```
(* Program II .3 .1 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
d = 1; (* in - major diameter *)
p = 0.2; (* in - pitch *)
μ = 0.15;
M = 60; (* lb-in *)

l = 2 p; (* in - lead *)
Print["Lead l = ", l, " in"];

dm = d - p / 2;
Print["dm = ", dm, " in"];

λ = ArcTan[l / (dm N[Pi])];
Print["λ = ", λ / Degree, " °"];

θ = ArcTan[μ];
Print["Friction angle θ = ", θ / Degree, " °"];

If[θ > λ, Print["the screw is sef-locking"],
  Print["the screw is not sef-locking"]];

(* to the right *)
F = M / (dm / 2 Tan[θ - λ]);
Print["Force required to advance screw to the right F = ", F, " lb"];

(* to the left *)
F = M / (dm / 2 Tan[θ + λ]);
Print["Force required to advance screw to the left F = ", F, " lb"];
```

```
Lead l = 0.4 in

dm = 0.9 in

λ = 8.05226 °

Friction angle θ = 8.53077 °

the screw is sef-locking

Force required to advance screw to the right F = 15964.8 lb

Force required to advance screw to the left F = 447.742 lb
```

```
(* Program II .3 .2 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];
"----------------"
" input data "
"----------------"
" (pitch) mean diameter dm [mm] "
" screw pitch p [mm] "
" coefficient of friction for thread μ "
" coefficient of collar friction for thread μc "
" mean collar diameter dc [mm]"
" external load F [kN]"
data = {dm → 30, p → 4, μ -> 0.08, μc -> 0.08, dc → 40, F → 6.4}
"----------------"
"solution"
"----------------"
l = 2 p; (* lead *)

Ml = 0.5 F dm (π μ dm - l) / (π dm + μ l) + 0.5 F dc μc;
Print[
 "moment to lower load Ml = 0.5 F dm ( π μ dm - l )/( π dm + μ l) + 0.5 F dc μc "]
Print["Ml = ", Ml /. data, " [N m] = ", 10^(-3) Ml /. data, " [N m]"]

sf = (π μ dm - l);
"sef-locking condition: ( π μ dm - l ) > 0 "
Print["( π μ dm - l ) = ", sf /. data]
If[(sf /. data) > 0, Print["the screw is sef-locking"],
 Print["the screw is not sef-locking"]]

Mr = 0.5 F dm ( l + π μ dm) / (π dm - μ l) + 0.5 F dc μc; (* momemnt to raise the load *)
e = F l / (2 π Mr);
Print["efficiency e = F l/( 2 π Mr ) = ", e /. data]
```

```
----------------

 input data

----------------

 (pitch) mean diameter dm [mm]

 screw pitch p [mm]

 coefficient of friction for thread μ

 coefficient of collar friction for thread μc

 mean collar diameter dc [mm]

 external load F [kN]

{dm → 30, p → 4, μ → 0.08, μc → 0.08, dc → 40, F → 6.4}
```

```
----------------

solution

----------------

moment to lower load Ml = 0.5 F dm ( π μ dm - l )/( π dm + μ l) + 0.5 F dc μc

Ml = 9.77443 [N m] = 0.00977443 [N m]

sef-locking condition: ( π μ dm - l ) > 0

( π μ dm - l ) = -0.460178

the screw is not sef-locking

efficiency e = F l/( 2 π Mr ) = 0.311294
```

```
(* Program II .3 .3 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];
"----------------"
" input data "
"----------------"
" (pitch) mean diameter dm [mm] "
" screw pitch p [mm] "
" coefficient of friction for thread μ "
data = {dm → 40, p → 12, μ -> 0.15}
"----------------"
"solution"
"----------------"
l = 2 p; (* lead *)

sf = (π μ dm - l);
"sef-locking condition: ( π μ dm - l ) > 0 "
Print["( π μ dm - l ) = ", sf /. data]
If[(sf /. data) > 0, Print["the screw is sef-locking"],
  Print["the screw is not sef-locking"]];
```

```
----------------

 input data

----------------

 (pitch) mean diameter dm [mm]

 screw pitch p [mm]

 coefficient of friction for thread μ

{dm → 40, p → 12, μ → 0.15}

----------------

solution

----------------

sef-locking condition: ( π μ dm - l ) > 0

( π μ dm - l ) = -5.15044

the screw is not sef-locking
```

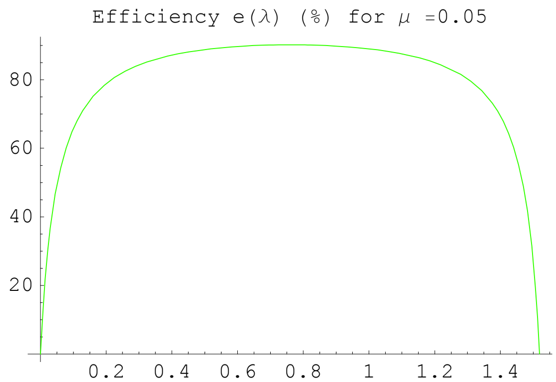
```
(* Program II .3 .4 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];
"----------------"
" input data "
"----------------"
" (pitch) mean diameter dm = 1 [in] "
" screw pitch p = 1/5 [in] "
" coefficient of static friction μ = 0.20 "
data = {dm → 1, p → 1 / 5, μ -> 0.20};
"----------------"
"solution"
"----------------"
l = p; (* lead for sigle threaded*)

λ = N[ArcTan[l / (π dm)] /. data];
"helix angle: λ = ArcTan[l/(π dm)] "
Print["λ = ", λ / Degree, "° "];

θ = ArcTan[μ] /. data;
Print["Friction angle θ = ", θ / Degree, " °"];
```

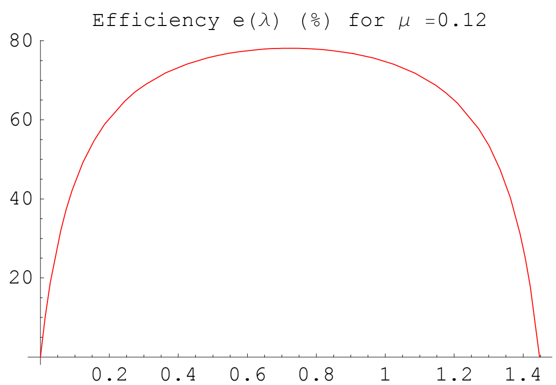
```
----------------

 input data

----------------

 (pitch) mean diameter dm = 1 [in]

 screw pitch p = 1/5 [in]

 coefficient of static friction μ = 0.20

----------------

solution

----------------

helix angle: λ = ArcTan[l/(π dm)]

λ = 3.64265°

Friction angle θ = 11.3099 °
```

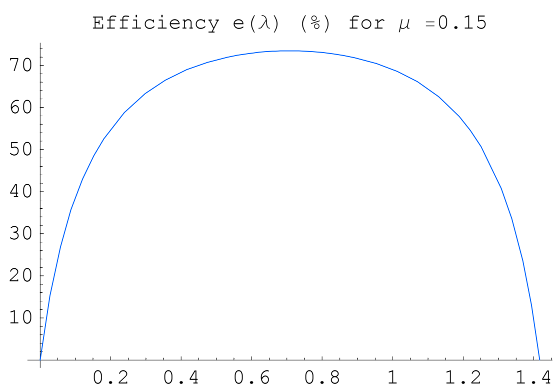
```
(* Program II .3 .5 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(*Given data*)
d = 3.; (* in *) (* major diameter *)
F = 4000.; (* lb *) (* weight of the load *)
dc = 4.; (* in *) (* mean diameter of plain thrust collar *)
μ = 0.08; μc = 0.1; (* coefficients of friction *)

(*Assumption: coefficient of starting friction is about one-
    third higher than the coefficient of friction (running friction)
     μs=(4/3) μ ;  μcs=(4/3) μc
 *)

(* a *)
p = 1 / 2.; (* in *) (* screw pitch; Standard sizes of power screw threads) for d=
  3 in. there are 2 (two) threads per inch, p=(1 in.)/2=0.5 in. *)
l = 3 p;  (* lead, because of the triple thread *)
dm = d - p / 2; (* mean diameter of thread contact from figure *)
λ = ArcTan[l / (π dm)]; (* rad *) (* lead angle *)

(* b *)
(*For starting, increase the coefficients of running friction by one third*)
μs = (4 / 3) μ;
 μcs = (4 / 3) μc ;
 (* coefficients of static friction *)
α = 14.5 * π / 180; (* rad *)
(* from Figure II .3 .6, 2 α=29 deg yields α=14.5 deg (Acme)*)
αn = ArcTan[Tan[α] * Cos[λ]]; (* thread angle in the normal plane *)
(* the torque for raising the load: *)
(* Moment using coefficients of static friction *)
Mrs =  0.5 F dm ( π μs dm + l Cos[αn]) / ( π dm Cos[αn] - μs l ) + 0.5 F dc μcs ;
(* Moment using coefficients of running friction *)
Mr =  0.5 F dm ( π μ dm + l Cos[αn]) / ( π dm Cos[αn] - μ l ) + 0.5 F dc μc;
(* for lowering the load*)
Mls =  0.5 F dm ( π μs dm - l Cos[αn]) / ( π dm Cos[αn] + μs l ) + 0.5 F dc μcs ;
Ml =  0.5 F dm ( π μ dm - l Cos[αn]) / ( π dm Cos[αn] + μ l ) + 0.5 F dc μc;

(* c *)
(* Efficiency (the ratio of friction-free moment to actual moment) *)
Mr0 = F l / (2 π);
e = F l / (2 π Mr);


Print["Screw pitch p = (1 in.)/2 = ", p, " in"];
Print["Lead l = 3 p = ", l, " in"];
Print["Mean pitch diameter dm = d-p/2 = ", dm, " in"];
Print["Lead angle λ=ArcTan[l/(π  dm)] = ", N[λ] * 180 / Pi, " deg"];
```

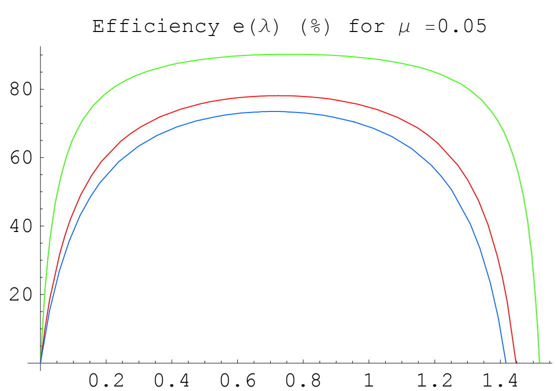
```
Print["Thread angle αn=ArcTan[Tan[α]*Cos[λ]] = ", αn * 180 / Pi, " deg"];
Print["Moment for raising the load with starting friction = ", Mrs, " lb in"];
Print["Moment for lowering the load with starting friction = ", Mls, " lb in"];
Print["Moment for raising the load with running friction = ", Mr, " lb in"];
Print["Moment for raising the load with no friction = ", N[Mr0], " lb in"];
Print[
  "Efficiency (the ratio of friction-free moment to actual moment) e = ", e, " %"];

deg = 180 / N[Pi];

μ = 0.05;
graph1 =
  Plot[(Cos[αn] - μ * Tan[λ]) / (Cos[αn] + μ * Cot[λ]) * 100, {λ, 0.0, 1.5192087045738232 },
   PlotLabel → "Efficiency e(λ) (%) for μ =0.05", PlotStyle → {Hue[.3]}];

μ = 0.12;
graph2 =
  Plot[(Cos[αn] - μ * Tan[λ]) / (Cos[αn] + μ * Cot[λ]) * 100, {λ, 0.0, 1.4475046197126569},
   PlotLabel → "Efficiency e(λ) (%) for μ =0.12", PlotStyle → {Hue[1]}];

μ = 0.15;
graph3 =
  Plot[(Cos[αn] - μ * Tan[λ]) / (Cos[αn] + μ * Cot[λ]) * 100, {λ, 0.0, 1.4171173868835931},
   PlotLabel → "Efficiency e(λ) (%) for μ =0.15", PlotStyle → {Hue[.6]}];

Show[graph1, graph2, graph3];
```

```
Screw pitch p = (1 in.)/2 = 0.5 in

Lead l = 3 p = 1.5 in

Mean pitch diameter dm = d-p/2 = 2.75 in

Lead angle λ=ArcTan[l/(π  dm)] = 9.84971 deg

Thread angle αn=ArcTan[Tan[α]*Cos[λ]] = 14.2951 deg

Moment for raising the load with starting friction = 2657.41 lb in

Moment for lowering the load with starting friction = 723.704 lb in

Moment for raising the load with running friction = 2229.48 lb in

Moment for raising the load with no friction = 954.93 lb in

Efficiency (the ratio of friction-free moment to actual moment) e = 0.42832 %
```


Efficiency e(λ) (%) for μ =0.05
80
60
40
20
0.2 0.4 0.6 0.8 1 1.2 1.4


Efficiency e(λ) (%) for μ =0.12
80
60
40
20
0.2 0.4 0.6 0.8 1 1.2 1.4


Efficiency e(λ) (%) for μ =0.15
70
60
50
40
30
20
10
0.2 0.4 0.6 0.8 1 1.2 1.4


Efficiency e(λ) (%) for μ =0.05
80
60
40
20
0.2 0.4 0.6 0.8 1 1.2 1.4

```
(* Problem II .3 .6 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* Given data *)
d = 0.5;
W = 250; (* clamping force *)
dc = 5 / 8; (* in - collar diameter *)
μ = 0.1; μc = 0.1; (* coefficients of friction *)
p = 0.1;
l = 0.1;

α = 14.5 Degree;

dm = d - p / 2;
Print["dm = ", dm, " in"];

λ = ArcTan[l / (N[Pi] dm)];
Print["λ = ", λ / Degree, " °"];

αn = ArcTan[Tan[α] Cos[λ]];
Print["αn = ", αn / Degree, " °"];

T = ((W dm) / 2) ((μ N[Pi] dm + l Cos[αn]) / (N[Pi] dm Cos[αn] - μ l)) + (W μc dc) / 2;
Print["At the end of a 6-in handle, the clamping force required = ", T / 6, " lb"];
```

```
dm = 0.45 in

λ = 4.04611 °

αn = 14.4654 °

At the end of a 6-in handle, the clamping force required = 2.94543 lb
```

```
(* Program II.3.7 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

d=14. 10^(-3); (* m *) (* major diameter *)
dr=12. 10^(-3); (* m *) (* minor diameter *)
p=2. 10^(-3); (* m *) (* pitch *)
l=60. 10^(-3); (* m *) (* joint axial length *)

Print["major thread diameter d=",d," m"];
Print["minor thread diameter dr=",dr," m"];
Print["pitch p=",p," m"];
Print["joint axial length l=",l," m"];

"modulus of elasticity [GPa] E=206.8 for steel"
Eb=206.8 10^9;
Print["modulus of elasticity of the bolt Eb=",Eb," Pa"];

"a. Bolt stiffness kb"
lt=l/3;
lte=lt+0.4 dr;
Print["effective length of threaded portion of the bolt lte=lt+0.4 dr=",lte," m"];
ls=(2 l)/3;
lse=ls+0.4 d;
Print["effective length of the unthreaded portion of the bolt lse=ls+0.4 d=",lse,"
m"];

Ar=N[Pi] dr^2/4.;
Print["minor diameter area Ar=Pi dr^2/4=",Ar," m^2"];
As=N[Pi] d^2/4.;
Print["major diameter area As=Pi d^2/4=",As," m^2"];

kt=Ar Eb/lte;
Print["stiffness of the threaded portion  kt=Ar Eb/lte=",kt," N/m"];
ks=As Eb/lse;
Print["stiffness of the unthreaded portion  ks=As Eb/lse=",ks," N/m"];
kb=kt ks/(kt+ks);
Print["bolt stiffness kb=kt ks/(kt+ks)=",kb," N/m"];

Print["joint axial length l=",l," m"];
l1=l2=l/2;
"axial length of the parts l1=l2=l/2"
"modulus of elasticity [GPa] E=100.0 for gray cast iron"
Ec=100 10^9;
Print["modulus of elasticity of the part Ec=",Ec," Pa"];
"Joint Stiffness kc"

"b. Stiffness of clamped parts (Shigley)"
Print["J.E.Shigley & C.R.Mischke, Mechanical Engineering Design, McGraw-Hill 1989"];
kc=0.577 N[Pi] Ec d/(2 Log[5 (0.577 l + 0.5 d)/(0.577 l + 2.5 d)]);
Print["kc=0.577 Pi Ec d/(2 Log[5 (0.577 l + 0.5 d)/(0.577 l + 2.5 d)])"]
Print["stiffness of clamped parts (Shigley) kc=",kc," N/m"];

"c. Stiffness of clamped parts (Wileman)"
Print["J.Wileman et al.,1990"];
"constants A=0.78715; B=0.62873 for steel"
```

```
"constants A=0.77871; B=0.61616 for cast iron"
"joint stiffness: kc = Ec d A e^(B d/l)"
"parts of the joint: cast iron "
A=0.77871;
B=0.61616;
kcw=Ec d A E^(B d/l);
Print["joint stiffness (Wileman)  kc=",kcw," N/m"];
```

major thread diameter d=0.014 m

minor thread diameter dr=0.012 m

pitch p=0.002 m

joint axial length l=0.06 m

modulus of elasticity [GPa] E=206.8 for steel

modulus of elasticity of the bolt Eb=2.068×10^{11} Pa

a. Bolt stiffness kb

effective length of threaded portion of the bolt lte=lt+0.4 dr=0.0248 m

effective length of the unthreaded portion of the bolt lse=ls+0.4 d=0.0456 m

minor diameter area Ar=Pi dr^2/4=0.000113097 m^2

major diameter area As=Pi d^2/4=0.000153938 m^2

stiffness of the threaded portion kt=Ar Eb/lte=9.43086×10^{8} N/m

stiffness of the unthreaded portion ks=As Eb/lse=6.98123×10^{8} N/m

bolt stiffness kb=kt ks/(kt+ks)=4.01161×10^{8} N/m

joint axial length l=0.06 m

axial length of the parts l1=l2=l/2

modulus of elasticity [GPa] E=100.0 for gray cast iron

modulus of elasticity of the part Ec=100000000000 Pa

Joint Stiffness kc

b. Stiffness of clamped parts (Shigley)

J.E.Shigley & C.R.Mischke, Mechanical Engineering Design, McGraw-Hill 1989

kc=0.577 Pi Ec d/(2 Log[5 (0.577 l + 0.5 d)/(0.577 l + 2.5 d)])

stiffness of clamped parts (Shigley) kc=1.15884×10^{9} N/m

c. Stiffness of clamped parts (Wileman)

J.Wileman et al.,1990

constants A=0.78715; B=0.62873 for steel

constants A=0.77871; B=0.61616 for cast iron joint stiffness: kc = Ec d A e^(B d/l)

parts of the joint: cast iron

joint stiffness (Wileman) $kc=1.25876\times10^{9}$ N/m

```
(* Program II.3.8 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

d=5/8; (* in *) (* major diameter *)
dr=0.5135; (* in *) (* minor diameter *)
p=1/11; (* m *) (* pitch *)
l=1.8; (* in *) (* joint axial length *)

Print["major thread diameter d=",d," in"];
Print["minor thread diameter dr=",dr," in"];
Print["pitch p=",p," in"];
Print["joint axial length l=",l," in"];

"modulus of elasticity [Mpsi] E=30 for steel"
Eb=30 10^6;
Print["modulus of elasticity of the bolt Eb=",Eb," psi"];

"a. Bolt stiffness kb"
lt=l/3;
lte=lt+0.4 dr;
Print["effective length of threaded portion of the bolt lte=lt+0.4 dr=",lte," in"];
ls=(2 l)/3;
lse=ls+0.4 d;
Print["effective length of the unthreaded portion of the bolt lse=ls+0.4 d=",lse,"
in"];

At = 0.7854(d - 0.9743/11)^2;
Print["tensile stress area At = 0.7854(d - 0.9743/11)^2 = ", At, " in^2"];

Ar=N[Pi] dr^2/4.;
Print["minor diameter area Ar=Pi dr^2/4=",Ar," in^2"];
As=N[Pi] d^2/4.;
Print["major diameter area As=Pi d^2/4=",As," in^2"];

kt=Ar Eb/lte;
Print["stiffness of the threaded portion  kt=Ar Eb/lte=",kt," lb/in"];
ks=As Eb/lse;
Print["stiffness of the unthreaded portion  ks=As Eb/lse=",ks," lb/in"];
kb = (As At Eb)/(As lt + At ls);
Print["bolt stiffness kb=kt ks/(kt+ks)=",kb," lb/in"];

Print["joint axial length l=",l," in"];
l1=l/3;
l2=(2 l)/3;
"axial length of the parts l1=l/3, l2=2l/3"
"modulus of elasticity [Mpsi] E=12 for gray cast iron"
Ec=12 10^6;
Print["modulus of elasticity of the cast iron part Ec=",Ec," psi"];
"Joint Stiffness kc"

"b. Stiffness of clamped parts"
k1=(0.577 N[Pi] Ec d)/(2 Log[5 (0.577 l1 + 0.5 d)/(0.577 l1 + 2.5 d)]);
Print["stiffness of the cast iron clamped part k1=",k1," lb/in"];
k2=(0.577 N[Pi] Eb d)/(2 Log[5 (0.577 l2 + 0.5 d)/(0.577 l2 + 2.5 d)]);
Print["stiffness of the steel clamped part k2=",k2," lb/in"];
```

```
kc = (k1 k2)/(k1 + k2);
Print["the resulting stiffness of the clamped parts is kc = ", kc, " lb/in"];

"c. Stiffness of clamped parts"
"constants A=0.78715; B=0.62873 for steel"
"constants A=0.77871; B=0.61616 for cast iron"
A=0.77871;
B=0.61616;
kcw1=Ec d A E^(B d/l1);
Print["stiffness of the cast iron clamped part kcw1=",kcw1," lb/in"];
A=0.78715;
B=0.62873;
kcw2=Eb d A E^(B d/l2);
Print["stiffness of the steel clamped part kcw2=",kcw2," lb/in"];
kcw = (kcw1 kcw2)/(kcw1 + kcw2);
Print["the resulting stiffness of the clamped parts is kcw = ", kcw, " lb/in"];
```

major thread diameter d= $\frac{5}{8}$ in

minor thread diameter dr=0.5135 in

pitch p= $\frac{1}{11}$ in

joint axial length l=1.8 in

modulus of elasticity [Mpsi] E=30 for steel

modulus of elasticity of the bolt Eb=30000000 psi

a. Bolt stiffness kb

effective length of threaded portion of the bolt lte=lt+0.4 dr=0.8054 in

effective length of the unthreaded portion of the bolt lse=ls+0.4 d=1.45 in

tensile stress area At = 0.7854(d - 0.9743/11)^2 = 0.226002 in^2

minor diameter area Ar=Pi dr^2/4=0.207096 in^2

major diameter area As=Pi d^2/4=0.306796 in^2

stiffness of the threaded portion kt=Ar Eb/lte= 7.71401×10^{6} lb/in

stiffness of the unthreaded portion ks=As Eb/lse= 6.34751×10^{6} lb/in

bolt stiffness kb=kt ks/(kt+ks)= 4.56883×10^{6} lb/in

joint axial length l=1.8 in

axial length of the parts l1=l/3, l2=2l/3

modulus of elasticity [Mpsi] E=12 for gray cast iron

modulus of elasticity of the cast iron part Ec=12000000 psi

Joint Stiffness kc

b. Stiffness of clamped parts

stiffness of the cast iron clamped part k1=1.24606×10^{7} lb/in

stiffness of the steel clamped part k2=2.12102×10^{7} lb/in

the resulting stiffness of the clamped parts is kc = 7.8493×10^{6} lb/in

c. Stiffness of clamped parts

constants A=0.78715; B=0.62873 for steel

constants A=0.77871; B=0.61616 for cast iron

stiffness of the cast iron clamped part kcw1=1.10964×10^{7} lb/in

stiffness of the steel clamped part kcw2=2.04774×10^{7} lb/in

the resulting stiffness of the clamped parts is kcw = 7.19664×10^{6} lb/in

```
(* Program II.3.9 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

d=N[12 10^(-3)]; (* m *) (* major diameter *)
p=N[1.25 10^(-3)]; (* m *) (* pitch *)
l=N[80 10^(-3)]; (* m *) (* joint axial length *)
dr=N[(d - p)]; (* m *) (* minor diameter *)

Print["major thread diameter d=",d," m"];
Print["minor thread diameter dr=",dr," m"];
Print["pitch p=",p," m"];
Print["joint axial length l=",l," m"];

"modulus of elasticity [GPa] E=206.8 for steel"
Eb=206.8 10^9;
Print["modulus of elasticity of the bolt Eb=",Eb," Pa"];

"Bolt stiffness kb"
lt=l/4;
lte=lt+0.4 dr;
Print["effective length of threaded portion of the bolt lte=lt+0.4 dr=",lte," m"];
ls=(3 l)/4;
lse=ls+0.4 d;
Print["effective length of the unthreaded portion of the bolt lse=ls+0.4 d=",lse," m"];

Ar=N[Pi] dr^2/4.;
Print["minor diameter area Ar=Pi dr^2/4=",Ar," m^2"];
As=N[Pi] d^2/4.;
Print["major diameter area As=Pi d^2/4=",As," m^2"];

kt=Ar Eb/lte;
Print["stiffness of the threaded portion  kt=Ar Eb/lte=",kt," N/m"];
ks=As Eb/lse;
Print["stiffness of the unthreaded portion  ks=As Eb/lse=",ks," N/m"];
kb=kt ks/(kt+ks);
Print["bolt stiffness kb=kt ks/(kt+ks)=",kb," N/m"];

Print["joint axial length l=",l," m"];
l1=l2=l/2;
"axial length of the parts l1=l2=l/2"
"modulus of elasticity [GPa] E=100.0 for gray cast iron"
Ec=100 10^9;
Print["modulus of elasticity of the part Ec=",Ec," Pa"];
"Joint Stiffness kc"

"Stiffness of clamped parts (Shigley)"
Print["J.E.Shigley & C.R.Mischke, Mechanical Engineering Design, McGraw-Hill 1989"];
kc=0.577 N[Pi] Ec d/(2 Log[5 (0.577 l + 0.5 d)/(0.577 l + 2.5 d)]);
Print["kc=0.577 Pi Ec d/(2 Log[5 (0.577 l + 0.5 d)/(0.577 l + 2.5 d)])"]
Print["stiffness of clamped parts (Shigley) kc=",kc," N/m"];

"minimum required value of initial preload to prevent loss of compression"
Fc = 0;
Fe = 20*10^3 - 0;
Fi = Fc + Fe (kc/(kb + kc));
Print["Fi = ", Fi, " N"];
```

```
major thread diameter d=0.012 m

minor thread diameter dr=0.01075 m
```

pitch p=0.00125 m

joint axial length l=0.08 m

modulus of elasticity [GPa] E=206.8 for steel

modulus of elasticity of the bolt Eb=2.068×10^{11} Pa

Bolt stiffness kb

effective length of threaded portion of the bolt lte=lt+0.4 dr=0.0243 m

effective length of the unthreaded portion of the bolt lse=ls+0.4 d=0.0648 m

minor diameter area Ar=Pi dr^2/4=0.0000907626 m^2

major diameter area As=Pi d^2/4=0.000113097 m^2

stiffness of the threaded portion kt=Ar Eb/lte=7.72416×10^{8} N/m

stiffness of the unthreaded portion ks=As Eb/lse=3.60934×10^{8} N/m

bolt stiffness kb=kt ks/(kt+ks)=2.45989×10^{8} N/m

joint axial length l=0.08 m

axial length of the parts l1=l2=l/2

modulus of elasticity [GPa] E=100.0 for gray cast iron

modulus of elasticity of the part Ec=100000000000 Pa

Joint Stiffness kc

Stiffness of clamped parts (Shigley)

J.E.Shigley & C.R.Mischke, Mechanical Engineering Design, McGraw-Hill 1989

kc=0.577 Pi Ec d/(2 Log[5 (0.577 l + 0.5 d)/(0.577 l + 2.5 d)])

stiffness of clamped parts (Shigley) kc=8.83584×10^{8} N/m

minimum required value of initial preload to prevent loss of compression

Fi = 15644.6 N

```
(* Program II.3.10 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

d=N[10 10^(-3)]; (* m *) (* major diameter *)
p=N[1 10^(-3)]; (* m *) (* pitch *)
l=N[60 10^(-3)]; (* m *) (* joint axial length *)
H=(.5) Sqrt[3] p;
dr=N[(d - 2 5 H/8)]; (* m *) (* minor diameter *)

Print["major thread diameter d=",d," m"];
Print["minor thread diameter dr=",dr," m"];
Print["pitch p=",p," m"];
Print["joint axial length l=",l," m"];

"modulus of elasticity [GPa] E=206.8 for steel"
Eb=206.8 10^9;
Print["modulus of elasticity of the bolt Eb=",Eb," Pa"];

"Bolt stiffness kb"
lt=l/2;
lte=lt+0.4 dr;
Print["effective length of threaded portion of the bolt lte=lt+0.4 dr=",lte," m"];
ls=l/2;
lse=ls+0.4 d;
Print["effective length of the unthreaded portion of the bolt lse=ls+0.4 d=",lse," m"];

Ar=N[Pi] dr^2/4.;
Print["minor diameter area Ar=Pi dr^2/4=",Ar," m^2"];
As=N[Pi] d^2/4.;
Print["major diameter area As=Pi d^2/4=",As," m^2"];

kt=Ar Eb/lte;
Print["stiffness of the threaded portion  kt=Ar Eb/lte=",kt," N/m"];
ks=As Eb/lse;
Print["stiffness of the unthreaded portion  ks=As Eb/lse=",ks," N/m"];
kb=kt ks/(kt+ks);
Print["bolt stiffness kb=kt ks/(kt+ks)=",kb," N/m"];

Print["joint axial length l=",l," m"];
l1=l/4;
l2=(3 l)/4;
"axial length of the parts l1=l/4, l2=3l/4"
"modulus of elasticity [GPa] E=100 for gray cast iron"
Ec=100 10^9;
Print["modulus of elasticity of the cast iron part Ec=",Ec," Pa"];
"Joint Stiffness kc"

"Stiffness of clamped parts"
"constants A=0.78715; B=0.62873 for steel"
"constants A=0.77871; B=0.61616 for cast iron"
A=0.77871;
B=0.61616;
kcw1=Ec d A E^(B d/l1);
Print["stiffness of the cast iron clamped part kcw1=",kcw1," N/m"];
A=0.78715;
B=0.62873;
kcw2=Eb d A E^(B d/l2);
Print["stiffness of the steel clamped part kcw2=",kcw2," N/m"];
kcw = (kcw1 kcw2)/(kcw1 + kcw2);
Print["the resulting stiffness of the clamped parts is kcw = ", kcw, " N/m"];

"minimum force in the plates"
Fi = 5*10^3;
Fe = 20*10^3 - 0;
Fc = Fi - Fe (kcw/(kb + kcw));
Print["Fc = ", Fc, " N"];
```

```
major thread diameter d=0.01 m
```

minor thread diameter dr=0.00891747 m

pitch p=0.001 m

joint axial length l=0.06 m

modulus of elasticity [GPa] E=206.8 for steel

modulus of elasticity of the bolt Eb=2.068×10^{11} Pa

Bolt stiffness kb

effective length of threaded portion of the bolt lte=lt+0.4 dr=0.033567 m

effective length of the unthreaded portion of the bolt lse=ls+0.4 d=0.034 m

minor diameter area Ar=Pi dr^2/4=0.0000624558 m^2

major diameter area As=Pi d^2/4=0.0000785398 m^2

stiffness of the threaded portion kt=Ar Eb/lte=3.84779×10^{8} N/m

stiffness of the unthreaded portion ks=As Eb/lse=4.77707×10^{8} N/m

bolt stiffness kb=kt ks/(kt+ks)=2.13118×10^{8} N/m

joint axial length l=0.06 m

axial length of the parts l1=l/4, l2=3l/4

modulus of elasticity [GPa] E=100 for gray cast iron

modulus of elasticity of the cast iron part Ec=100 000 000 000 Pa

Joint Stiffness kc

Stiffness of clamped parts

constants A=0.78715; B=0.62873 for steel

constants A=0.77871; B=0.61616 for cast iron

stiffness of the cast iron clamped part kcw1=1.17428×10^{9} N/m

stiffness of the steel clamped part kcw2=1.87192×10^{9} N/m

the resulting stiffness of the clamped parts is kcw = 7.21607×10^{8} N/m

minimum force in the plates

Fc = -10 440. N

```
(* Program II.3.11 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
kc = 7 kb;
Fe = 2500;

"a. minimum required value of initial preload to prevent loss of compression"
Fc = 0;
Fi = Fc + Fe (kc/(kb + kc));
Print["Fi = ", N[Fi], " lb"];

"b. minimum force in the plates at 3500 lb preload"
Fi = 3500;
Fc = Fi - Fe (kc/(kb + kc));
Print["Fc = ", N[Fc], " lb"];
```

```
a. minimum required value of initial preload to prevent loss of compression

Fi = 2187.5 lb

b. minimum force in the plates at 3500 lb preload

Fc = 1312.5 lb
```

```
(* Program II.3.12 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
kc = 7 kb;
Fe = 8500;

"a. minimum required value of initial preload to prevent loss of compression"
Fc = 0;
Fi = Fc + Fe (kc/(kb + kc));
Print["Fi = ", N[Fi], " lb"];

"b. minimum force in the plates at 3500 lb preload"
Fi = 3500;
Fc = Fi - Fe (kc/(kb + kc));
Print["Fc = ", N[Fc], " lb"];
```

```
a. minimum required value of initial preload to prevent loss of compression

Fi = 7437.5 lb

b. minimum force in the plates at 3500 lb preload

Fc = -3937.5 lb
```

```
(* Program II.3.13 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
d = 3/4; (* in *)
n = 16;
p = 1/16;
kc = 6 kb;
nf = 2;
Sp = 85*10^3; (* psi - from Table II.3.4 *)

Const = N[kb/(kb + kc)];
Print["the joint constant Const = ", Const];

At = 0.7854 (d - 0.9382 p)^2;
Print["tensile stress area At = ", At, " in^2"];

Fp = At Sp;
Print["the proof load Fp = ", Fp, " lb"];

Fi = 0.75 Fp;
Print["the preload for reused connections is Fi = ", Fi, " lb"];

Fmaxb = (Sp At - Fi)/(nf Const);
Print["the maximum external load applied to the bolt Fmaxb = ", Fmaxb, " lb"];

Fmax = Fi/(nf - nf Const);
Print["maximum external load applied to the joint before separation Fmax = ", Fmax, "
lb"];
```

```
the joint constant Const = 0.142857

tensile stress area At = 0.375407 in^2

the proof load Fp = 31909.6 lb

the preload for reused connections is Fi = 23932.2 lb

the maximum external load applied to the bolt Fmaxb = 27920.9 lb

maximum external load applied to the joint before separation Fmax = 13960.5 lb
```

```
(* Program II.3.14 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
d = 10*10^(-3); (* m *)
p = 1.5*10^(-3); (* m *)
Const = 0.45;
Fmaxb = 6*10^3; (* N *)
nf = 2;
Sp = 225*10^6; (* Pa - from Table II.3.3 *)
At = 58*10^(-6); (* m^2 - from Table II.3.1 *)

Fp = At Sp;
Print["the proof load Fp = ", Fp, " N"];

Fi = 0.75 Fp;
Print["the preload for reused connections is Fi = ", Fi, " N"];

N1 = (Const nf Fmaxb)/(Sp At - Fi);
Print["Number of bolts N1 = ", N1];

N1F = Floor[N1];
N1C = Ceiling[N1];

nff = (Sp At - Fi)/(Const Fmaxb / N1F);
nfc = (Sp At - Fi)/(Const Fmaxb / N1C);

If[nfc >= nf, Print["Number of bolts N = ",N1C],
If[nff >= nf, Print["Number of bolts N = ",N1F],""]];
```

```
the proof load Fp = 13050 N

the preload for reused connections is Fi = 9787.5 N

Number of bolts N1 = 1.65517

Number of bolts N = 2
```

```
(* Program II.3.15 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
d = 16*10^(-3); (* m *)
p = 2*10^(-3); (* m *)
dr = d - p;
No = 10; (* no of seal bolts *)
Sp = 600*10^6; (* Pa - from Table II.3.3 *)
At = 157*10^(-6); (* m^2 - from Table II.3.2 *)
Pin = 5.5*10^6; (* Pa - inside pressure inside vesel *)
l=45. 10^(-3); (* m *) (* joint axial length *)
dv = 120*10^(-3); (* m - diameter of the vesel *)
Ap = (dv / 2)^2 * N[Pi]; (* m^2 - area where the pressure Pin is exerted *)
Fmaxb = Ap * Pin; (* N - maximum external load *)

"modulus of elasticity [GPa] E=206.8 for steel"
Eb=206.8 10^9;
Print["modulus of elasticity of the bolt Eb=",Eb," Pa"];

"------------------"
"Bolt stiffness kb"
"------------------"
lt=35*10^(-3);
lte=lt+0.4 dr;
Print["effective length of threaded portion of the bolt lte=lt+0.4 dr=",lte," m"];
ls = l - lt;
lse=ls+0.4 d;
Print["effective length of the unthreaded portion of the bolt lse=ls+0.4 d=",lse,"
m"];

Ar=N[Pi] dr^2/4.;
Print["minor diameter area Ar=Pi dr^2/4=",Ar," m^2"];
As=N[Pi] d^2/4.;
Print["major diameter area As=Pi d^2/4=",As," m^2"];

kt=Ar Eb/lte;
Print["stiffness of the threaded portion  kt=Ar Eb/lte=",kt," N/m"];
ks=As Eb/lse;
Print["stiffness of the unthreaded portion  ks=As Eb/lse=",ks," N/m"];
kb=kt ks/(kt+ks);
Print["bolt stiffness kb=kt ks/(kt+ks)=",kb," N/m"];

"---------------------------------------"
"Stiffness of clamped parts (Wileman)"
"---------------------------------------"
"constants A=0.78715; B=0.62873 for steel"
A=0.78715;
B=0.62873;
l1 = 20*10(-3);
l2 = 25*10(-3);
kc1=Eb d A E^(B d/l1);
kc2=Eb d A E^(B d/l2);
kc = (kc1 kc2)/(kc1 + kc2);
Print["joint stiffness (Wileman)  kc=",kc," N/m"];
```

```
"---------------------"
"joint constant"
"---------------------"
Const = kb / (kb + kc);
Print["Const = ", Const];

"---------------------"
"safety factor"
"---------------------"
Fi = 0.75 Sp At;
nfc = (Sp At - Fi) / (Const Fmaxb / No);
Print["nfc = ", nfc];
```

modulus of elasticity [GPa] E=206.8 for steel

modulus of elasticity of the bolt Eb=2.068×10^{11} Pa

Bolt stiffness kb

----

effective length of threaded portion of the bolt lte=lt+0.4 dr=0.0406 m

effective length of the unthreaded portion of the bolt lse=ls+0.4 d=0.0164 m

minor diameter area Ar=Pi dr^2/4=0.000153938 m^2

major diameter area As=Pi d^2/4=0.000201062 m^2

stiffness of the threaded portion kt=Ar Eb/lte=7.84098×10^{8} N/m

stiffness of the unthreaded portion ks=As Eb/lse=2.53534×10^{9} N/m

bolt stiffness kb=kt ks/(kt+ks)=5.98883×10^{8} N/m

Stiffness of clamped parts (Wileman)

----

constants A=0.78715; B=0.62873 for steel

joint stiffness (Wileman) kc=1.30224×10^{9} N/m

----

joint constant

Const = 0.315015

----

safety factor

```
---------------------

nfc = 12.0183
```

```
(* Program II.3.16 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
d = 16*10^(-3); (* m *)
p = 2*10^(-3); (* m *)
dr = d - p;
No = 10; (* no of seal bolts *)
Sp = 600*10^6; (* Pa - from Table II.3.3 *)
At = 157*10^(-6); (* m^2 - from Table II.3.2 *)
Pin = 5.5*10^6; (* Pa - inside pressure inside vesel *)
l=45. 10^(-3); (* m *) (* joint axial length *)
dv = 120*10^(-3); (* m - diameter of the vesel *)
Ap = (dv / 2)^2 * N[Pi]; (* m^2 - area where the pressure Pin is exerted *)
Fmaxb = Ap * Pin; (* N - maximum external load *)

"modulus of elasticity [GPa] E=206.8 for steel"
Eb=206.8 10^9;
"modulus of elasticity [GPa] E=206.8 for aluminum"
Ea=70 10^9;
"modulus of elasticity [GPa] E=100.0 for gray cast iron"
Ec=100 10^9;

"------------------"
"Bolt stiffness kb"
"------------------"
lt=35*10^(-3);
lte=lt+0.4 dr;
Print["effective length of threaded portion of the bolt lte=lt+0.4 dr=",lte," m"];
ls = l - lt;
lse=ls+0.4 d;
Print["effective length of the unthreaded portion of the bolt lse=ls+0.4 d=",lse,"
m"];

Ar=N[Pi] dr^2/4.;
Print["minor diameter area Ar=Pi dr^2/4=",Ar," m^2"];
As=N[Pi] d^2/4.;
Print["major diameter area As=Pi d^2/4=",As," m^2"];

kt=Ar Eb/lte;
Print["stiffness of the threaded portion  kt=Ar Eb/lte=",kt," N/m"];
ks=As Eb/lse;
Print["stiffness of the unthreaded portion  ks=As Eb/lse=",ks," N/m"];
kb=kt ks/(kt+ks);
Print["bolt stiffness kb=kt ks/(kt+ks)=",kb," N/m"];

"--------------------------------------"
"Stiffness of clamped parts (Wileman)"
"--------------------------------------"
"constants A=0.79670; B=0.63816 for aluminum"
A=0.79670;
B=0.63816;
l1 = 20*10(-3);
kc1=Ea d A E^(B d/l1);
"constants A=0.77871; B=0.61616 for gray cast iron"
```

```
A=0.77871;
B=0.61616;
l2 = 25*10(-3);
kc2=Ec d A E^(B d/l2);
kc = (kc1 kc2)/(kc1 + kc2);
Print["joint stiffness (Wileman)  kc=",kc," N/m"];

"---------------------"
"joint constant"
"---------------------"
Const = kb / (kb + kc);
Print["Const = ", Const];

"---------------------"
"safety factor"
"---------------------"
Fi = 0.75 Sp At;
nfc = (Sp At - Fi) / (Const Fmaxb / No);
Print["nfc = ", nfc];
```

```
modulus of elasticity [GPa] E=206.8 for steel

modulus of elasticity [GPa] E=206.8 for aluminum

modulus of elasticity [GPa] E=100.0 for gray cast iron

-------------------

Bolt stiffness kb

-------------------

effective length of threaded portion of the bolt lte=lt+0.4 dr=0.0406 m

effective length of the unthreaded portion of the bolt lse=ls+0.4 d=0.0164 m

minor diameter area Ar=Pi dr^2/4=0.000153938 m^2

major diameter area As=Pi d^2/4=0.000201062 m^2
```

stiffness of the threaded portion kt=Ar Eb/lte=7.84098×10^{8} N/m

stiffness of the unthreaded portion ks=As Eb/lse=2.53534×10^{9} N/m

bolt stiffness kb=kt ks/(kt+ks)=5.98883×10^{8} N/m

```
---------------------------------------

Stiffness of clamped parts (Wileman)

---------------------------------------

constants A=0.79670; B=0.63816 for aluminum

constants A=0.77871; B=0.61616 for gray cast iron
```

joint stiffness (Wileman) kc=5.19931×10^{8} N/m

```
---------------------

joint constant

---------------------

Const = 0.535284

---------------------

safety factor

---------------------

nfc = 7.0728
```

```
(* Program II.3.17 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
F = 10*10^3; (* N - the nominal load for each of the two bolts *)
Sp = 310*10^6; (* Pa - from Table II.3.3 *)

(* assumption: use a safety factor of 4 *)
nb = 4;

At = (nb F) / Sp;
Print["At = ", N[At]*10^(6), " mm^2"];
Print["From Table II.3.1 an apropriate standard size is M16x2"];
d = 16 10^-3;

Fi = 0.9 At Sp; (* 0.9 for permanent connections *)
Print["The initial tightening tension Fi = ", Fi, " N"];

T = 0.2 Fi d; (* Juvinall and Marshek *)
Print["Tightening moment T = ", T, " Nm"];
```

```
At = 129.032 mm^2

From Table II.3.1 an apropriate standard size is M16x2

The initial tightening tension Fi = 36000. N

Tightening moment T = 115.2 Nm
```

```
(* Program II.3.18 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

(* input data *)
d = 8*10^(-3); (* m *)
p = 1.25*10^(-3); (* m *)
Su = 400*10^6; (* Pa - from Table II.3.3 *)
Sy = 240*10^6; (* Pa - from Table II.3.3 *)
Sp = 225*10^6; (* Pa - from Table II.3.3 *)
μ = 0.3;
At = 36.6*10^(-6); (* m^2 - from Table II.3.1 *)

Fi = Sp At;
Print["Force required to slip each of the 2 interfaces = ", μ Fi, " N"];
Print["Thus  the value of F required to overcome friction is estimated to be in the
region of 5000 N"];

Print["Larger value of force can be transmitted through the bolt itself"];
A = (N[Pi] d^2)/4;
Ssy = 0.58 Sy;
F = 2 Ssy A;
Print["For yielding of the 2 shear planes F = ", F, " N"];

Print["Total failure load is calculated as above except for replacing Ssy with Sus"];
Sus = 0.58 Su;
F = 2 Sus A;
Print["For failure load F = ", F, " N"];
```

```
Force required to slip each of the 2 interfaces = 2470.5 N

Thus  the value of F required to overcome friction is estimated to be in the region of 5000 N

Larger value of force can be transmitted through the bolt itself

For yielding of the 2 shear planes F = 13993.9 N

Total failure load is calculated as above except for replacing Ssy with Sus

For failure load F = 23323.2 N
```