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(*Problem I .6 .9*)
Apply[Clear, Names["Global`*"]];
Off[General::spell];
Off[General::spell1];
(*Input data*)
 AB = .250;
 BC = .650;
 AD = .600;
 DE = .200;
 EF = .600;
 CD = .350;
 CE = CD + DE;
 La = .100;
 phi = N[Pi] / 3;
 n = 2500; (*rpm*)
 ω = n * N[Pi] / 30; (*rad/s*)
  (*Position of joint A*)
 xA = yA = 0;
rA = {0, 0, 0};
(*Postiton of joint D*)
xD = AD;
yD = 0;
 rD = {xD, yD, 0};
  (*Position of joint B*)
 xB = AB Cos[phi];
yB = AB Sin[phi]; rB = {xB, yB, 0};
  (*Position of joint C*)
 eqnC1 = (xB - xCsol) ^ 2 + (yB - yCsol) ^ 2 - BC ^ 2 == 0;
eqnC2 = (xCsol - xD) ^ 2 + (yCsol - yD) ^ 2 - CD ^ 2 == 0;
solutionC = Solve[{eqnC1, eqnC2}, {xCsol, yCsol}];
  (*Two solutions for C*)
 xC1 = xCsol /. solutionC[[1]];
yC1 = yCsol /. solutionC[[1]];
xC2 = xCsol /. solutionC[[2]];
yC2 = yCsol /. solutionC[[2]];
(*Select the correct position for C*)
 If[yC1 ≥ 0, xC = xC1; yC = yC1, xC = xC2; yC = yC2];
 rC = {xC, yC, 0};
(*Position of joint E*)
phi3 = ArcTan[(yD - yC) / (xD - xC)];
 xE = xC - (CD + DE) Cos[phi3];
yE = yC - (CD + DE) Sin[phi3];
rE = {xE, yE, 0};
(*Position of joint F*)
 yF = -La;
 xF = xE + Sqrt[EF ^ 2 - (yF - yE) ^ 2];
 rF = {xF, yF, 0};
\(■(*Graph of the mecanism*)■\)
 markers = Table[{Point[{xA, yA}], Point[{xB, yB}], Point[{xC, yC}],
    Point[{xD, yD}], Point[{xE, yE}], Point[{xF, yF}]}];
 name = Table[{Text["A", {xA, yA}, {-1, 1}],
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      Text["B", {xB, yB}, {0, -1}], Text["C", {xC, yC}, {-1, 1}],
      Text["D", {xD, yD}, {-1, -1}], Text["E", {xE, yE}, {0, -1}],
      Text["F", {xF, yF}, {0, -1}]}];
  graph = Graphics[{{RGBColor[1, 0, 0], Line[{{xA, yA}, {xB, yB}}]},
     {RGBColor[0, 1, 0], Line[{{xB, yB}, {xC, yC}}]},
     {RGBColor[0, 0, 1], Line[{{xC, yC}, {xD, yD}}]},
     {RGBColor[0, 0, 1], Line[{{xC, yC}, {xE, yE}}]},
     {RGBColor[0, 1, 1], Line[{{xE, yE}, {xF, yF}}]},
     {RGBColor[1, 1, 1], PointSize[0.01], markers}, {name}}];
  Show[Graphics[graph], PlotRange → {All, All}, Frame → True,
    AxesOrigin → {xA, yA}, FrameLabel → {"x", "y"},
    Axes → {True, True}, AspectRatio → Automatic];
  Print["0-Ar-1-Br-2-Cr-3-Dr-0"];
  ω10 = {0, 0, ω};
ω21v = {0, 0, omega21};
ω32v = {0, 0, omega32};
  ω03v = {0, 0, omega03};
  eqIkv = (ω10 + ω21v + ω32v + ω03v)[[3]] == 0;
eqIijv = Cross[rB, ω21v] + Cross[rC, ω32v] + Cross[rD, ω03v];
eqIiv = eqIijv[[1]] == 0;
eqIjv = eqIijv[[2]] == 0;
solIvel =
   Solve[{eqIkv, eqIiv, eqIjv}, {omega21, omega32, omega03}];
  omega21s = omega21 /. solIvel[[1]];
omega32s = omega32 /. solIvel[[1]];
omega03s = omega03 /. solIvel[[1]];
ω21 = {0, 0, omega21s};
ω32 = {0, 0, omega32s};
  ω03 = {0, 0, omega03s};
  Print["ω21 = ", ω21, " rad/s"];
Print["ω32 = ", ω32, " rad/s"];
Print["ω03 = ", ω03, " rad/s"];
ω20 = ω10 + ω21;
ω30 = -ω03;
  Print["ω20 = ", ω20, " rad/s"];
Print["ω30 = ", ω30, " rad/s"];
vB = Cross[ω10, rB];
vC = vB + Cross[ω20, rC - rB];
  vE = Cross[ω30, rE - rD];
  Print["vB = ", vB, "  m/s"];
Print["vC = ", vC, "  m/s"];
  Print["vE = ", vE, "  m/s"];
  (*accelerations*)
  α10 = D[ω10, t];
α21v = {0, 0, alpha21};
α32v = {0, 0, alpha32};
α03v = {0, 0, alpha03};
eqIka = (α10 + α21v + α32v + α03v)[[3]] == 0;
eqIija = Cross[rB, α21v] + Cross[rC, α32v] + Cross[rD, α03v] -
    ω10.ω10 rB - ω20.ω20 (rC - rB) - ω30.ω30 (rD - rC);
eqIia = eqIija[[1]] == 0;
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eqIja = eqIija[[2]] == 0;
solIacc =
   Solve[{eqIka, eqIia, eqIja}, {alpha21, alpha32, alpha03}];
alpha21s = alpha21 /. solIacc[[1]];
alpha32s = alpha32 /. solIacc[[1]];
alpha03s = alpha03 /. solIacc[[1]];
 α21 = {0, 0, alpha21s};
α32 = {0, 0, alpha32s};
α03 = {0, 0, alpha03s};
 Print["α21 = ", α21, " rad/s^2"];
Print["α32 = ", α32, " rad/s^2"];
Print["α03 = ", α03, " rad/s^2"];
α20 = α10 + α21;
α30 = -α03;
 Print["α20 = ", α20, " rad/s^2"];
Print["α30 = ", α30, " rad/s^2"];
aB = Cross[α10, rB] - ω10.ω10 rB;
aC = aB + Cross[α20, rC - rB] - ω20.ω20 (rC - rB);
 aE = Cross[α30, rE - rD] - ω30.ω30 (rE - rD);
 Print["aB = ", aB, "  m/s^2"];
Print["aC = ", aC, "  m/s^2"];
Print["aE = ", aE, "  m/s^2"];
 Print[" "];
 Print["0-Dr-3-Er-4-Fr-5-Ft-0"];
 ω43v = {0, 0, omega43};
ω54v = {0, 0, omega54};
 vF05v = {vF05, 0, 0};
 eqIIkv = (ω30 + ω43v + ω54v)[[3]] == 0;
eqIIijv = Cross[rD, ω30] + Cross[rE, ω43v] + Cross[rF, ω54v] + vF05v;
eqIIiv = eqIIijv[[1]] == 0;
eqIIjv = eqIIijv[[2]] == 0;
solIvelI =
   Solve[{eqIIkv, eqIIiv, eqIIjv}, {omega43, omega54, vF05}];
omega43s = omega43 /. solIvelI[[1]];
omega54s = omega54 /. solIvelI[[1]];
vF05s = vF05 /. solIvelI[[1]];
ω43 = {0, 0, omega43s};
ω54 = {0, 0, omega54s};
 v05 = {vF05s, 0, 0};
 Print["ω43 = ", ω43, " rad/s"];
Print["ω54 = ", ω54, " rad/s"];
Print["vF05 = ", v05, " m/s"];
 ω40 = ω30 + ω43;
 Print["ω40 = ", ω40, " rad/s"];
vF = vE + Cross[ω40, rF - rE];
 Print["vF = ", Chop[vF], "  m/s"];
 α43v = {0, 0, alpha43};
α54v = {0, 0, alpha54};
 aF05v = {aF05, 0, 0};
 eqIIka = (α30 + α43v + α54v)[[3]] == 0;
eqIIija = Cross[rD, α30] + Cross[rE, α43v] +
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    Cross[rF, α54v] + aF05v - ω30.ω30 (rE - rD) - ω40.ω40 (rF - rE);
eqIIia = eqIIija[[1]] == 0;
eqIIja = eqIIija[[2]] == 0;
solIIa =
   Solve[{eqIIka, eqIIia, eqIIja}, {alpha43, alpha54, aF05}];
alpha43s = alpha43 /. solIIa[[1]];
alpha54s = alpha54 /. solIIa[[1]];
aF05s = aF05 /. solIIa[[1]];
α43 = {0, 0, alpha43s};
α54 = {0, 0, alpha54s};
 a05 = {aF05s, 0, 0};
 Print["α43 = ", α43, " rad/s^2"];
Print["α54 = ", α54, " rad/s^2"];
Print["aF05 = ", a05, " m/s^2"];
 α40 = α30 + α43;
 Print["α40 = ", α40, " rad/s^2"];
aF = aE + Cross[α40, rF - rE] - ω40.ω40 (rF - rE);
 Print["aF = ", Chop[aF], "  m/s^2"];
Print["  "]
 Print["  "]
 Fext = -Sign[vF] {1600, 0, 0};
Print["Fext = ", Fext, "  N"];
α1 = α5 = {0, 0, 0};
α2 = α20;
α3 = α30;
 α4 = α40;
h = 0.01;
d = 0.001;
hSlider = 0.02;
wSlider = 0.05;
ρ = 8000.;
g = 9.807;
 (*Link 1*)
m1 = ρ AB h d;
rC1 = rB / 2;
aC1 = aB / 2;
Fin1 = -m1 aC1;
G1 = {0, -m1 g, 0};
F1 = (Fin1 + G1);
IC1 = m1 (AB^2 + h^2) / 12;
M1 = Min1 = -IC1 α1;
Print["rC1 = ", rC1, "  m"];
 Print["aC1 = ", aC1, "  m/s^2"];
 Print["m1 = ", m1, "  kg"];
Print["IC1 = ", IC1, "  kg m^2"];
Print["Fin1 = -m1 aC1 = ", Fin1, "  N "];
Print["G1 = -m1 g = ", G1, "  N "];
Print["F1 = -m1 aC1 + G1 = ", F1, "  N "];
Print["M1 = Min1 = -IC1 α1 = ", {0, 0, 0}, "  N m"];
(*Link 2*)
m2 = ρ BC h d;
rC2 = (rB + rC) / 2;
aC2 = (aB + aC) / 2;
```

```
Fin2 = -m2 aC2;
G2 = {0, -m2 g, 0};
F2 = (Fin2 + G2);
IC2 = m2 (BC^2 + h^2) / 12;
M2 = Min2 = -IC2 α2;
Print["rC2 = ", rC2, "  m"];
  Print["aC2 = ", aC2, "  m/s^2"];
  Print["m2 = ", m2, "  kg"];
Print["IC2 = ", IC2, "  kg m^2"];
Print["Fin2 = -m2 aC2 = ", Fin2, "  N "];
Print["G2 = -m2 g = ", G2, "  N "];
Print["F2 = -m2 aC2 + G2 = ", F2, "  N "];
Print["M2 = Min2 = -IC2 α2 = ", M2, "  N m"];
(*Link 3*)
m3 = ρ CE h d;
  rC3 = (rC + rE) / 2;
  aC3 = (aC + aE) / 2;
Fin3 = -m3 aC3;
G3 = {0, -m3 g, 0};
F3 = (Fin3 + G3);
  IC3 = m3 (CE^2 + h^2) / 12;
M3 = Min3 = -IC3 α3;
Print["rC3 = ", rC3, "  m"];
  Print["aC3 = ", aC3, "  m/s^2"];
  Print["m3 = ", m3, "  kg"];
Print["IC3 = ", IC3, "  kg m^2"];
Print["Fin3 = -m3 aC3 = ", Fin3, "  N "];
Print["G3 = -m3 g = ", G3, "  N "];
Print["F3 = -m3 aC3 + G3 = ", F3, "  N "];
Print["M3 = Min3 = -IC3 α3 = ", M3, "  N m"];
(*Link 4*)
  m4 = ρ EF h d;
rC4 = (rE + rF) / 2;
aC4 = (aE + aF) / 2;
Fin4 = -m4 aC4;
G4 = {0, -m4 g, 0};
F4 = (Fin4 + G4);
IC4 = m4 (EF^2 + h^2) / 12;
M4 = Min4 = -IC4 α4;
Print["rC4 = ", rC4, "  m"];
  Print["aC4 = ", aC4, "  m/s^2"];
  Print["m4 = ", m4, "  kg"];
Print["IC4 = ", IC4, "  kg m^2"];
Print["Fin4 = -m4 aC4 = ", Fin4, "  N "];
Print["G4 = -m4 g = ", G4, "  N "];
Print["F4 = -m4 aC4 + G4 = ", F4, "  N "];
Print["M4 = Min4 = -IC4 α4 = ", M4, "  N m"];
  (*Link 5*)
  m5 = ρ hSlider wSlider d;
rC5 = rF;
aC5 = aF;
Fin5 = -m5 aC5;
G5 = {0, -m5 g, 0};
F5 = (Fin5 + G5);
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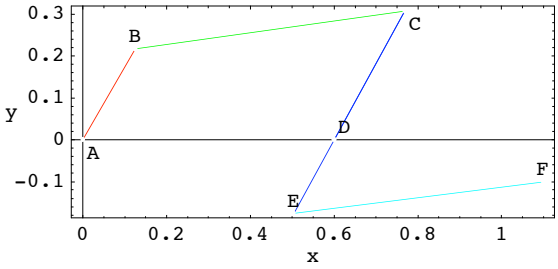
```
IC5 = m5 (hSlider^2 + wSlider^2) / 12;
M5 = Min5 = -IC5 α5;
Print["rC5 = ", rC5, "  m"];
  Print["aC5 = ", aC5, "  m/s^2"];
  Print["m5 = ", m5, "  kg"];
Print["IC5 = ", IC5, "  kg m^2"];
Print["Fin5 = -m5 aC5 = ", Fin5, "  N "];
Print["G5 = -m5 g = ", G5, "  N "];
Print["F5 = -m5 aC5 + G5 = ", F5, "  N "];
Print["M5 = Min5 = -IC5 α5 = ", M5, "  N m"];
  Print[" "];
Print[" 4&5 "];
F05 = {0, F05y, 0};
F34 = {F34x, F34y, 0};
eqF45 = (F5 + F4 + F05 + F34 + Fext);
eqMF4 = (Cross[rE - rF, F34] + Cross[rC4 - rF, F4] + M4)[[3]];
  sol45 = Solve[
     {eqF45[[1]] == 0, eqF45[[2]] == 0, eqMF4 == 0}, {F05y, F34x, F34y}]
F05s = F05 /. sol45[[1]];
F34s = F34 /. sol45[[1]];
Print["F05 = ", F05s, "  N"];
Print["F34 = ", F34s, "  N"];
  F54 = F05s + F5 + Fext;
  Print["F54 = ", F54, "  N"];
  Print[" "];
Print[" 2&3 "];
F12 = {F12x, F12y, 0};
F03 = {F03x, F03y, 0};
  eqF23 = (F2 + F3 + F03 + F12 - F34s);
  eqMC3 = (Cross[rD - rC, F03] +
      Cross[rC3 - rC, F3] + Cross[rE - rC, -F34s] + M3)[[3]];
  eqMC2 = (Cross[rB - rC, F12] + Cross[rC2 - rC, F2] + M2)[[3]];
  sol23 = Solve[{eqF23[[1]] == 0, eqF23[[2]] == 0, eqMC3 == 0, eqMC2 == 0
     {F03x, F03y, F12x, F12y}];
F03s = F03 /. sol23[[1]];
F12s = F12 /. sol23[[1]];
Print["F03 = ", F03s, "  N"];
Print["F12 = ", F12s, "  N"];
F23 = F12s + F2;
  Print["F23 = ", F23, "  N"];
  Print["  "]
(*Link 1*)
F01 = -F1 + F12s;
Print["F01 = ", F01, "  N"];
Mm = -Cross[rB, -F12s] - Cross[rC1, F1] - M1;
Print["Meq = ", Mm, "  N m"];
```



0-Ar-1-Br-2-Cr-3-Dr-0

ω21 = {0, 0, -264.389} rad/s

ω32 = {0, 0, 186.669} rad/s

ω03 = {0, 0, -184.079} rad/s

ω20 = {0, 0, -2.59006} rad/s

ω30 = {0, 0, 184.079} rad/s

vB = {-56.6812, 32.7249, 0.} m/s

vC = {-56.4478, 31.0577, 0.} m/s

vE = {32.2559, -17.7472, 0.} m/s

α21 = {0, 0, 10131.7} rad/s^2

α32 = {0, 0, 2155.67} rad/s^2

α03 = {0, 0, -12287.4} rad/s^2

α20 = {0, 0, 10131.7} rad/s^2

α30 = {0, 0, 12287.4} rad/s^2

aB = {-8567.36, -14839.1, 0.} m/s^2

aC = {-9484.99, -8317.73, 0.} m/s^2

aE = {5419.99, 4752.99, 0.} m/s^2

0-Dr-3-Er-4-Fr-5-Ft-0

ω43 = {0, 0, -154.265} rad/s

ω54 = {0, 0, -29.814} rad/s

vF05 = {-30.013, 0, 0} m/s

ω40 = {0, 0, 29.814} rad/s

vF = {30.013, 0, 0} m/s

α43 = {0, 0, -20159.7} rad/s^2

α54 = {0, 0, 7872.33} rad/s^2

aF05 = {-5483.1, 0, 0} m/s^2

```
α40 = {0, 0, -7872.33} rad/s^2

aF = {5483.1, 0, 0}  m/s^2



Fext = {-1600, 0, 0}  N

rC1 = {0.0625, 0.108253, 0}  m

aC1 = {-4283.68, -7419.56, 0.}  m/s^2

m1 = 0.02  kg

IC1 = 0.000104333  kg m^2

Fin1 = -m1 aC1 = {85.6736, 148.391, 0.}  N

G1 = -m1 g = {0, -0.19614, 0}  N

F1 = -m1 aC1 + G1 = {85.6736, 148.195, 0.}  N

M1 = Min1 = -IC1 α1 = {0, 0, 0}  N m

rC2 = {0.44686, 0.261578, 0}  m

aC2 = {-9026.18, -11578.4, 0.}  m/s^2

m2 = 0.052  kg

IC2 = 0.00183127  kg m^2

Fin2 = -m2 aC2 = {469.361, 602.078, 0.}  N

G2 = -m2 g = {0, -0.509964, 0}  N

F2 = -m2 aC2 + G2 = {469.361, 601.568, 0.}  N

M2 = Min2 = -IC2 α2 = {0, 0, -18.5539}  N m

rC3 = {0.636154, 0.0657106, 0}  m

aC3 = {-2032.5, -1782.37, 0.}  m/s^2

m3 = 0.044  kg

IC3 = 0.00110953  kg m^2

Fin3 = -m3 aC3 = {89.4299, 78.4243, 0.}  N

G3 = -m3 g = {0, -0.431508, 0}  N

F3 = -m3 aC3 + G3 = {89.4299, 77.9928, 0.}  N

M3 = Min3 = -IC3 α3 = {0, 0, -13.6333}  N m

rC4 = {0.801222, -0.137614, 0}  m

aC4 = {5451.55, 2376.5, 0.}  m/s^2

m4 = 0.048  kg
```

IC4 = 0.0014404 kg m^2

Fin4 = -m4 aC4 = {-261.674, -114.072, 0.} N

G4 = -m4 g = {0, -0.470736, 0} N

F4 = -m4 aC4 + G4 = {-261.674, -114.543, 0.} N

M4 = Min4 = -IC4 α4 = {0, 0, 11.3393} N m

rC5 = {1.09885, -0.1, 0} m

aC5 = $\{5483.1, -1.20792\times10^{-12}, 0.\}$ m/s^2

m5 = 0.008 kg

IC5 = 1.93333×10^{-6} kg m^2

Fin5 = -m5 aC5 = $\{-43.8648, 9.66338\times10^{-15}, 0.\}$ N

G5 = -m5 g = {0, -0.078456, 0} N

F5 = -m5 aC5 + G5 = {-43.8648, -0.078456, 0.} N

M5 = Min5 = -IC5 α5 = {0, 0, 0} N m

4&5

F05 = {0, -185.982, 0} N

F34 = {1905.54, 300.603, 0} N

F54 = {-1643.86, -186.061, 0.} N

2&3

F03 = {2809.92, 122.681, 0} N

F12 = {-1463.18, -501.639, 0} N

F23 = {-993.815, 99.9288, 0.} N

F01 = {-1548.85, -649.834, 0.} N

Meq = {0., 0., 254.094} N m