

```
(* Problem 5.1 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 40 at 160°F"
T = 160; (* °F *)
ρ = 0.89 - 0.00035 (T - 60);

Print["density ρ = ",ρ, " g/cm^3"];

SAE 40 at 160°F

density ρ = 0.855 g/cm^3
```

```
(* Problem 5.3 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

T = 93; (* °C *)
t = 50; (* sec *)

ρ = 0.89 - 0.00063 (T - 15.6);
Print["density ρ = ",ρ, " g/cm^3"];

μ = (0.22 t - 180/t) ρ;
Print["μ = ",μ, " mPa s"];

"from Figure II.5.3 => SAE 20"

density ρ = 0.841238 g/cm^3

μ = 6.22516 mPa s

from Figure II.5.3 => SAE 20
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```
(* Problem 5.5 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 10";
T = 130; (* °F *)
Diam = 4; (* in *)
R = Diam/2; (* in *)
c = 0.0015; (* in *)
n = 2000; (* rpm *)
L = 6; (* in *)

 $\mu = 2.3 \cdot 10^{-6}$ ; (* lb sec / in2 - from Fig.5.4*)

Tf = (4 Pi2  $\mu$  n/60 L R3)/c;
Print["Friction torque = ", Tf, " lb in = ", Tf/12, " lb ft"];
H = (Tf/12 n)/5252;
Print["Power loss = ", H, " hp"];

Friction torque = 96.8537 lb in = 8.07114 lb ft

Power loss = 3.07355 hp
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(* Problem 5.7 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 20";
T = 70; (* °C *)
Diam = 200*10^-3; (* m *)
R = Diam/2; (* m *)
L = 100*10^-3; (* m *)
c = 0.1*10^-3; (* m *)
n = 1000/60; (* rps *)
W = 20*10^3; (* N *)

μ = 12.5*10^-3; (* Pa sec - from Fig.5.3*)
P = W / (Diam*L);

S = (μ n / P) (R/c)^2;

Print["Sommerfeld number = ", S];
Print["L/D = ", L/Diam];

"from Fig 5.9 h0/c = 0.32"
h0 = 0.32*c;
Print["minimum film thickness h0 = ", h0];

"from Fig 5.11 (R/c)f = 5.5"
f = 5.5*c/R;
Print["bearing coefficient of friction f = ", f];

"from Fig 5.14 P/pmax = 0.32"
pmax = P/0.32;
Print["maximum pressure within oil film pmax = ", pmax, " psi"];

"from Fig 5.10 the position angle of minimum film thickness φ = 42°"

"from Fig 5.15 terminating position of the oil film θp0 = 56°"
"from Fig 5.15 angular position angle of maximum pressure θpmax = 17°"

"from Fig 5.12 Q/RcnL = 5.2"
Q = R c n L 5.2;
Print["total flow Q = ", Q, " m^3/s"];

"from Fig 5.13 Qs/Q = 0.8. Of the volume of oil Q pumped by the rotating journal, an
amount Qs flows out the ends. The side leakage that must be made up by the oil
represents 80% of the flow. The remaining 20% of the flow is recirculated."

Sommerfeld number = 0.208333

L/D =  $\frac{1}{2}$ 

from Fig 5.9 h0/c = 0.32

minimum film thickness h0 = 0.000032

from Fig 5.11 (R/c)f = 5.5

bearing coefficient of friction f = 0.0055

from Fig 5.14 P/pmax = 0.32

maximum pressure within oil film pmax = 3.125×106 psi

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from Fig 5.10 the position angle of minimum film thickness $\phi = 42^\circ$

from Fig 5.15 terminating position of the oil film $\theta_{p0} = 56^\circ$

from Fig 5.15 angular position angle of maximum pressure $\theta_{pmax} = 17^\circ$

from Fig 5.12 $Q/RcnL = 5.2$

total flow $Q = 0.0000866667 \text{ m}^3/\text{s}$

from Fig 5.13 $Q_s/Q = 0.8$. Of the volume of oil Q pumped by the rotating journal, an amount Q_s flows out the ends. The side leakage that must be made up by the oil represents 80% of the flow. The remaining 20% of the flow is recirculated.

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(* Problem 5.9 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 30";
T = 60; (* °C *)
Diam = 60*10^-3; (* m *);
R = Diam/2; (* m *);
L = Diam; (* m *)
c = 0.04*10^-3; (* m *)
n = 200/60; (* rps *)
W = 3000; (* N *)

 $\mu$  = 28*10^-3; (* Pa sec - from Fig.5.3*)
P = W / (Diam*L);

S = ( $\mu$  n / P) (R/c)^2;

Print["Sommerfeld number = ", S];
Print["L/D = ", L/Diam];

"from Fig 5.9 h0/c = 0.24"
h0 = 0.24*c;
Print["minimum film thickness h0 = ", h0];

"from Fig 5.11 (R/c)f = 1.8"
f = 1.8*c/R;
Print["bearing coefficient of friction f = ", f];

"from Fig 5.14 P/pmax = 0.36"
pmax = P/0.36;
Print["maximum pressure within oil film pmax = ", pmax, " psi"];

"from Fig 5.10 the position angle of minimum film thickness  $\phi = 40^\circ$ "

"from Fig 5.15 terminating position of the oil film  $\theta_{p0} = 58^\circ$ "
"from Fig 5.15 angular position angle of maximum pressure  $\theta_{pmax} = 18.5^\circ$ "

"from Fig 5.13  $Q_s/Q = 0.8$ . Of the volume of oil Q pumped by the rotating journal, an
amount  $Q_s$  flows out the ends. The side leakage that must be made up by the oil
represents 80% of the flow. The remaining 20% of the flow is recirculated."

Sommerfeld number = 0.063

L/D = 1

from Fig 5.9 h0/c = 0.24

minimum film thickness h0 =  $9.6 \times 10^{-6}$ 

from Fig 5.11 (R/c)f = 1.8

bearing coefficient of friction f = 0.0024

from Fig 5.14 P/pmax = 0.36

```

maximum pressure within oil film $p_{\max} = 2.31481 \times 10^6$ psi

from Fig 5.10 the position angle of minimum film thickness $\phi = 40^\circ$

from Fig 5.15 terminating position of the oil film $\theta_{p0} = 58^\circ$

from Fig 5.15 angular position angle of maximum pressure $\theta_{p\max} = 18.5^\circ$

from Fig 5.13 $Q_s/Q = 0.8$. Of the volume of oil Q pumped by the rotating journal, an amount Q_s flows out the ends. The side leakage that must be made up by the oil represents 80% of the flow. The remaining 20% of the flow is recirculated.

```

(* Problem 5.10 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 40";
T = 40; (* °C *)
Diam = 100*10^-3; (* m *)
R = Diam/2; (* m *)
L = Diam/4; (* m *)
c = 0.04*10^-3; (* m *)
n = 2000/60; (* rps *)
W = 5000; (* N *)

μ = 75*10^-3; (* Pa sec - from Fig.5.3*)
P = W / (Diam*L);

"Calculation for "
Smin = 0.012;
c = R Sqrt[(μ n)/(P Smin)];

Print["Sommerfeld number = ", Smin];
Print["L/D = ", L/Diam];

"from Fig 5.9 h0/c = 0.025"
h0 = 0.025*c;
Print["minimum film thickness h0 = ", h0];

"from Fig 5.11 (R/c)f = 1"
f = 1*c/R;
Print["bearing coefficient of friction f = ", f];

"from Fig 5.14 P/pmax = 0.11"
pmax = P/0.11;
Print["maximum pressure within oil film pmax = ", pmax, " psi"];

"from Fig 5.10 the position angle of minimum film thickness φ = 12°"

"from Fig 5.15 terminating position of the oil film θp0 = 18°"
"from Fig 5.15 angular position angle of maximum pressure θpmax = 4.5°"

"from Fig 5.12 Q/RcnL = 5.9"
Q = R c n L 5.9;
Print["total flow Q = ", Q, " m^3/s"];

"from Fig 5.13 Qs/Q = 0.94. Of the volume of oil Q pumped by the rotating journal, an
amount Qs flows out the ends. The side leakage that must be made up by the oil
represents 94% of the flow. The remaining 6% of the flow is recirculated."

"Calculation for "
Smax = 0.42;
c = R Sqrt[(μ n)/(P Smax)];

Print["Sommerfeld number = ", Smax];

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Print["L/D = ", L/Diam];

"from Fig 5.9  $h_0/c = 0.26$ "
h0 = 0.26*c;
Print["minimum film thickness  $h_0 =$ ", h0];

"from Fig 5.11  $(R/c)f = 14$ "
f = 14*c/R;
Print["bearing coefficient of friction  $f =$ ", f];

"from Fig 5.14  $P/p_{max} = 0.27$ "
pmax = P/0.27;
Print["maximum pressure within oil film  $p_{max} =$ ", pmax, " psi"];

"from Fig 5.10 the position angle of minimum film thickness  $\phi = 36^\circ$ "

"from Fig 5.15 terminating position of the oil film  $\theta_{p0} = 46^\circ$ "
"from Fig 5.15 angular position angle of maximum pressure  $\theta_{pmax} = 13.5^\circ$ "

"from Fig 5.12  $Q/RcnL = 5.35$ "
Q = R c n L 5.35;
Print["total flow  $Q =$ ", Q, " m^3/s"];

"from Fig 5.13  $Q_s/Q = 0.84$ . Of the volume of oil  $Q$  pumped by the rotating journal, an
amount  $Q_s$  flows out the ends. The side leakage that must be made up by the oil
represents 84% of the flow. The remaining 16% of the flow is recirculated."

"Same calculation for any  $s \in [0.082, 0.21]$ "

Calculation for

Sommerfeld number = 0.012

 $L/D = \frac{1}{4}$ 

from Fig 5.9  $h_0/c = 0.025$ 

minimum film thickness  $h_0 = 0.0000127578$ 

from Fig 5.11  $(R/c)f = 1$ 

bearing coefficient of friction  $f = 0.0102062$ 

from Fig 5.14  $P/p_{max} = 0.11$ 

maximum pressure within oil film  $p_{max} = 1.81818 \times 10^7$  psi

from Fig 5.10 the position angle of minimum film thickness  $\phi = 12^\circ$ 

from Fig 5.15 terminating position of the oil film  $\theta_{p0} = 18^\circ$ 

from Fig 5.15 angular position angle of maximum pressure  $\theta_{pmax} = 4.5^\circ$ 

from Fig 5.12  $Q/RcnL = 5.9$ 

total flow  $Q = 0.000125451$  m^3/s

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from Fig 5.13 $Q_s/Q = 0.94$. Of the volume of oil Q pumped by the rotating journal, an amount Q_s flows out the ends. The side leakage that must be made up by the oil represents 94% of the flow. The remaining 6% of the flow is recirculated.

Calculation for

Sommerfeld number = 0.42

$$L/D = \frac{1}{4}$$

from Fig 5.9 $h_0/c = 0.26$

minimum film thickness $h_0 = 0.0000224271$

from Fig 5.11 $(R/c)f = 14$

bearing coefficient of friction $f = 0.0241523$

from Fig 5.14 $P/p_{max} = 0.27$

maximum pressure within oil film $p_{max} = 7.40741 \times 10^6$ psi

from Fig 5.10 the position angle of minimum film thickness $\phi = 36^\circ$

from Fig 5.15 terminating position of the oil film $\theta_{p0} = 46^\circ$

from Fig 5.15 angular position angle of maximum pressure $\theta_{pmax} = 13.5^\circ$

from Fig 5.12 $Q/RcnL = 5.35$

total flow $Q = 0.0000192284$ m³/s

from Fig 5.13 $Q_s/Q = 0.84$. Of the volume of oil Q pumped by the rotating journal, an amount Q_s flows out the ends. The side leakage that must be made up by the oil represents 84% of the flow. The remaining 16% of the flow is recirculated.

Same calculation for any $S \in [0.082, 0.21]$

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(* Problem 5.11 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 30 at 80°C"
W = 30000; (* N *)
n = 1000/60; (* rps *)
μ = 12*10^-3; (* Pa sec - from Fig.5.3 *)
P = 0.8*10^6; (* Pa - from Table 5.2 *)

Smin = 0.082;
Smax = 0.21;

Diam = Sqrt[W/P];
Print["D = ", Diam, " m = ", 10^3*Diam, " mm"];
Print["Select D = 200 mm"];
Diam = 0.2; (* m *)
R = Diam/2; (* m *)
L = Diam; (* m *)

c = R Sqrt[(μ n)/(P Smin)];
Print["For Smin = ", Smin, " the clearance c = ", c, " m = ", c*10^3, " mm"];

c = R Sqrt[(μ n)/(P Smax)];
Print["For Smax = ", Smax, " the clearance c = ", c, " m = ", c*10^3, " mm"];

SAE 30 at 80°C

D = 0.193649 m = 193.649 mm

Select D = 200 mm

For Smin = 0.082 the clearance c = 0.000174608 m = 0.174608 mm

For Smax = 0.21 the clearance c = 0.000109109 m = 0.109109 mm
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```
(* Problem 5.12 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 20 at 60°C"
W = 10000; (* N *)
n = 1000/60; (* rps *)
μ = 18*10^-3; (* Pa sec - from Fig.5.3 *)
P = 0.8*10^6; (* Pa - from Table 5.2 *)

Smin = 0.037;
Smax = 0.35;

Diam = Sqrt[W/P];
Print["D = ", Diam, " m = ", 10^3*Diam, " mm"];
Print["Select D = 120 mm"];
Diam = 0.12; (* m *)
R = Diam/2; (* m *)
L = Diam/2; (* m *)

c = R Sqrt[(μ n)/(P Smin)];
Print["For Smin = ", Smin, " the clearance c = ", c, " m = ", c*10^3, " mm"];

c = R Sqrt[(μ n)/(P Smax)];
Print["For Smax = ", Smax, " the clearance c = ", c, " m = ", c*10^3, " mm"];

SAE 20 at 60°C

D = 0.111803 m = 111.803 mm

Select D = 120 mm

For Smin = 0.037 the clearance c = 0.000191014 m = 0.191014 mm

For Smax = 0.35 the clearance c = 0.0000621059 m = 0.0621059 mm
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```

(* Problem 5.13 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"SAE 30 at 65°C"
d=100. 10^-3 ; (* m *)
R=d/2 ; (* m *)
n0=1200; (* rpm *)
n=n0/60.; (* rps *)
W=20000; (* N *)

"mu=22 mPa s"
mu=22*10^(-3); (* Pa s *)

"select P=0.8 MPa unit load for gear reducers"
P=1.5 10^6; (* Pa *)

L=W/(P d); (* m *)
Print["L=W/(P D)= ",L];

L=0.1;
"Select L=100 mm "

P=W/(d L);
Print["P= ",P," Pa"];
Smin=0.082;
Smax=0.21;

(* S=(R/c)^2 (mu n/P) *)
cf=R/(Smin P/(mu n))^0.5;
cl=R/(Smax P/(mu n))^0.5;
Print[" min. friction => c=",cf," m"];
Print[" max load => c=",cl," m"];

Smax=0.21; Hl=0.52; Fl=5; ql=4.1 R cl n L; qsl=0.54 ql;
Smin=0.082;Hf=0.31; Ff=2.4; qf=4.5 R cf n L; qsf=0.76 ql;

hl=cl Hl ;
hf=cf Hf ;

ff=Ff cf/R;
fl=Fl cl/R;

clm=cl 10^3;
cfm=cf 10^3;

hlm=hl 10^3;
hfm=hf 10^3;

Print["c=cl=",cl," S=Smax=",Smax," h0=",hl," f=",fl];
Print["c=cf=",cf," S=Smin=",Smin," h0=",hf," f=",ff];

Print["c[mm]          S          h[mm]          f"];
Print[clm,"          ",Smax,"          ",hlm,"          ",fl];
Print[cfm,"          ",Smin,"          ",hfm,"          ",ff];

```

```

homin=0.005+0.00004 d 10^3;
Print[" homin = 0.005+0.00004 D = ",homin," mm"];

"extreme case c=0.08189 mm =>"
Cs=2;
S=(R/cf)^2 (mu n/(Cs P));
Print["S=",S];
" from figure => h0/c=0.06"
hos=0.06 cf;
Print[" ho = 0.06 c = ",hos 10^3," mm > homin "];

"friction torque for tightest bearing fit"
"c=0.0511766 f=0.00511766"

Tf=W f l d/2;
Print["Tf = W f d/2 = ",Tf," N m"];
FP=n0 Tf/9549;
Print["friction power = n[rpm] Tf[N m]/9549 = ",FP," kW"];

SAE 30 at 65°C

mu=22 mPa s

select P=0.8 MPa unit load for gear reducers

L=W/(P D)= 0.133333

Select L=100 mm

P= 2. ×106 Pa

min. friction => c=0.0000818982 m

max load => c=0.0000511766 m

c=c1=0.0000511766 S=Smax=0.21 h0=0.0000266118 f=0.00511766

c=cf=0.0000818982 S=Smin=0.082 h0=0.0000253884 f=0.00393111

c[mm] S h[mm] f

0.0511766 0.21 0.0266118 0.00511766

0.0818982 0.082 0.0253884 0.00393111

homin = 0.005+0.00004 D = 0.009 mm

extreme case c=0.08189 mm =>

S=0.041

from figure => h0/c=0.06

ho = 0.06 c = 0.00491389 mm > homin

friction torque for tightest bearing fit

c=0.0511766 f=0.00511766

Tf = W f d/2 = 5.11766 N m

```

friction power = n[rpm] Tf[N m]/9549 = 0.643124 kW