ENGINEERING PHYSICS

1-3 Rotational kinetic energy

1. $I = 0.048\ kgm^2$, $\omega_1 = 20\ rads^{-1}$

(a) rotational k.e. = $\frac{1}{2} I\omega^2 = \frac{1}{2} \times 0.048 \times 20^2 = 9.6$ J

(b) T = ?, $\omega_1 = 0\ rads^{-1}$, $\omega_2 = 20\ rads^{-1}$, t = 5.0 s

(i) $\alpha = \frac{\omega_2 - \omega_1}{t} = \frac{20 - 0}{5.0} = 4.0\ rads^{-2}$

$T = \alpha I = 4.0 \times 0.048 = 0.192$ Nm

(ii) $\theta = \frac{1}{2}(\omega_1 + \omega_2)t = \frac{1}{2}(0 + 20) \times 5 = 50$ rad

OR

$W = T\theta$ therefore $\theta = \frac{W}{T}$ (W = k.e. from (a))

$= \frac{9.6}{0.192}$

$= 50$ rad

OR

$\omega^2 = \omega_0^2 + 2\alpha\theta$ therefore $\theta = \frac{\omega^2 - \omega_0^2}{2\alpha} = \frac{20^2 - 0}{2 \times 4.0} = 50$ rad

OR

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2 = 0 + \frac{1}{2} \times 4.0 \times 5.0^2 = 50$ rad

2. m = 0.65 kg, s = 1.9 m, t = 4.6 s, axle diameter, d = 8.5 mm

(a) p.e. loss = $mg\Delta h$ = $0.65 \times 9.8 \times 1.0$

= 12.103

= 12 J to 2 sf

(b) t after release = 14 s, time of fall and rise = 4.6 s to fall and rise

3 x 4.6 s = 13.8 s so essentially 14s after release it is essentially at the bottom of the fall

No of times made by flywheel as mass falls $= \frac{distance\ fallen\ by\ mass}{circumference\ of\ shaft}$

$= \frac{1.9}{\pi \times 8.5 \times 10^{-3}}$

= 71.15…

= 71 to 2 sf

Angle turned through = $2\pi \times 71 = 447$ rad

Average angular velocity = $\frac{447}{4.6} = 97\ rads^{-1}$

Therefore max angular velocity = $2 \times 97 = 194\ rads^{-1}$

Speed of object, $v = r\omega = \frac{8.5 \times 10^{-3}}{2} \times 194 = 0.83\ ms^{-1}$

OR

Average velocity during fall = $\frac{1.9}{4.6}$

Therefore max velocity at bottom = $\frac{1.9}{4.6} \times 2 = 0.83\ ms^{-1}$

k.e. = ½ mv^2 = ½ x 0.65 x 0.83^2 = 0.22 J = 0.2 J to 1 sf

(c) (i) k.e. of flywheel = 12.1 – 0.2 = 11.9 J

(ii) moment of inertia of flywheel:

E_K = = ½ $I\omega^2$ therefore $I = \frac{2E_K}{\omega^2} = \frac{2 \times 11.9}{194^2} = 6.3 \times 10^{-4}\ kgm^2$

3. At the top of the slope the ball possesses p.e.

As it rolls down the slope the p.e. becomes rotational and translational k.e.

As it rolls on the horizontal surface, it loses the rotational and translational k.e. because of frictional forces and the energy becomes internal energy.

4. d = 0.31 m, t = 0.08 m, $\rho_{STEEL} = 7800\ kgm^{-3}$

(a) (i) $m = \rho V = \rho \frac{\pi d^2 t}{4} = 7800 \times \frac{\pi 0.31^2 \times 0.08}{4}$ = 47.0975…. = 47 kg to 2 sf

(ii) moment of inertia I = ½ MR^2 = ½ x 47 x $\left(\frac{0.31}{2}\right)^2$ = 0.5657… = 0.57 kgm^2

(b) (i) 3000 revolutions per minute

$\omega = \frac{\theta}{t} = \frac{3000 \times 2\pi}{60} = 314.15... = 314\ rads^{-1}$

flywheel k.e. = ½ $I\omega^2$ = ½ x 0.57 x 314^2

= 28128

= 2.8 x 10^4 J or 28 kJ to 2 sf

(ii) time of transfer = 30s

Average power = $\frac{\text{energy transfer}}{\text{time}} = \frac{2.8 \times 10^4}{30}$

= 940 W to 2 sf