Rotation – Questions – 1

A Physics

1. A roundabout accelerates from rest with a steady acceleration of 0.03 rad s^{-2}. After 1 minute it reaches maximum speed, and rotates at this speed for a further 5 minutes. It then slows steadily + comes to rest after a further 1.5 min

(a) What was the maximum angular velocity? 2

(b) What was the final angular deceleration? 2

(c) What was the angular distance turned in each of the 3 stages of rotation? 2 + 2 + 1.5

(d) How many revolutions did the roundabout make? 2

(e) Sketch a graph of angular velocity against time. — — — 1 + 2 + 2 = 5

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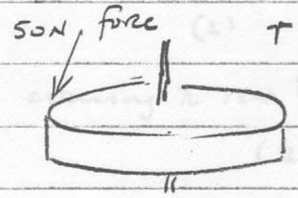
2. The diagram shows a roundabout. which can be treated as a simple solid disk.



(a) What is its moment of inertia? 2

A person pushes the roundabout at the rim with 50 N for 1 revolution, then lets go. (Assume friction = 0.)

(b) What torque is produced? 2

(c) How much work does the person do? 2

(d) What is the roundabout's KE after 1 revolution? 2

(e) What was the roundabout's angular acceleration? 2

(f) What was its final angular velocity?

— Show how you can use 2 methods for this. 3 × 2

(g) What is the roundabout's angular momentum?

(h) How long does it take to do 1 revolution? 2

(i) What speed must a child run to be able to step onto the roundabout? — what is its rim velocity? 2

Imagine the roundabout spinning with angular velocity of 3 rad/s, with friction operating, and bringing it to rest after 15 revolutions.

(j) What is the frictional torque? 3

(k) How long does it take for it to stop? 4

$\boxed{27}$

JN 4.97

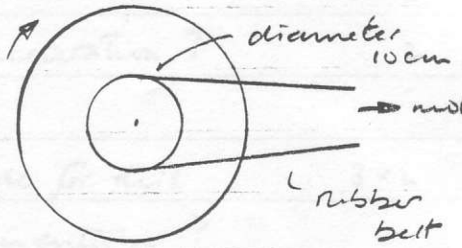
Rotation - Questions - 2

A Physics

3. A record deck turntable is a solid aluminium disc, as shown →
The density of aluminium is 2700 kg/m³.

(a) Show that the mass of the turntable is 286 g. (2)
(b) What is the turntable's moment of inertia? (2)
(c) The turntable is rotating at $33\frac{1}{3}$ rpm. What is its angular velocity? (2)
The motor is switched off and the turntable comes to rest in 20 s.
(d) What is the angular deceleration? (2)
(e) What is the angular distance turned in coming to rest? (2)
(f) What is the frictional torque? (2)
(g) What power of motor is needed to maintain a constant speed of $33\frac{1}{3}$ rpm? (2)

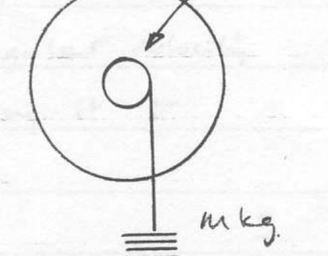
(H) When the motor is switched on, it brings the turntable up to a speed of $33\frac{1}{3}$ rpm in 2.0 sec.
The turntable is driven by a rubber belt, as shown →



(h) What tension is produced in the rubber belt? (3)
(i) What is the average power needed from the motor in starting up? (3)

[20]

(H) 4 A Physics student is measuring the M.I. of an iron flywheel.



(a) She needs a 220 g mass to maintain steady rotation. What is the frictional torque? (2)
(b) With a 1 kg mass, the times for 1 revolution from rest are 2.4 s, 2.62 and 2.57 s. What is I of the flywheel? (5)
(c) If the flywheel is a solid disc, how thick is it? (hmm...) $D_{iron} = 7700$ kg/m³
(d) Is this a question? (1).

TJN
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(H)

Rotation — Answers — 1

A Physics
Rotation

1 (a) $\omega_1 = \omega_0 + \alpha t \rightarrow \omega_1 = 0 + 0.03 \times 60 = \underline{1.8 \text{ rad/s}}$ (2)
($v = u + at$)

(b) $\alpha = \Delta\omega / t \rightarrow \alpha = 1.8 / 90 = \underline{0.02 \text{ rad/s}^2}$ (2)

(c) Accel... $\theta = \frac{1}{2}\alpha t^2 =$ 54 rad (2)

Steady ω... $\theta = \omega t =$ 540 rad (1)

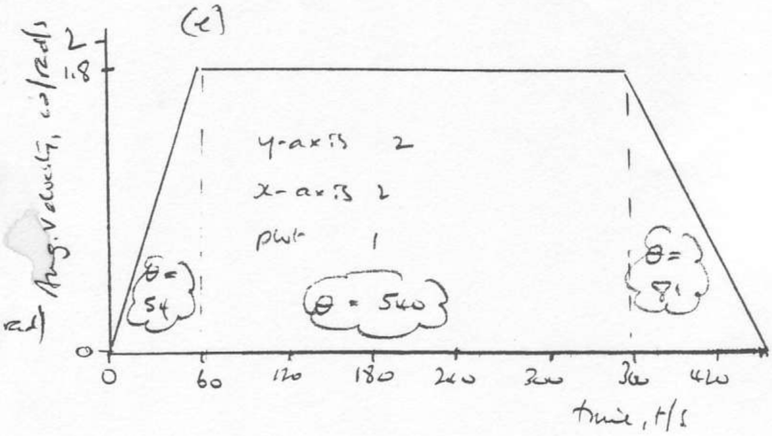
decel... $\theta = \omega t - \frac{1}{2}\alpha t^2$ rad (2)

= 81

(d) Total = $\underline{675 \text{ rad}}$

= $\underline{107 \text{ revs}}$ (1rev = 2π rad) (2)

(e)



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2. (a) $I = \frac{1}{2}mr^2 = \underline{225 \text{ kg m}^2}$ (2)

(b) Torque $T = Fr = 50 \times 1.5 = \underline{75 \text{ Nm}}$ (2)

(c) Work $W = T\theta = 75 \times 2\pi = \underline{471 \text{ J}}$ (2) (W linear = Fd)

(d) all work → KE so $\frac{1}{2}I\omega^2 = \underline{471 \text{ J}}$ (2)

(f) method 1 — energy method

$\frac{1}{2}I\omega^2 = 471$ (1)

so $\omega = \sqrt{\frac{2 \times 471}{225}} = \underline{2.05 \text{ rad/s}}$ (1)

method 2 — eq. motion

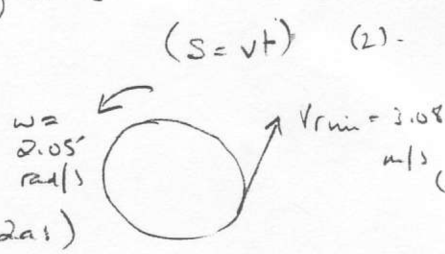
$\omega_1^2 = \omega_0^2 + 2\alpha\theta$ (1) $\rightarrow \omega = 2.05$ (1) rad/s

/(4)

(g) angular "p" = $I\omega = 225 \times 2.05 = \underline{460}$ kg m² s⁻¹ (2)

(h) Time 1 rev $T = \theta/\omega = 2\pi/\omega = \underline{3.06 \text{ s}}$. ($s = vt$) (2).

(i) Rim velocity $v_{rim} = \omega r = \underline{3.08}$ m/s



(2)

(j) Slowing down $\omega_1^2 = \omega_0^2 + 2\alpha\theta$ (1) ($v^2 = u^2 + 2as$)

$\omega_1 = 0$ $\omega_0 = 3$ rad/s 15 revs = 15×2π rad.

so α (decel.) $= -\frac{\omega_0^2}{2\theta} = \underline{-0.048}$ (1) rad/s²

T (friction) $= I\alpha = 225 \times -0.048 = -10.7$ (1) Nm (ie in reverse direction) (3)

(k) Time to stop $\omega_1 = \omega_0 + \alpha t$ ($v = u + at$)

or $\alpha = \Delta\omega / t \Rightarrow t = \Delta\omega/\alpha = 3/0.048 = \underline{62.8 \text{ s}}$ (2)

(e) ang. accel.... use $T = I\alpha \Rightarrow \alpha = T/I = \underline{0.333 \text{ rad/s}^2}$ (2)

TW
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Total 25

Rotation — Answers — No. 2   A Physics

3. (a) $M = DV$: vol $V = \pi r^2 t$ (thickness) $= \pi (13\times10^{-2})^2\, 2\times10^{-3} = \underline{106\times10^{-6}\ m^3}$ ①

so mass $M = 2700 \times 106\times10^{-6} = 0.286$ kg $= \underline{286\ g}$ (2)

(b) $I_{disc} = \frac{1}{2} m r^2 = \underline{0.00242}$ kg m^2 (2)

(c) $33\frac{1}{3}$ rpm $= 33.33/60 = 0.556$ rev/s, Hz $\rightarrow \omega = 2\pi f = \underline{3.49}$ rad/s (2)

(d) angular decel... $\alpha = \Delta\omega/t = 3.49/20 = \underline{0.175\ rad/s^2}$ (2)

(e) $v^2 = u^2 + 2as \longrightarrow \omega_f^2 = \omega_i^2 + 2\alpha\theta$; come to rest... so $\omega_f = 0$

so $\omega_i^2 = -2\alpha\theta \longrightarrow \theta$ ang. distance $= \omega_i^2/_{-2\alpha} = \underline{34.8\ rad.}$ (2)

(or $\omega_{average} = \frac{1}{2}\omega_{initial} = 1.75$ rad/s ; so $\theta = \omega_{av.} \times t = 34.9$ rad.)

(f) $T_{friction} = I\alpha$ ($F = ma$) so $T = \underline{4.24\times10^{-4}\ Nm}$ (2)

(g) $P_{motor} = T\omega$ ($P_{engine} = Fv$) so $P = \underline{1.5\times10^{-3}}$ Watts, J/s (2)
(0.0015 W.)

(h) starting up turntable...

accel $\alpha = \Delta\omega/t = 3.49/2 = \underline{1.75\ rad/s^2}$ ① so Torque $T = I\alpha = 0.00423$ Nm ①

but Torque = Tension force in belt × radius $= F_{belt} \times 5\times10^{-2}$

so $F_{belt} = \underline{0.085\ N}$ ① (3)

(i) average power = KE gained by turntable / time taken ①

KE turntable $= \frac{1}{2} I\omega^2 = \underline{0.0148}$ J ①

so average power $= 0.0148/2 = \underline{0.0074}$ ① J/s, watts ignoring friction! (3)

(if you include work against friction? $\theta = \omega_0 t + \frac{1}{2}\alpha t^2 = 3.5$ rad

so W against friction $W = T_{friction}.\theta = 4.24\times10^{-4} \times 3.5 = 0.00148$ J.

so True motor power $= \dfrac{(KE\ gained + W_{friction})}{time} = \underline{0.0081}$ Watts)

4. (a) $T_{friction} = Fr = mgr = 0.044$ Nm. (2)

(b) time average $= \underline{2.55\ sec.}$ ①

Effective accelerating mass $= 1000 - 220 = 780g$ ①

Effective Torque $T = mgr = 0.78\times10\times2\times10^{-2} = \underline{0.156\ Nm}$ ①

To find acceleration α, use $\theta = \omega_0 t + \frac{1}{2}\alpha t^2 \rightarrow \alpha = 2\theta/t^2 = \dfrac{2\times2\pi}{t^2}$

so accel. $\alpha = \underline{1.93\ rad/s^2}$ ① (5)

so since $T = I\alpha \longrightarrow I = T/\alpha = 0.156/1.93 = \underline{0.081}$ ① kg m^2

(c) Solid disc $\rightarrow I = \frac{1}{2} m r^2 \longrightarrow$ mass $m = 2I/r^2 = \underline{7.18}$ kg

$m = dV \longrightarrow$ volume $V = m/d = 7.18/7700 = \underline{932\times10^{-6}\ m^3}$

© JN '98   since $1\ m^3 = 10^6\ cm^3$ Volume $V = 932\ cm^3 = \pi r^2 t$ ← thickness

so thickness $t = V/\pi r^2 = 932/\pi\times15^2$ $\dfrac{cm^3}{cm^2}$ $= \underline{1.32\ cm}$ (1)

(d) Hmm... "Yes, if this is an answer." (1)