Problem on two wheeler

1) Each road wheel of a motor cycle has a moment of inertia of $2\ kg \cdot m^2$. The rotating parts of the engine of the motor cycle has a moment of inertia $0.2\ kg \cdot m^2$. The speed of engine is 5 times the speed of wheel and is in same sense. The mass of motor cycle with rider is 200kg & C.G is 500mm above ground level. The dia of wheel is 500mm. The motor cycle is travelling at 15m/sec. on a curve of 30m radius. find.

1) Gyroscopic couple, centrifugal couple, overturning couple, Balancing couple in term of angle of heel. 2) Angle of heel.

Sol: $I_w = 2\ kg \cdot m^2$ $I_e = 0.2\ kg \cdot m^2$ Gear ratio $(i) = \frac{\omega_e}{\omega_w} = 5$

$m = 200kg$. C.G $= (h) = 500mm = 0.5m$.

Dia of wheel $(D_w) = 500mm = 0.5m$ $R_w = 0.25m$.

$V = 15m/sec$ (R) curve radius $(R) = 30m$.

1) Gyroscopic couple:

$$C = \frac{V^2}{R\, r_w}(2 I_w + G I_E)\cos\theta$$

$$C = \frac{15^2}{0.25 \times 30}(2 \times 2 + 5 \times 0.2)\cos\theta$$

$$C = 150\cos\theta.$$

Centrifugal couple $\quad F_c = \frac{mv^2}{R}$.

$C_c = F_c \times h\cos\theta$

$= \frac{mv^2}{R} \times h\cos\theta$

$= \frac{200 \times 15^2}{30} \times 0.5\cos\theta = 750\cos\theta$

Overturning couple: $= C_g + C_c$

$= 150\cos\theta + 750\cos\theta = 900\cos\theta$

Balancing couple: $= mgh\sin\theta$

$= 200 \times 9.81 \times 0.5\sin\theta = 981\sin\theta$.

2) Angle of heel:

for equilibrium

Balancing couple = overturning couple

$981\sin\theta = 900\cos\theta$

$\tan\theta = \frac{900}{981} \quad \theta = 42.53'$

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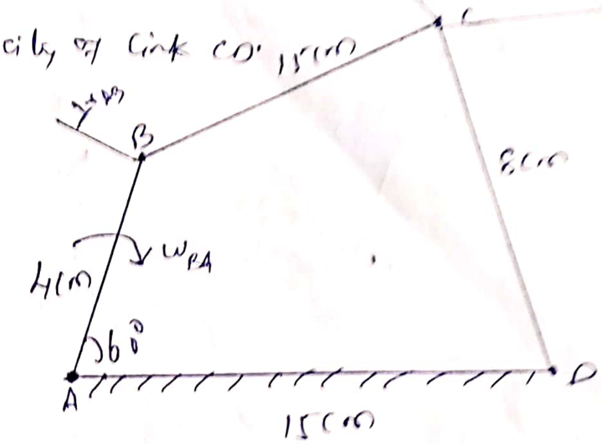
four bar chain ABCD link AD is fixed and is 15 cm long. The crank is AB is 4 cm long rotates at 180 rpm cw while link CD rotates about D & is 8 cm long BC = AD.

∠BAD = 60° find angular velocity of link CD.

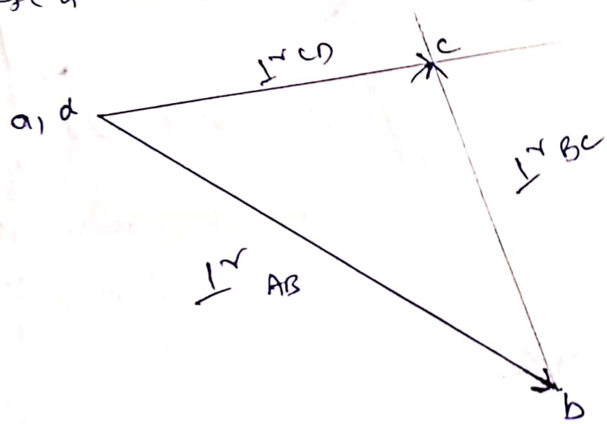


$V_b = \omega r$

$= \omega_{ba} \times AB$ = 0.50 m/sec

$= \frac{2\pi \times 120}{60} \times 4 = 50.24$ cm/sec

Choose a suitable scale 1 cm = 20 cm/s



$V_{cb} = \vec{bc}$

$V_c = \vec{dc} = V_{cd} = 38$ cm/sec

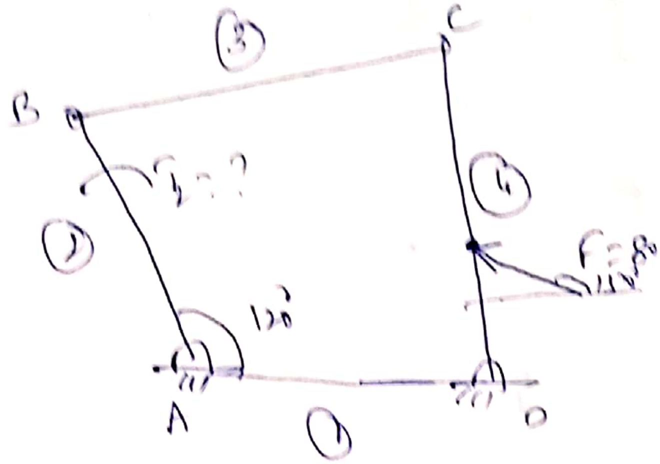
WKT $V = \omega R$

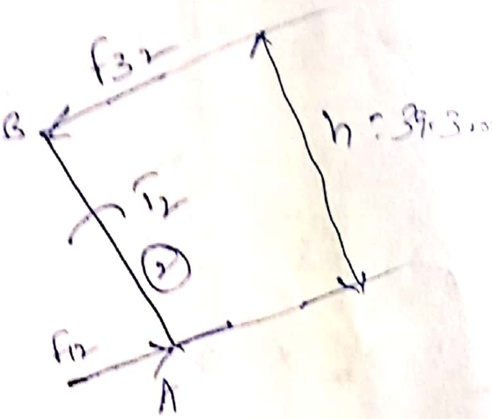
$V_{CD} = \omega_{CD} \times CD$

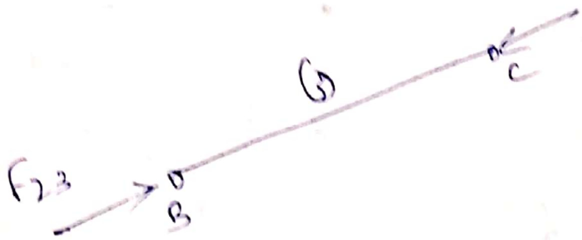
$\omega_{CD} = \frac{V_{CD}}{CD} = \frac{38}{8}$

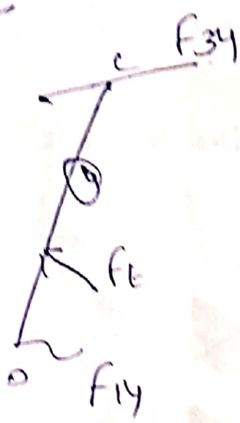
$= 4.7$ r/sec

A four link mechanism is acted upon by force as shown. Determine torque T_2. AD = 50 mm, AB = 40 mm, BC = ..., DC = 75, DE = 35 mm

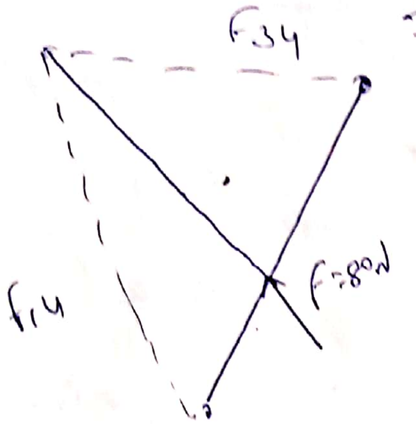




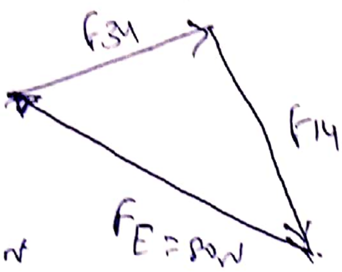




Taking scale 20 N = 1 cm



$F_{34} = 47.8$ N



measure from

$F_{34} = 47.8$ N

$F_{43} = -F_{34} = -F_{23} = 47.8$ N

$F_{23} = -F_{32} = 47.8$ N

$-F_{32} = F_{12} = 47.8$ N

$T_2 = 47.8 \times 39.3$

$= 18.78$ N-mm

by spree of ... in aeroplane makes a complete half circle of 50m radius towards left when flying at 200km/hr. The mass of rotary engine and propeller is 400kg with radius of gyration 300mm. The engine runs at 3000 rpm counter clockwise when viewed from the rear. Determine gyroscopic couple & its effect on the aircraft.

Sol: Given $R = 50m$

$V = 200km/hr = \frac{200 \times 1000}{3600} = 55.56 m/s$

Mass $(m) = 400kg$

$k = 300mm = 0.3m$ $N = 3000 rpm$

$C = I\omega\omega_p$

$= mk^2 \left(\frac{2\pi N}{60}\right)\left(\frac{v}{R}\right) = 400 \times 0.3^2 \times \left(\frac{2\pi \times 3000}{60}\right)\left(\frac{55.56}{50}\right)$

$= 12566.24$ N·m

Effect dip the nose & raise the tail.

(3) An aeroplane makes a complete half circle of 40m radius towards left when flying at 175 km/hr. The mass of the rotary engine & propeller is 400kg with radius of gyration 300mm. The engine runs at 2400 rpm CW when viewed from rear. Find gyroscopic couple and what is effect of aeroplane turn towards right instead of left.

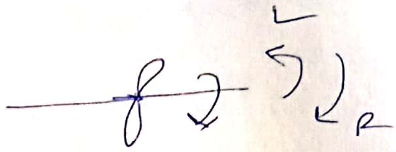
Sol: (R) = 40 m

$V = 175\ km/hr = \frac{175 \times 1000}{3600} = 48.6\ m/s$

$m = 400\ kg$

$k = 300\ mm = 0.3\ m$

$N = 2500\ rpm$



$C = I \omega \omega_p$

$= m k^2 \cdot \frac{2\pi N}{60} \cdot \frac{v}{R} = 400 \times 0.3^2 \times \frac{2\pi \times 2500}{60} \times \frac{48.611}{40} = 11453.7\ N \cdot m$

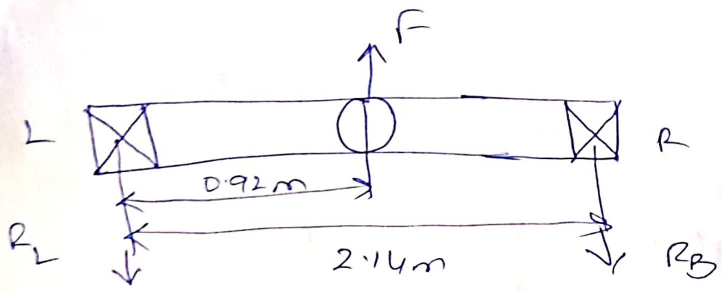
Left turn

Raise nose of plane

Right turn (case 2)

Dip the nose & raise tail

(5) The rotor of a 'jet' aeroplane engine is supported by two bearings 2.14 m apart. The rotor assembly including compressor, turbine, shaft has a mass of 688 kg. Its C.G. is situated at 0.92 m from left bearing & length 'k' = 0.229 m. Determine the max bearing force on the aeroplane when it undergoes a pull out on a 1830 m radius curve at a constant speed of 960 km/hr. Speed of engine rotor is 10,000 rpm. Include the effect of centrifugal force due to pull out as well as gyroscopic effect.



length (l) = 2.14m

m = 688 kg

(k) = 0.229 m

R = 1830

v = 960 km/hr = 266.6 m/s   N = 10,000

1) Consider centrifugal force effect

$$F = \frac{mv^2}{R} = \frac{688 \times (266.6)^2}{1830} = 26733.33\,N$$

Take moments about left bearing

$$R_b \times 2.14 = F \times 0.92$$

R_b = 11492.8 N force on right bearing due to CF

$R_L + R_b = F \Rightarrow R_L = 15240.53\,N$ Force on LB due to CF

2) <u>Gyroscopic couple</u>

$$C = I \omega \omega_p$$

$$= mk^2 \times \frac{2\pi N}{60} \times \frac{v}{R}$$

$$= 688 \times 0.299^2 \times \frac{2\pi \times 10{,}000}{60} \times \frac{960 \times 1000}{3600 \times 1830}$$

$$= 9385.9\ N\text{-}m$$

A40

$C = F \times L$

$93859 = F \times 2.14$

$F = 4385.9$ N force on each bearing due to gyro Effect

∴ Resultant force on right bearing

$= \sqrt{R_B^2 + F^2} = \sqrt{11492.8^2 + 4385.9^2}$

$= 12301.2$ N

Resultant force on left bearing

$= \sqrt{R_L^2 + F^2} = \sqrt{15260.53^2 + 4385.9^2}$

$= 15859.0$ N

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i turbine rotor of sea vessel having mass of 950kg rotates at 1200rpm CW while looking from stern. The vessel pitches with angular velocity 1.2 rad/s. What will be the gyroscopic couple transmitted to the hull when the bow raises. K = 300mm

Sol: $m = 950kg$ $N = 1200$ $\omega = 1.2$ rad/sec $k = 0.3m$

$I = mk^2 = 950 \times 0.3^2 = 85.5 kg \cdot m^2$ $\omega_p = \frac{2\pi N}{60} = 125.6$ rad/s

$C = I \omega \omega_p$ $85.5 \times 1.2 \times 125.6$

$= 12886.5 N \cdot m$

(3) A Ship is propelled by a rotor turbine which has mass of 5000kg and has a speed of 2100 rpm. Radius k = 0.5m rotates in CW when view from stern. Find gyroscopic effect in following conditions

a) Ship runs at speed of 16 knots (1 knot = 1880 m/hr) & it steers to the left in a curve of 60m radius.

b) The ship pitches 6° above & 6° below in horizontal position. The bow descends with its max velocity. The motion due to pitching is SHM & the periodic time is 20sec

c) The ship rolls at a certain instant has an angular velocity 0.03 rad/sec CW when view from stern.

Sol: $m = 5000kg$ $N = 2100$ rpm $k = 0.5m$ $v = 16$ knots $= \frac{16 \times 1860}{3600}$ m/s

$R = 60m$ ϕ = pitching of ship = 6° $= 6 \times \pi/180$ rad/s

Periodic time $t_p = 20sec$ $\omega_p = 0.03$ rad/sec.

1) Steering $\omega_p = \frac{v}{r}$

$C = I \omega \omega_p = 5000 \times 0.5^2 \times \frac{2\pi \times 2100}{60} \times \frac{16 \times 1860}{3600 \times 60}$

$= 378736 N m$

Effect: raise the bow & dip the stern

2) Pitching: $C = I\omega\omega_p$

$= mk^2 \times \frac{2\pi N}{60} \times \phi \frac{2\pi}{t_p}$

$= 5000 \times 0.5^2 \times \frac{2\pi \times 2100}{60} \times 6 \times \frac{2\pi}{20} \times \frac{\pi}{180} = 9043.49\,Nm$

Effect: tends to turn left side

3) Rolling: $C = I\omega\omega_p = 5000 \times 0.1^2 \times \frac{2\pi \times 2100}{60} \times 0.03$

$= 8246.68\,Nm$

in Rolling no gyroscopic effect

(3) The rotor of a marine having mass of 1000kg & k = 0.3m rotates at 1550 rpm cw when looked from bow. determine g.c & its effect on following cases

a) when the ship pitches with an angular velocity of 1rad/sec when the bow rising, falling

b) when the ship is running at 40km/hr & takes a right turn in circular path of 200m radius

c) when the ship rolls at a certain instant, it has angular velocity of 0.5 rad/sec when viewed from stern.

Sol: $k = 0.3m$ $N = 1550\,rpm$ $m = 1000kg$

$(\omega_p)_{pitching} = 1\,rad/sec$

$V = 40\,km/hr =$ $R = 200m$.

$(\omega_p)_{rolling} = 0.5\,rad/sec$

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