M1.(a) Law of conservation of <u>angular</u> momentum applies and $I_1 \omega_1 = I_2\omega_2$
OR Law of conservation of <u>angular</u> 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) $I \times 3.46 = (I + 0.016 \times 0.125^2) \times 3.31$ ✓
$I = 0.00552$ 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) $\Delta E = \frac{1}{2}I \omega_1^2 - \frac{1}{2}(I + mr^2)\omega_2^2$
$= [\frac{1}{2} \times 5.52 \times 10^{-3} \times 3.46^2] - [\frac{1}{2} \times 5.77 \times 10^{-3} \times 3.31^2]$ ✓
$= 1.39 \times 10^{-3}$ 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 acclerate plasticine ✓

Allow heat loss on collision

Do not allow energy to sound

1

[9]

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

mgh = 2.94 J

(0.200 × 9.81 × 1.50) = (0.5 × 0.200 × 2.22^2) +(0.5 × I × 6.73^2)

$½mv^2$ = 0.493 J

+ (7.5 × 10^{-3} × 4.55)

$T\theta$ = 0.0728 J

E_P <u>or</u> 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 × 10^{-3} / 0.107 = 0.0701 rad s^{-2} ✓

1

substitution of ω_2 = 0, ω_1 = 6.73 and α into $\omega_2^2 = \omega_1^2 - 2\alpha\theta$

leading to θ = 323 rad ✓

OR

$½I\omega^2 = T\theta$ 0.5 × 0.107× 6.73^2 = 7.5 × 10^{-3} θ ✓

θ = 323 rad ✓

Give CE if

I = 0.108 kg m^2 used

1

[7]

M3.(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 × 25^2)

+ (0.5 × 85 × 2.2^2)

+ (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 = $\boldsymbol{W}$ = 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]

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

= 4.8 N m ✓

1

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

total torque = 4.8 + 1.2 = 6.0 N m ✓

$P = T\omega$

= 6.0 × 270 = 1620 W ✓

3

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

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

OR use of $\Theta = ½(\omega_2 + \omega_1)t$ (= 1150 rad) ✓

and $½I\,\omega^2 = T\Theta$ leading to I = 0.038 ✓ kg m^2 ✓

3

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

$= 0.5 \times 0.038 \times 270^2 = 1400$ J ✓

$P = E/t = 1400 / 0.005 = 280$ kW ✓

2

[9]