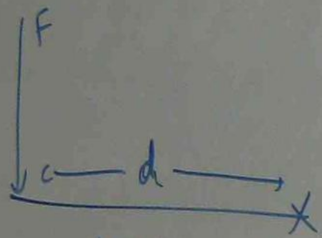
TORQUE AND ROTATIONAL MOTION



LEVER

TORQUE = FORCE × DISTANCE

$$\boxed{T = F \times d} \quad N\text{-}m$$

$$\boxed{T = I\alpha}$$

T = TORQUE N-m

I = MASS MOMENT OF INERTIA kg-m^2

α = ANGULAR ACCELERATION rad/s^2

pb/ DETERMINE THE NET TORQUE REQUIRED TO GIVE A FLYWHEEL WITH A MASS MOMENT OF INERTIA 0.75 Kg-m^2, AN ANGULAR ACCELERATION 16 rad/s^2

$I = 0.75$ kg-m^2, $\alpha = 16$ rad/s^2

$T = I \times \alpha = 0.75 \times 16 = 12$ N-m

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pb/ DETERMINE THE TORQUE REQUIRED TO ACCELERATE A TURBINE ROTOR UNDERGOING A DYNAMIC BALANCING TEST FROM REST TO A SPEED OF 15000 RPM IN 80 SECONDS. IF THE MASS MOMENT OF INERTIA OF ROTOR IS 11.5 kg m^2

$$\omega = \text{rad/sec} = \frac{2\pi \times RPM}{60} = \frac{2 \times 3.1416 \times 15000}{60} = 1571 \text{ rad/s}$$

$$\omega_1 = 0 \xrightarrow[t = 80 \text{ sec}]{} \omega_2 = 1571 \text{ rad/s}$$

$$\omega_2 = \omega_1 + \alpha t$$

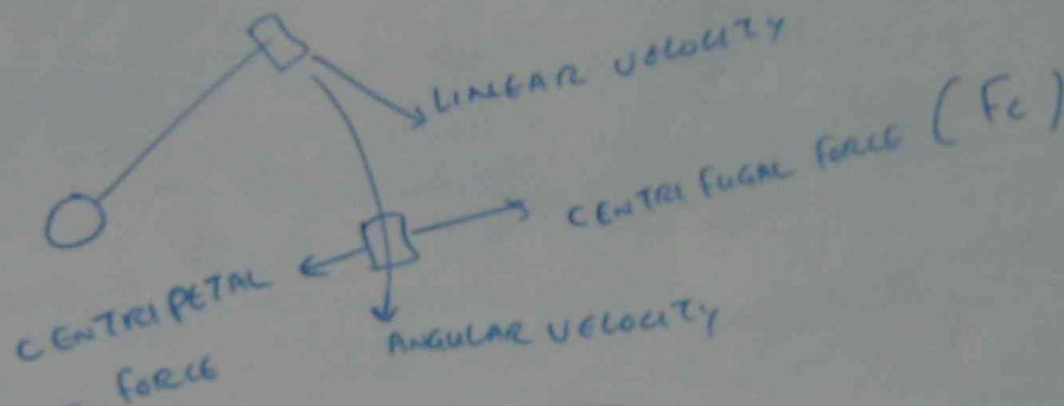
$$1571 = 0 + \alpha \times 80 \longrightarrow \alpha = \frac{1571}{80} = 19.63 \text{ rad/s}^2$$

$$T = I \times \alpha$$

$$= 11.5 \times 19.63 = 225.8 \text{ N-m}$$

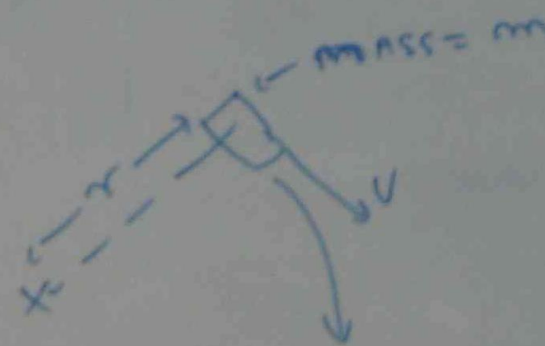
CENTRIFUGAL FORCE

THE FORCE PRODUCED BY THE ROTATIONAL BODY AT THE RIGHT ANGLE TO THE CURVATURE



$$\boxed{F_c = \frac{m v^2}{r}}$$

F_c IN N



Ex

DETERMINE THE CENTRIFUGAL FORCE ACTING ON A PASSENGER OF MASS 75 kg IN A CAR TRAVELLING AT 90 km/hr AROUND A CURVE OF 100m RADIUS.

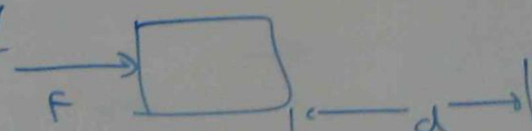
$m = 75\ kg$ $\qquad v = \frac{90 \times 1000}{3600} = 25\ m/s$

$r = 100m$

$$F_c = \frac{mv^2}{r} = \frac{75 \times (25)^2}{100} = 468.75\ N$$

WORK & POWER

LINEAR MOVEMENT

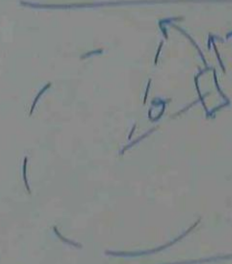


$$\boxed{W = f \times d}\ (J)$$

f = FORCE (N) $\qquad$ W = WORK (J)

d = DISTANCE (m)

ANGULAR MOVEMENT



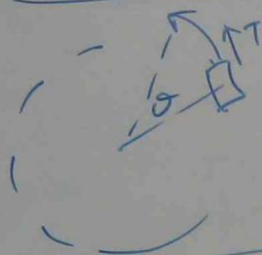
$$\boxed{W = T \times \theta}$$

T = TORQUE (N-m)

θ = ANGLE (rad)

W = WORK (J)

ANGULAR MOVEMENT



$$\boxed{W = T \times \theta}$$

T = TORQUE (N-m)

θ = ANGLE (rad)

W = WORK (J)

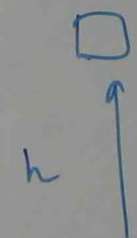
pb ① DETERMINE THE WORK DONE BY THE FORCE OF 50N MOVING DISTANCE OF 3m IN THE DIRECTION OF FORCE

pb ② A HOIST LIFTS A LOAD OF 1.5 TON THROUGH A VERTICAL DISTANCE OF 20m . DETERMINE THE AMOUNT OF WORK DONE AGAINST GRAVITY

pb ③ A FLYWHEEL MAKES 200 REVOLUTIONS WHILE THE TORQUE APPLIED TO IT IS 35N . DETERMINE THE WORK DONE.

① $W = F \times S = 50 \times 3 = 150\ J$

② 1.5 TON = 1500 kg



$F = mg = 1500 \times 9.8$

$W = F \times h = 1500 \times 9.8 \times 20 = 294300\ J$

$= 294.3\ kJ$

③ $W = T \times \theta$

$T = 35\ N$

$\theta = 200 \times 2\pi = 1257\ rad$

$\boxed{RAD = REV \times 2\pi}$ (θ)

$W = T\theta = 35 \times 1257 = 43980\ J = 43.98\ kJ$

POWER

TIME RATE OF DOING WORK.

$$\boxed{P = \frac{W}{t}}$$

$$P = \frac{F \times S}{t}$$

S = DISTANCE TRAVELLED (m)

t = TIME (sec)

$$\boxed{P = F \times V}$$ LINEAR

F = FORCE = (N)

V = VELOCITY (m/s)

P = POWER (WATT)

$$P = \frac{W}{t} = \frac{T\theta}{t} = T \times \frac{\theta}{t}$$

ANGULAR $\boxed{P = T \times \omega}$

T = TORQUE (N-m)

ω = ANGULAR VELOCITY rad/s = $\frac{\theta \text{ (rad)}}{t \text{ (sec)}}$

pb (1)

A HOIST LIFTS A LOAD OF 1.5 TON THROUGH A VERTICAL DISTANCE OF 20 m IN 27 SECONDS. WHAT IS AVERAGE POWER?

pb (2)

A TRAIN MOVING AT 63 Km/hr REQUIRES 40 KN OF TRACTIVE EFFORT AT THIS SPEED.
DETERMINE DRIVING POWER

pb (3)

AN OUTPUT SHAFT OF AN ELECTRIC MOTOR ROTATES AT 1450 RPM AND PRODUCES TORQUE 81 N-m
WHAT IS SHAFT POWER?

(1) $P = \frac{W}{t} = \frac{mgh}{t} = \frac{1500 \times 9.8 \times 20}{27} = 10900\,W = 10.9\,kW$

(2) $V = 63\,km/hr = \frac{63 \times 1000}{3600} = 17.5\,m/s$

$F = 40\,kN = 40{,}000\,N$

$P = F \times V = 40{,}000 \times 17.5 = 700{,}000\,W = 700\,kW$

(3) $P = \tau \times \omega$

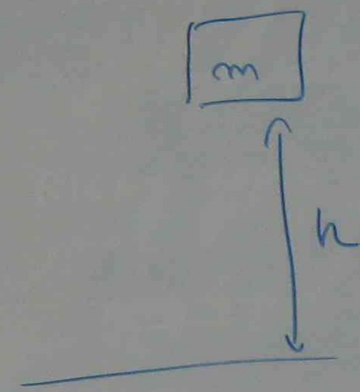
$= 81\,(N\text{-}m) \times \frac{Rpm \times 2\pi}{60}$

$= 81 \times \frac{1450 \times 2 \times 3.1416}{60}$

$= 12300\,W$

$= 12.3\,kW$

POTENTIAL ENERGY – THE ENERGY WHICH A BODY POSSESSES DUE TO IT'S POSITION IN THE GRAVITATIONAL FIELD



$$PE = m\,g\,h$$

m = MASS (kg)
h = HEIGHT (m)
g = GRAVITATION
PE = POTENTIAL ENERGY (J)

KINETIC ENERGY – THE ENERGY WHICH THE BODY POSSESSES DUE TO IT'S VELOCITY

LINEAR movement

$$KE = \frac{m v^2}{2}$$

v = VELOCITY (m/s)
KE = KINETIC ENERGY (J)

Pb (1) CALCULATE THE POTENTIAL ENERGY OF A DROP HAMMER WHICH HAS A MASS OF 1 TONNE AND IS RAISED 1.5 m ABOVE THE PILE HEAD BEFORE BEING ALLOWED TO DROP FREELY IN ORDER TO DRIVE IT INTO GROUND.

Pb (2) CALCULATE THE KINETIC ENERGY OF A VEHICLE OF 1700 kg MASS MOVING WITH A VELOCITY OF 80 km/hr

① $PE = mgh = 1000\,kg \times 9.81 \times 1.5\,m = 14715\,J$

② $V = \dfrac{80 \times 10^3}{3600} = 22.2\,m/s$

$$KE = \frac{mv^2}{2} = \frac{1700 \times (22.2)^2}{2} = 424700\,J$$
$$= 424.7\,KJ$$

$$\boxed{KE = \frac{I\omega^2}{2}}$$

ANGULAR MOVEMENT

I = MOMENT OF INERTIA $kg\text{-}m^2$

ω = ANGULAR VELOCITY rad/sec

Pb

CALCULATE THE KINETIC ENERGY OF A FLYWHEEL OF MASS MOMENT OF INERTIA OF 61 Kg-m^2 ROTATING AT 250 RPM.

$$\omega = \frac{2\pi \times RPM}{60} = \frac{2 \times 3.1416 \times 250}{60} = 26.16 \text{ rad/s}$$

$$KE = \frac{I\omega^2}{2} = \frac{61 \times (26.16)^2}{2} = 20883 \text{ J} = 20.883 \text{ KJ}$$

MOMENTUM IS DESCRIBED AS THE QUANTITY OF MOTION AND IS THE PRODUCT OF THE MASS OF A BODY (m) AND IT'S VELOCITY AT (V)

MOMENTUM = m . V

kg. m/s

MASS = Kg

VELOCITY (m/s)

Pb ①

A ROCKET OF 2.5 t MASS IS FIRED VERTICALLY UPWARD WITH A VELOCITY OF 250 m/s. WHAT IS MOMENTUM.

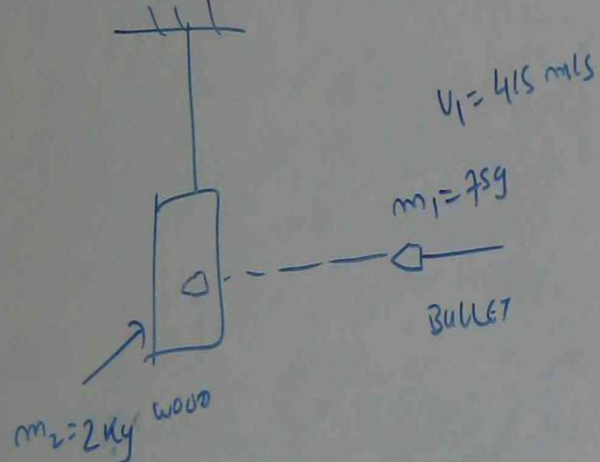
Pb(2)

A BLOCK OF WOOD OF MASS 2 Kg IS FREELY SUSPENDED ON A STRING. A BULLET OF MASS 75 g IS FIRED HORIZONTALLY INTO THE BLOCK. IF THE VELOCITY OF THE BULLET BEFORE IMPACT IS 415 m/s, CALCULATE THE VELOCITY OF THE BLOCK, WITH THE BULLET IMBEDDED IN IT, IMMEDIATELY AFTER THE IMPACT.

(1)

momentum: $mV = 2500\,kg \times 250\,m/s = 625000\,kg\text{-}m/s$

(2)



$V_2 = 0$

momentum of BULLET & WOOD BEFORE HITTING = momentum of BULLET & WOOD AFTER HITTING

$$m_1 V_1 + m_2 V_2 = (m_1 + m_2) \times V_F$$

$$\frac{75}{1000}\,kg \times 415 + 2 \times 0 = \left(\frac{75}{1000} + 2\right) \times V_F$$

$$31.13 = 2.075\,V_f$$

$$V_f = \frac{31.13}{2.075} = 15\,m/s$$