

- M1.(a)** Law of conservation of angular momentum applies and $I_1 \omega_1 = I_2 \omega_2$
 OR Law of conservation of angular momentum applies and angular momentum = $I \omega$ ✓
 (because no external torque acts)

Adding plasticine increases I ✓

So ω must decrease to maintain $I \omega$ constant / to conserve angular momentum ✓

3

- (b) $I \times 3.46 = (I + 0.016 \times 0.125^2) \times 3.31$ ✓
 $I = 0.00552 \text{ kg m}^2$ ✓ 3 sf ✓

Useful: $mr^2 = 2.5 \times 10^{-4}$

Sig fig mark s an independent mark

If method correct but incorrect conversion of g to kg or mm to m, award 1 mark out of first 2 marks

3

- (c) (i) $\Delta E = \frac{1}{2} I \omega_1^2 - \frac{1}{2} (I + mr^2) \omega_2^2$
 $= [\frac{1}{2} \times 5.52 \times 10^{-3} \times 3.46^2] -$
 $[\frac{1}{2} \times 5.77 \times 10^{-3} \times 3.31^2]$ ✓
 $= 1.39 \times 10^{-3} \text{ J}$ ✓

CE for I of turntable or I of plasticine from 2b

Answers will vary depending on rounding e.g. accept 1.43×10^{-3}

2

- (ii) Work done against friction / deforming plasticine as it collides with turntable / to move or accelerate plasticine ✓

Allow heat loss on collision

Do not allow energy to sound

1

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- M2.(a)** (Gravitational potential energy of falling mass) is converted to linear/translational ke of mass and rotational ke of wheel ✓

1

and internal energy in bearings / air around wheel ✓

1

(b) (Use of $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + T\theta$)

$$mgh = 2.94 \text{ J}$$

$$(0.200 \times 9.81 \times 1.50) = (0.5 \times 0.200 \times 2.22^2) + (0.5 \times I \times 6.73^2)$$

$$\frac{1}{2}mv^2 = 0.493 \text{ J}$$

$$+ (7.5 \times 10^{-3} \times 4.55)$$

$$T\theta = 0.0728 \text{ J}$$

E_p or E_k correct ✓

1

*If friction torque not worked out out, give up to max 2 marks.
Give full marks if friction torque worked out and stated as negligible.*

All E_p , E_k and $T\theta$ correct ✓

1

Leading to $I = 2.41(3) / 22.6$ ✓ (= 0.107 kg m²)

Gives

$$I = 0.108 \text{ kg m}^2$$

1

(c) $\alpha = T/I = 7.5 \times 10^{-3} / 0.107 = 0.0701 \text{ rad s}^{-2}$ ✓

1

substitution of $\omega_2 = 0$, $\omega_1 = 6.73$ and α into $\omega_2^2 = \omega_1^2 - 2\alpha\theta$

leading to $\theta = 323 \text{ rad}$ ✓

OR

$$\frac{1}{2}I\omega^2 = T\theta \quad 0.5 \times 0.107 \times 6.73^2 = 7.5 \times 10^{-3} \theta \quad \checkmark$$

$$\theta = 323 \text{ rad } \checkmark$$

Give CE if

$$I = 0.108 \text{ kg m}^2 \text{ used}$$

1

[7]

$$\text{M3.(a)} \quad \frac{3.5}{(2\pi \times 0.088)} = 6.3 \text{ rev}$$

$$6.3 \times 2\pi = 39.8 \text{ rad or } 40 \text{ rad } \checkmark$$

OR

$$\frac{3.5}{0.088} = 39.8 \text{ or } 40 \text{ rad } \checkmark$$

*If correct working shown with answer 40 rad give the mark
Accept alternative route using equations of motion*

1

$$(b) \quad \omega = v/r = 2.2 / 0.088 = 25 \text{ rad s}^{-1} \checkmark$$

1

$$(c) \quad (i) \quad E = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 + mgh \\ = (0.5 \times 7.4 \times 25^2) \\ + (0.5 \times 85 \times 2.2^2) \\ + (85 \times 9.81 \times 3.5) \\ = 2310 \checkmark \\ + 206 \quad \checkmark \\ + 2920 \quad \checkmark \\ (= 5440 \text{ J} \quad \text{or } 5400 \text{ J})$$

CE from 1b

$$\frac{1}{2} I \omega^2 + \frac{1}{2} m v^2 = 2310 + 210 = 2520 \text{ J}$$

$$\frac{1}{2} I \omega^2 + mgh = 2310 + 2920 = 5230 \text{ J}$$

$$\frac{1}{2} m v^2 + mgh = 210 + 2920 = 3130 \text{ J}$$

Each of these is worth 2 marks

3

$$(ii) \quad \text{Work done against friction} = T\theta \\ = 5.2 \times 40 = 210 \text{ J } \checkmark \\ \text{Total work done} = W = 5400 + 210 \\ = 5600 \text{ J } \checkmark \text{ 2 sig fig } \checkmark$$

CE if used their answer to i rather than 5400J

Accept 5700 J (using 5440 J)

Sig fig mark is an independent mark

(d) Time of travel = distance / average speed = $3.5 / 1.1 = 3.2\text{s}$ ✓

5600

$$P_{\text{ave}} = 3.2 = 1750 \text{ W}$$

$$P_{\text{max}} = P_{\text{ave}} \times 2 = 3500 \text{ W} \quad \checkmark$$

OR accelerating torque = $T = W / \theta$
 $= 5600 / 40 = 140 \text{ N m}$ ✓

$$P = T \omega_{\text{max}} = 140 \times 25 = 3500 \text{ W} \quad \checkmark$$

CE from ii

1780 W if 5650 J used

2

[10]

M4. (a) (i) $T = Fr = 32 \times 0.15$

$$= 4.8 \text{ N m} \quad \checkmark$$

1

(ii) $\omega = 2600 \times 2\pi/60$ (= 270 rad s⁻¹) ✓ accept 272 rad s⁻¹

$$\text{total torque} = 4.8 + 1.2 = 6.0 \text{ N m} \quad \checkmark$$

$$P = T\omega$$

$$= 6.0 \times 270 = 1620 \text{ W} \quad \checkmark$$

3

(b) $\alpha = \frac{270 - 0}{8.5} = 32 \text{ rad s}^{-2} \quad \checkmark$

$$I = T/\alpha = \frac{1.2}{32} = 0.038 \quad \checkmark \text{ kg m}^2 \quad \checkmark$$

OR use of $\Theta = \frac{1}{2}(\omega_2 + \omega_1)t$ (= 1150 rad) ✓

and $\frac{1}{2}I\omega^2 = T\Theta$ leading to $I = 0.038 \quad \checkmark \text{ kg m}^2 \quad \checkmark$

3

(c) $E = \frac{1}{2} I \omega^2$
 $= 0.5 \times 0.038 \times 270^2 = 1400 \text{ J} \quad \checkmark$
 $P = E/t = 1400/0.005 = 280 \text{ kW} \quad \checkmark$

2

[9]