(* Problem II.4.1 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"no.208 radial ball"
B10 = 4000; (* hour *)
n = 1200; (* rpm *)
L = B10 * 60 * n; (* rev *)

"Assumption: the life given is for 90% reliability"
LR = 90*10^6;
Print["LR = ", LR, " rev"];

d = 40; (* mm - the bore - from Table.II.4.1 *)
Print["d = ", d, " mm"];

Cap = 9.40 * 10^3; (* N - from Table II.4.2 *)
Print["C = ", Cap, " N"];

Kr = 1; (* from Figure II.4.9 *)
Print["Kr = ", Kr];

"Assumption: the loading is steady"
Ka = 1; (* from Table II.4.3 *)
Print["Ka = ", Ka];

Fr = Cap (LR / L)^(3/10); (* from eq II.4.22 *)
Print["Fr = ", Fr, " N"];

no.208 radial ball

Assumption: the life given is for 90% reliability

LR = 90000000 rev
d = 40 mm
C = 9400. N
Kr = 1

Assumption: the loading is steady

Ka = 1
Fr = 6631.06 N
no.207 angular ball bearing
Fr = 250; (* lb *)
Fa = 150; (* lb *)
n = 1000; (* rpm *)

"Assumption: 25° angular ball bearing"
r = N[Fa/Fr];
Print["Fa/Fr = ", r];

"for 0 < Fa/Fr < 0.68 => Fe = Fr"
Fe = Fr;
Fe = Fe * 4.448222; (* convert from lb to N *)
Print["Fe = ", Fe, " N"];

"for steady loading Ka = 1 (Table II.4.3)"
Ka = 1;

"Assumption: the life given is for 90% reliability"
LR = 90*10^6;
Print["LR = ", LR, " rev"];

Kr = 1; (* from Figure II.4.9 *)
Print["Kr = ", Kr];

d = 35; (* mm - the bore - from Table.II.4.1 *)
Print["d = ", d, " mm"];

Cap = 8.20*10^3; (* N - from Table II.4.2 *)
Print["C = ", Cap, " N"];

L = Kr LR (Cap / (Ka Fe) )^(10/3);
Print["L = ", L, " rev"];

B10 = L / (60 n);
Print["B10 = ", B10, " hr"];

no.207 angular ball bearing
Assumption: 25° angular ball bearing
Fa/Fr = 0.6
for 0 < Fa/Fr < 0.68 => Fe = Fr
Fe = 1112.06 N
for steady loading Ka = 1 (Table II.4.3)
Assumption: the life given is for 90% reliability
LR = 90000000 rev
\[ Kr = 1 \]
\[ d = 35 \text{ mm} \]
\[ C = 8200. \text{ N} \]
\[ L = 7.02318 \times 10^{10} \text{ rev} \]
\[ B_{10} = 1.17053 \times 10^6 \text{ hr} \]
(* Problem II.4.7 *)
Apply[Clear, Names["Global\:*"]];
Off[General::spell];
Off[General::spell1];

Fr = 3; (* kN *)
Fa = 2; (* kN *)
n = 1200; (* rpm *)

L = 6000 * 60 * 900;
LR = 90*10^6;
Print["LR = ", LR, " rev"];

Kr = 0.33; (* for 98% reliability from Figure II.4.9 *)
Print["Kr = ", Kr];
r = N[Fa/Fr];
Print["Fa/Fr = ", r];

"a)"
"for 0.35 < Fa/Fr < 10 => Fe = Fr (1+1.115 (Fa/Fr - 0.35)) - for radial ball bearings"
Fe = Fr (1+1.115 (Fa/Fr - 0.35));
Print["Fe = ", Fe, " kN"];

"for light to moderate impacts Ka = 2 (Table II.4.3) - radial ball bearing"
Ka = 2;
Creq = Ka Fe ( L / (Kr LR))^0.3;
Print["Creq = ", Creq, " kN"];

"for 17 kN => d = 70 mm and 200 series - from Table II.4.2"
"from Table II.4.1 => no.214 - for radial ball bearing"

"b)"
"for 0 < Fa/Fr < 0.68 => Fe = Fr - for angular ball bearings"
Fe = Fr;
Print["Fe = ", Fe, " kN"];

"for light to moderate impacts Ka = 2 (Table II.4.3) - angular ball bearing"
Ka = 2;
Creq = Ka Fe ( L / (Kr LR))^0.3;
Print["Creq = ", Creq, " kN"];

"for 13.6 kN => d = 55 mm and 200 series - from Table II.4.2"
"from Table II.4.1 => no.211 - for angular ball bearing"
for $0.35 < \frac{F_a}{F_r} < 10$ => $F_e = F_r (1+1.115 (\frac{F_a}{F_r} - 0.35))$ - for radial ball bearings

$F_e = 4.05925$ kN

for light to moderate impacts $K_a = 2$ (Table II.4.3) - radial ball bearing

$C_{req} = 16.6269$ kN

for 17 kN => $d = 70$ mm and 200 series - from Table II.4.2

from Table II.4.1 => no.214 - for radial ball bearing

b)

for $0 < \frac{F_a}{F_r} < 0.68$ => $F_e = F_r$ - for angular ball bearings

$F_e = 3$ kN

for light to moderate impacts $K_a = 2$ (Table II.4.3) - angular ball bearing

$C_{req} = 12.2882$ kN

for 13.6 kN => $d = 55$ mm and 200 series - from Table II.4.2

from Table II.4.1 => no.211 - for angular ball bearing
Problem II.4.9

A
pply\[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

"no.207 radial ball bearing"
\[n\] = 1500; (* rpm *)
\[t1\] = 0.3;
\[Fr1\] = 5; (* kN *)
\[t2\] = 0.3;
\[Fr2\] = 2; (* kN *)
\[t3\] = 0.4;
\[Fr3\] = 10; (* kN *)
\[Ka\] = 1;

\[LR\] = 90*10^6;
Print["LR = ", LR, " rev"];

\[Kr\] = 1; (* from Figure II.4.9 *)
Print["Kr = ", Kr];

"from Table II.4.1 => d = 35 mm"
"from Table II.4.2 => C = 8.5 kN"
\[Cap\] = 8.5; (* kN *)

\[L1\] = Kr LR (Cap / (Ka Fr1))^(10/3);
\[L2\] = Kr LR (Cap / (Ka Fr2))^(10/3);
\[L3\] = Kr LR (Cap / (Ka Fr3))^(10/3);

Print["L1 = ", L1, " rev"]; Print["L2 = ", L2, " rev"]; Print["L3 = ", L3, " rev"];

\[n1\] = \[t1\] * \[n\];
\[n2\] = \[t2\] * \[n\];
\[n3\] = \[t3\] * \[n\];
\[X\] = 1 / (\[n1\]/\[L1\] + \[n2\]/\[L2\] + \[n3\]/\[L3\]);

Print["B10 = ", X/60, " hr"]; Print["Median life = B10 * 5 = ", X/12, " hr"];
\[ B_{10} = 1349.22 \text{ hr} \]

Median life = \( B_{10} \times 5 = 6746.12 \text{ hr} \)
(* Problem II.4.10 *)
Apply[Clear, Names["Global\"*"]];
Off[General::spell];
Off[General::spell1];
n = 900; (* rotational speed [rpm] *)
FaA = 500; (* [N] *)
FaB = 500; (* [N] *)
fr = 900; (* [N] *)
FR = \{0, -fr \* Sin[N[Pi]/4], fr \* Cos[N[Pi]/4]\}; (* [N] *)
FA = \{0, FAy, FAz\};
FB = \{0, FBy, FBz\};
l = 0.3; (* [m] *)

"\( \sum M_A = r_{AB} \times FB + r_{AR} \times FR = 0 \Rightarrow \)"
raB = \{1, 0, 0\};
rAR = \{2, 1, 0, 0\};
MA = Cross[raB, FB] + Cross[rAR, FR];
sB = Solve[\{MA [[2]] == 0, MA [[3]] == 0\}, \{FBy, FBz\}];
By = FBy /. sB[[1]];
Bz = FBz /. sB[[1]];
Print["FBy = ", By, " N"];
Print["FBz = ", Bz, " N"];
FrB = Sqrt[By^2 + Bz^2];
Print["FrB = (FBy^2 + FBz^2)^0.5 = ", FrB, " N"];
eB = FaB/ FrB;
Print["FaB/ FrB = ", eB];
FeB = FrB;
Print["FeB = FrB = ", FeB, " N"];

"\( \sum F = 0 \Rightarrow FA = -FB -FR \)"
fA = \{-0, By, Bz\} - FR;
Ay = fA [[2]];
Az = fA [[3]];
Print["FAd = ", Ay, " N"];
Print["FAz = ", Az, " N"];
FrA = Sqrt[Ay^2 + Az^2];
Print["FrA = (FAy^2 + FAz^2)^0.5 = ", FrA, " N"];
eA = FaA / FrA;
Print["FaA/ FrA = ", eA];
FeA = FrA \*(1 + 1.115(FaA/FrA - 0.35));
Print["FeA = FrA(1 + 1.115(FaA/FrA - 0.35)) = ", FeA, " N"];

"design life DL = 30 000 h"
DL = 30000; (* h *)
L = n DL 60;
Print["life L = n DL 60 = ", L, " rev "];
"application factor Ka = 1 uniform no impact (Table II.4.3)"
Ka = 1;
Kr = 0.33 (* r=98% Figure II.4.9 *)
LR = 90 10^6;
"LR = 90 x 10^6; Kr = 0.33 (r=98%)

"Creq = Ka Fe (L/(Kr LR))^0.3"
CreqA = Ka FeA (L/(Kr LR))^0.3;
CreqB = Ka FeB (L/(Kr LR))^0.3;
Print["rated capacity at A: CreqA = ",CreqA," N"];  
Print["rated capacity at B: CreqB = ",CreqB," N"];  

"from Table II.4.2 with CreqA and L00 series => C=4.2 kN and d=35 mm bore"
"from Table II.4.2 with CreqB and 200 series => C=8.5 kN and d=35 mm bore"

"from Table II.4.1 with d=35 mm bore and L00 series => L07 bearing number"
"from Table II.4.1 with d=35 mm bore and 200 series => L207 bearing number"

\[
\sum M_A = r_{AB} \times F_B + r_{AR} \times F_R = 0 =>
\]

FBy = 1272.79 N  
FBz = -1272.79 N  
FrB = (FBy^2 + FBz^2)^0.5 = 1800. N  
FaB/FrB = 0.277778  
FeB=FrB=1800. N  
\[
\sum F = 0 => FA = -FB -FR
\]

FAY = -636.396 N  
FAz = 636.396 N  
FrA = (FAY^2 + FAz^2)^0.5 = 900. N  
FaA/FrA = 0.555556  
FeA=FrA(1+1.115(FaA/FrA-0.35))=1106.28 N  

design life DL = 30 000 h  
life L = n DL 60 = 1620000000 rev  
application factor Ka = 1 uniform no impact (Table II.4.3)  
LR = 90 x 10^6; Kr = 0.33 (r=98%)  
Creq = Ka Fe (L/(Kr LR))^0.3  
rated capacity at A: CreqA = 3671.9 N  
rated capacity at B: CreqB = 5974.48 N  
from Table II.4.2 with CreqA and L00 series => C=4.2 kN and d=35 mm bore  
from Table II.4.2 with CreqB and 200 series => C=8.5 kN and d=35 mm bore  
from Table II.4.1 with d=35 mm bore and L00 series => L07 bearing number  
from Table II.4.1 with d=35 mm bore and 200 series => L207 bearing number
(* Problem II.4.11 *)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];

n=1000; (* rotational speed [rpm] *)
FP = {0, -500, 600};
FR = {0, -1000, 0};
FA={0, FAy, FAz};
FB={0, FBy, FBz};
l=0.2; (* [m] *)
s=0.1; (* [m] *)

"\[Sigma]\_M\_A = r\_AP \times FP + r\_AR \times FR + r\_AB \times FB = 0 \Rightarrow"
\[\begin{align*}
r\_AP &= \{-s, 0, 0\} \\
r\_AB &= \{2 l, 0, 0\} \\
r\_AR &= \{l, 0, 0\} \\
\end{align*}\]
MA=Cross[rAP,FP] + Cross[rAR,FR] + Cross[rAB,FB];
sB=Solve[{MA[[2]]==0, MA[[3]]==0}, {FBy, FBz}];
By=FBy/.sB[[1]];
Bz=FBz/.sB[[1]];
Print["FBy = ", By, " N" ];
Print["FBz = ", Bz, " N" ];
FrB=Sqrt[By^2+Bz^2];
Print["FrB = (FBy^2 + FBz^2)^0.5 = ", FrB, " N" ];
FeB=FrB;
Print["FeB=FrB=", FeB, " N" ];

"\[Sigma]\_F = 0 \Rightarrow FA = -FB -FR -FP"
fA=-{0, By, Bz}-FR-FP;
\[\begin{align*}
Ay &= fA[[2]] \\
Az &= fA[[3]] \\
\end{align*}\]
Print["FAy = ", Ay, " N" ];
Print["FAz = ", Az, " N" ];
FrA=Sqrt[Ay^2+Az^2];
Print["FrA = (FAy^2 + FAz^2)^0.5 = ", FrA, " N" ];
FeA=FrA;
Print["FeA=FrA=", FeA, " N" ];

"design life DL = 5 000 h 
DL=5000; (* h *)
L=n DL 60;
Print["life L = n DL 60 = ",L, " rev "]; "application factor Ka = 1.5 light to moderate impact (Table II.4.3)"
Ka = 1.5;
Kr = 0.33 (* r=98% Figure II.4.9 *)
LR=90 10^6;
"LR = 90 x 10^6; Kr = 0.33 (r=98%)"

"Creq = Ka \( Fe \frac{L}{(Kr LR)^{0.3}} \)"
CreqA = Ka*FeA *(L/(Kr LR)^{0.3};
CreqB = Ka*FeB *(L/(Kr LR)^{0.3};
Print["rated capacity at A: CreqA = ",CreqA," N" ];
Print["rated capacity at B: CreqB = ",CreqB," N" ];
"from Table II.4.2 with CreqA and L00 series => C=4.2 kN and d=35 mm bore"
"from Table II.4.1 with d=35 mm bore and L00 series => L07 bearing number"

\[
\sum F_A = r_{AP} x F_P + r_{AR} x F_R + r_{AB} x F_B = 0 \Rightarrow \\
F_{By} = 375. \text{ N} \\
F_{Bz} = 150. \text{ N} \\
F_{RB} = (F_{By}^2 + F_{Bz}^2)^{0.5} = 403.887 \text{ N} \\
F_{EB} = F_{RB} = 403.887 \text{ N} \\
\sum F = 0 \Rightarrow F_A = -F_B -F_R -F_P \\
F_{Ay} = 1125. \text{ N} \\
F_{Az} = -750. \text{ N} \\
F_{RA} = (F_{Ay}^2 + F_{Az}^2)^{0.5} = 1352.08 \text{ N} \\
F_{EA} = F_{RA} = 1352.08 \text{ N} \\
design \text{ life DL} = 5 \, 000 \, h \\
life \text{ L} = n \, DL \, 60 = 300000000 \, \text{rev} \\
application \text{ factor } Ka = 1.5 \, \text{light to moderate impact (Table II.4.3)} \\
LR = 90 \times 10^6; \, Kr = 0.33 \, (r=98\%) \\
C_{req} = Ka \, F_e \, (L/(Kr \, LR))^{0.3} \\
rated \text{ capacity at A: } C_{reqA} = 4058.86 \text{ N} \\
rated \text{ capacity at B: } C_{reqB} = 1212.44 \text{ N} \\
from \text{ Table II.4.2 with } C_{reqA} \text{ and L00 series => C=4.2 kN and d=35 mm bore} \\
from \text{ Table II.4.1 with d=35 mm bore and L00 series => L07 bearing number}
(* Problem II.4.12 *)
Apply[Clear,Names["Global`*"]];
Off[General::spell];
Off[General::spell1];
n = 300; (* rotational speed [rpm] *)
FP = {0, -200, 500};
FR = {0, -600, -1500};
FA = {0, FAy, FAz};
FB = {0, FBy, FBz};
l = 0.025; (* [m] *)
s = 0.1; (* [m] *)
OP = 0.15; (* [m] *)
QR = 0.05; (* [m] *)

"\[Sigma]M_A = rAP x FP + rAB x FB + rAR x FR = 0 =>"

rP = {0, OP, 0};
rA = {l, 0, 0};
rB = {l + s, 0, 0};
rR = {2*l + s, QR, 0};

rAP = rP - rA;
rAB = rB - rA;
rAR = rR - rA;

MA = Cross[rAP, FP] + Cross[rAB, FB] + Cross[rAR, FR];
sB = Solve[{MA[[2]] == 0, MA[[3]] == 0}, {FBy, FBz}];
By = FBy /. sB[[1]];
Bz = FBz /. sB[[1]];
Print["FBy = ", By, " N"];
Print["FBz = ", Bz, " N"];
FrB = Sqrt[By^2 + Bz^2];
Print["FrB = (FBy^2 + FBz^2)^0.5 = ", FrB, " N"];

FeB = FrB;
Print["FeB=FrB=", FeB, " N"];

"\[Sigma]F = 0 => FA = -FB -FR -FP"
fA = {0, By, Bz} - FR - FP;
Ay = fA[[2]];
Az = fA[[3]];
Print["FAy = ", Ay, " N"];
Print["FAz = ", Az, " N"];
FrA = Sqrt[Ay^2 + Az^2];
Print["FrA = (FAy^2 + FAz^2)^0.5 = ", FrA, " N"];
FeA = FrA;
Print["FeA=FrA=" , FeA, " N"];

"design life DL = 30 000 h from Table II.4.4"
DL = 30000; (* h *)
L = n * DL 60;
Print["life L = n DL 60 = ", L, " rev "];
"Application factor Ka = 1.3 Gearing (Table II.4.3)"
Ka = 1.3;
Kr = 1 (* r=90% Figure II.4.9 *);
LR=90 10^6;
"LR = 90 x 10^6; Assumption: Kr = 1 (r=90%)"

"Creq = Ka Fe (L/(Kr LR))^0.3"
CreqA = Ka FeA (L/(Kr LR))^0.3;
CreqB = Ka FeB (L/(Kr LR))^0.3;
Print["rated capacity at A: CreqA = ",CreqA," N"];
Print["rated capacity at B: CreqB = ",CreqB," N"];

"from Table II.4.2 with CreqB and L00 series => C=5.8 kN and d=45 mm bore"
"from Table II.4.1 with d=45 mm bore and L00 series => L09 bearing number"

ΣM_A = rAP x FP + rAB x FB + rAR x FR = 0 =>
FBy = 700. N
FBz = 2000. N
FrB = (FBy^2 + FBz^2)^0.5 = 2118.96 N
FeB=FrB=2118.96 N
ΣF = 0 => FA = -FB -FR -FP
FAy = 100. N
FAz = -1000. N
FrA = (FAy^2 + FAz^2)^0.5 = 1004.99 N
FeA=FrA=1004.99 N
design life DL = 30 000 h from Table II.4.4
life L = n DL 60 = 540000000 rev
Application factor Ka = 1.3 Gearing (Table II.4.3)
LR = 90 x 10^6; Assumption: Kr = 1 (r=90%)
Creq = Ka Fe (L/(Kr LR))^0.3
rated capacity at A: CreqA = 2236.4 N
rated capacity at B: CreqB = 4715.33 N
from Table II.4.2 with CreqB and L00 series => C=5.8 kN and d=45 mm bore
from Table II.4.1 with d=45 mm bore and L00 series => L09 bearing number