M1.(a) (i) $\alpha = T / I$ =8.80 / 0.565 (= 15.6 rad s^{-2}) ✓

use of $t = (\omega_2 - \omega_1) / \alpha$

leading to t = 8.08 s ✓

2

(ii) θ = ½ (172 + 195) × 126 ✓

= 23100 rad

23100 / 2π = 3680 rev ✓

OR

rev per s = 1200 / 60 (=20) ✓

θ = ½ (172 + 195) × 20 ✓

= 3670 rev ✓

Accept alternative ways of calculating area under graph

Areas are: 504 rad or 80 rev

21670 rad or 3450 rev

945 rad or 150 rev

Numbers will vary if 8.1 s used for acceleration period

Last mark: give CE for wrong θ

3

(b) (i) Shows curve of increasing gradient up to first vertical dotted line ✓

OR Shows curve of decreasing gradient up to first vertical dotted line ✓

MARK ii BEFORE i

Answer must match the answer given in part ii

i.e. α increasing: decreasing gradient

α decreasing: increasing gradient

Mark awarded for shape only; ignore any changes to the height of the graph or where curve reaches 126 rad s^{-1}

1

(ii) Mass of washing will decrease as it loses water, so M of I will decrease ✓

(T constant) so α increases ✓

OR washing moves closer to drum, increasing M of I ✓

(T constant) so α decreases ✓

OR friction (torque) increases with speed ✓

so α decreases ✓

Do not credit answers in terms of conservation of angular momentum

2
[8]

M2.(a) The (total) angular momentum (of a system) remains constant provided no external torque acts (on the system) ✓

Do not accept 'force' in place of 'torque'

1

(b) I is the sum of the $m\,r^2$ products for point masses m at radius r ✓

Or WTTE

Not m is the mass and r the radius – must refer to point or small masses or distribution of mass

OR

$\Sigma\, m\, r^2$ with m and r defined

OR

I is a measure of the mass and the way the mass is distributed about an axis

1

More of the satellite's mass is at greater radius ✓

1

(Small change in r) gives large change in r^2, hence large change in I

OR even though m of panels is small, much of m is at a greater radius and radius is squared ✓

For 2nd mark must refer to effect of r^2.

1

(c) Angular momentum = 110 × 5.2 = 572 ✓

1

N m s **OR** kg m^2 s^{-1} ✓

accept

kg m^2 rad s^{-1}

1

(d) (Use of conservation of ang momtm) $572 = 230 \times \omega_2$ ✓

1

$\omega_2 = 572 / 230 = 2.49$ rad s^{-1} ✓

1

[8]

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

$6.3 \times 2\pi = 39.8$ 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) $E = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 + mgh$

$= (0.5 \times 7.4 \times 25^2)$
$+ (0.5 \times 85 \times 2.2^2)$
$+ (85 \times 9.81 \times 3.5)$

= 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]