M1.(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 $mgh = ½mv^2 + ½I\omega^2 + T\theta$)

$mgh = 2.94$ J

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

$½mv^2 = 0.493$ J

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

$T\theta = 0.0728$ 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 m^2)

Gives

$I = 0.108$ kg m^2

1

(c) $\alpha = T / I = 7.5 \times 10^{-3} / 0.107 = 0.0701$ 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 θ = 323 rad ✓

OR

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

θ = 323 rad ✓

Give CE if
I = 0.108 kg m² used

1

[7]

M2.(a) $\frac{3.5}{(2\pi \times 0.088)}$ = 6.3 rev

6.3 × 2π = 39.8 rad or 40 rad ✓

OR

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

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

1

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

1

(c) (i) $E = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 + mgh$
= (0.5 × 7.4 × 25²)
+ (0.5 × 85 × 2.2²)
+ (85 × 9.81 × 3.5)
= 2310 ✓
+ 206 ✓
+ 2920 ✓
(= 5440 J or 5400 J)

CE from 1b
$\frac{1}{2} I \omega^2 + \frac{1}{2}mv^2 = 2310 + 210 = 2520$ J
$\frac{1}{2} I \omega^2 + mgh = 2310 + 2920 = 5230$ J
$\frac{1}{2}mv^2 + mgh = 210 + 2920 = 3130$ J
Each of these is worth 2 marks

3

(ii) Work done against friction = $T\theta$

= 5.2 × 40 = 210J ✓
Total work done = ***W*** = 5400 + 210
= 5600J ✓ 2 sig fig ✓

CE if used their answer to i rather than 5400J
Accept 5700 J (using 5440 J)
Sig fig mark is an independent mark

3

(d) Time of travel = distance / average speed = 3.5 / 1.1 = 3.2s ✓

$P_{ave} = \frac{5600}{3.2}$ = 1750 W

$P_{max} = P_{ave} \times 2$ = 3500 W ✓

OR accelerating torque = $T = W / \theta$
= 5600 / 40 = 140 N m ✓
P = $T\,\omega_{max}$ = 140× 25 = 3500 W ✓

CE from ii
1780 W if 5650 J used

2

[10]

M3.(a) (i) 8.3 rev = 8.3 × 2π rad ✓ (= 52 rad)

Use of $\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$0 = 6.4^2 + 2 \times \alpha \times 52$ ✓

If eqtn(s) of motion used correctly with θ = 8.3 (giving α = 2.5), give 2 out of first 3 marks.

OR use of $\theta = \frac{1}{2}(\omega_1 + \omega_2)t$ leading to t = 16.25 s and $\omega_2 = \omega_2 + \alpha t$

α = (−) 0.39 ✓ rad s^{-2} ✓

Accept: s^{-2}
Unit mark is an independent mark

4

(ii) $T = I\alpha$

= 8.2 × 10^{-3} × 0.39 = 3.2 × 10^{-3} N m ✓

Give CE from a i

1

(b) (i) ($W = T\theta$ *or* $W = T\omega t$) where $\theta = 0.78 \times 270$ √ (= 210 rad)

$= 3.2 \times 10^{-3} \times 210 = 0.67$ J ✓

Give CE from a ii

2

$$\text{ratio} = \frac{900 \times 270}{0.67} \text{ or } \frac{2.4(3) \times 10^5}{0.67} \quad \checkmark$$

(b) (ii) $= 3.6 \times 10^5$ ✓

CE from b i. Must be in the form: number × 10^5 with number calculated correctly.

900 × 270 or 2.4(3) × 10^5 or equivalent must be seen for 1st mark

1 mark for only writing 3.6 × 10^5

2

(Total 9 marks)

M4. (a) (i) $T = Fr = 7.0 \times 0.075$

= 0.53 **(1)** N m **(1)**

2

(ii) $P = T\omega$

= 0.53 × 120 = 64 W **(1)**

1

(b) use of equation(s) of motion:

θ = ½(120 + 0) × 6.2 = 370 rad **(1)**

370/2π = 59 rotations **(1)**

2

[5]