage rating
p =2;// Number of poles
rpm = 2500;// R.p.m.
f = 50;// Frequency (in Hz)
D = 1.3;// Stator bore (in meter)
```

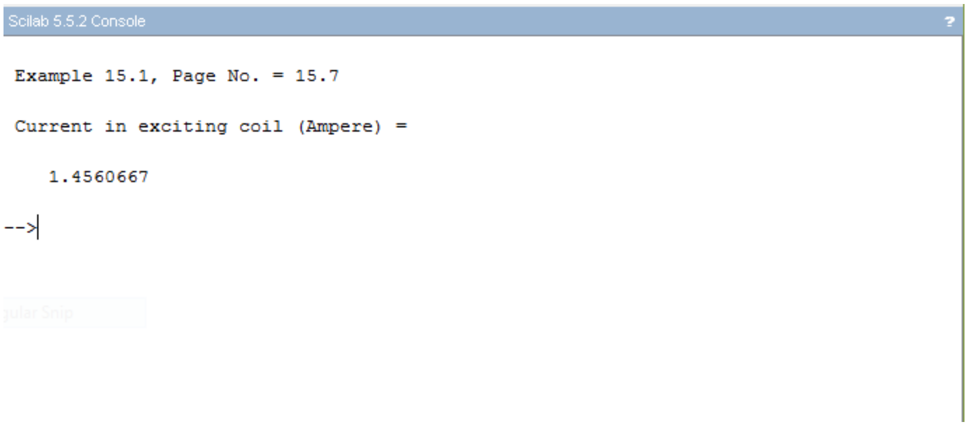
```
L = 6;// Core length (in meter)
Nc =2;// Number of conductors per slot
a = 2;// Circuits per phase
ac = 200000;// Ampere conductors per meter
Kw = 0.92;// Winding factor
// Winding is infinitely distributed with a phase spread of 60 degree
// Calculation of the number of stator slots and average flux density
ns = rpm/60;// Speed (r.p.s)
Eph = E/3^(1/2);// Voltage per phase
Iph = Q*10^(6)/(3^(1/2)*E);// Current per phase
Is = Iph/a;// Current in each conductor (in ampere)
Z = %pi*D*ac/Is;// Total number of armature conductors
Tph = int(Z/6+1);// Turns per phase for a three phase machine
Z = 6*Tph;// Actual number of conductors used
S = Z/Nc;// Number of slots
disp(S,'(a) Number of slots =');
F_pole = a*Eph/(4.44*f*Tph*Kw);// Flux per pole (in Wb)
pole_pitch = %pi*D/p;//Pole pitch (in meter)
Bav = F_pole/(pole_pitch*L);// Average flux density (in Wb per meter square)
disp(Bav,'(b) Average flux density (Wb per meter square) =');
//in book answers are 54 and 0.565 Wb per meter square respectively.  The answers vary due to round off error
```

Chapter 15

Design of Magnetic Circuits

Scilab code Exa 15.1 `Calculating the current in exciting coil`

```
// Calculating the current in exciting coil
clc;
disp('Example 15.1, Page No. = 15.7')
// Given Data
F = 200;// Mass (in kg)
lg = 5;// Distance (in mm)
A = 5*10^(-3);// Area of pole face (in meter square)
T = 3000;// Exciting coil turns
u0 = 4*%pi*10^(-7);// Permeability of free space
// Calculation of the current in exciting coil
B = (F*u0/(0.051*A))^(1/2);// flux density in air gap (in Wb per meter square)
mmf_air = 800000*B*lg*10^(-3);// Mmf required for air (in A)
mmf_iron = 0.1*mmf_air;// Mmf required for iron parts (in A). Since mmf required for iron parts is 10% of air gap mmf
AT = mmf_air+mmf_iron;// Total mmf
I = AT/T;// Current in exciting coil (in Ampere)
```



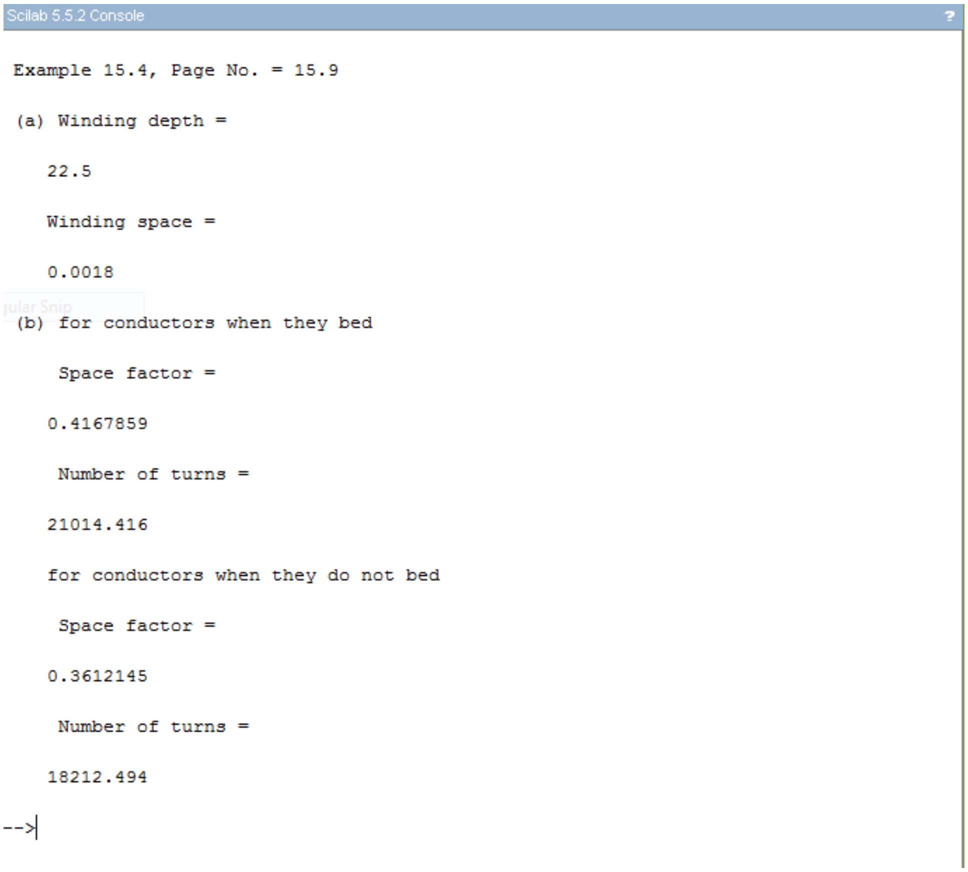
```
Example 15.1, Page No. = 15.7

Current in exciting coil (Ampere) =

   1.4560667

-->
```

Figure 15.1: Calculating the current in exciting coil

```
disp(I,'Current in exciting coil (Ampere) =');
//in book answer is 1.456 Ampere.  The answers vary due to round off error
```

Scilab code Exa 15.4 `Calculating the winding depth and winding space and space fac`

```
// Calculating the winding depth and winding space and space factor and the number of turns
clc;
disp('Example 15.4, Page No. = 15.9')
// Given Data
hf = 80;// in between flanges (in mm)
Do = 75;// in flange diameter (in mm)
Di = 30;// in gross diameter tube (in mm)
a = 0.0357;// Area of copper wire
d = 0.213;// Diameter of bare conductor (in mm)
d1 = 0.213+2*0.05;// Diameter of insulated conductor (in mm)
// Calculation of the winding depth and winding
```



```
 Example 15.4, Page No. = 15.9

 (a) Winding depth =

    22.5

    Winding space =

    0.0018

 (b) for conductors when they bed

     Space factor =

    0.4167859

     Number of turns =

    21014.416

    for conductors when they do not bed

     Space factor =

    0.3612145

     Number of turns =

    18212.494

-->
```

Figure 15.2: Calculating the winding depth and winding space and space factor and the number of turns

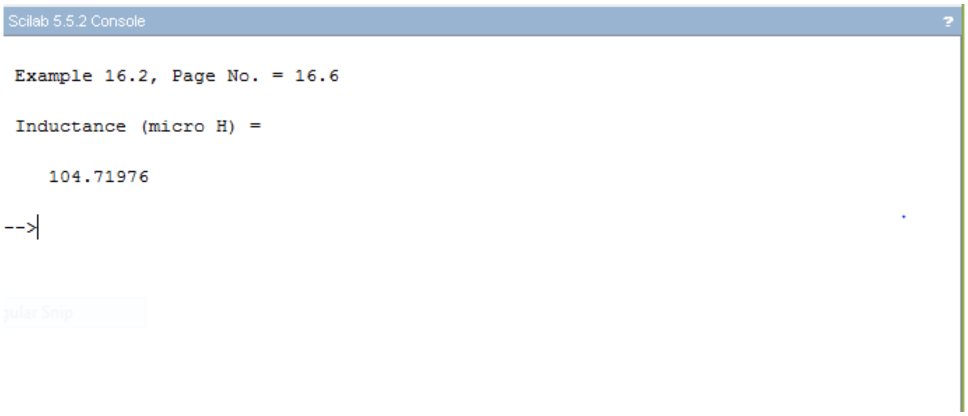
```
space and space factor and the number of turns
df = (Do-Di)/2;// Winding depth (in mm)
Aw = hf*10^(-3)*df*10^(-3);// Winding space
disp(df,'(a) Winding depth =');
disp(Aw,'   Winding space =');
disp('(b) for conductors when they bed')
Sf = 0.9*(d/d1)^(2);// Space factor
T = Sf*Aw/a*10^(6);// Number of turns
disp(Sf,'    Space factor =');
disp(T,'    Number of turns =');
disp('   for conductors when they do not bed')
Sf = 0.78*(d/d1)^(2);// Space factor
T = Sf*Aw/a*10^(6);// Number of turns
disp(Sf,'    Space factor =');
disp(T,'    Number of turns =');
//in book answers are 22.5 mm, 0.0018 mm square, 0.417, 21025, 0.361 and 18200.  The answers vary due to round off error
```

Chapter 16

Design of Heating Elements and Inductors and Welding Transformers

Scilab code Exa 16.2 `Calculating the inductance`

```
// Calculating the inductance
clc;
disp('Example 16.2, Page No. = 16.6')
// Given Data
N = 25;// Number of turns
Ac = 1;// Cross sectional area of the core (in cm
    square)
u0 = 4*%pi*10^(-7);// Permeability of free space
ur = 200;// Relative permeability
lc = 15;// (in cm)
// Calculation of the inductance
L = u0*ur*Ac*10^(-4)*N^(2)/(lc*10^(-2))*10^(6);//
    Inductance (in micro H)
disp(L,'Inductance (micro H) =');
//in book answer is 105 micro H.  The answers vary
```



```
 Example 16.2, Page No. = 16.6

 Inductance (micro H) =

    104.71976

-->
```

Figure 16.1: Calculating the inductance

```
   due to round off error
```

Chapter 18

Design of Starters and Field Regulators

Scilab code Exa 18.1 `Calculating the upper and lower limits of current during star`

```
// Calculating the upper and lower limits of current during starting and resistance of each section
clc;
disp('Example 18.1, Page No. = 18.3')
// Given Data
// d.c. shunt motor
P = 37;// Power rating (in kW)
V = 250;// Voltage rating (in Volts)
e = 0.84;// Full load efficiency
rm = 0.2;// Armature circuit resistance (in ohm)
ns = 8;// Number of studs
// Maximum torque is 150% of full load torque
// Calculation of the upper and lower limits of current during starting
Ifl = P*10^(3)/(V*e);// Full load current (in Ampere)
I1 = 1.5*Ifl;// Maximum current (in Ampere). Since
```

```
    torque is proportional to current
n = ns-1;// Number of sections
alpha = (rm*I1/V)^(1/n);
I2 = alpha*I1;// Lower limit of current (in Ampere)
disp(I1,'Upper limit of current (Ampere) =');
disp(I2,'Lower limit of current (Ampere) =');
// Calculation of the resistance of each section
R1 = V/I1;// Total resistance at starting (in ohm)
r1 = (1-alpha)*R1;
r2 = alpha*r1;
r3 = alpha*r2;
r4 = alpha*r3;
r5 = alpha*r4;
r6 = alpha*r5;
r7 = alpha*r6;
disp(R1,'Total resistance at starting (ohm) =');
disp('Resistance of each section')
disp(r1,'r1 (ohm) =');
disp(r2,'r2 (ohm) =');
disp(r3,'r3 (ohm) =');
disp(r4,'r4 (ohm) =');
disp(r5,'r5 (ohm) =');
disp(r6,'r6 (ohm) =');
disp(r7,'r7 (ohm) =');
//in book answers are I1 = 264 ampere, I2 = 211
    ampere, R1 = 0.947 ohm, r1 = 0.189 ohm,, r2 =
    0.151 ohm, r3 = 0.121 ohm, r4 = 0.097 ohm, r5 =
    0.077 ohm, r6 = 0.062 ohm, r7 = 0.050 ohm.    The
     answers vary due to round off error
```