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) $\Delta E = ½I\omega_1^2 - ½(I + mr^2)\omega_2^2$

$= [½ \times 5.52 \times 10^{-3} \times 3.46^2] - [½ \times 5.77 \times 10^{-3} \times 3.31^2]$ ✓

$= 1.39 \times 10^{-3}$ 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) 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 × ω_2 ✓

1

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

1

[8]

M3.(a) Use of $I = \Sigma mr^2$ or expressed in words ✓

With legs close to chest, more mass at smaller r, so I smaller ✓

2

(b) (i) Angular momentum is conserved / must remain constant **OR** no external torque acts √

WTTE

as I decreases, ω increases and vice versa to maintain $I\omega$ constant ✓
OR as I varies, ω must vary to maintain $I\omega$ constant

2

(ii) (Angular velocity increases initially then decreases (as he straightens up to enter the water)).

No mark for just ang. vel starts low then increases then decreases, i.e. for describing ω only at positions 1,2 and 3.

With one detail point e.g. ✓

- Angular velocity when entering water is greater than at time $t = 0$ s.
- Angular velocity increases, decreases, increases, decreases
- Maximum angular velocity at $t = 0.4$ s
- Greatest rate of change of ang. vel. is near the start
- Angular velocity will vary as inverse of M of I graph

1

(c) angular. momentum = 10.9 × 4.4 = 48 (N m s) ✓

(ω_{max} occurs at minimum I)

Allow 6.3 to 6.5. If out of tolerance e.g. 6.2 give AE for final answer

minimum $I = 6.4$ kg m^2 (at 0.4 s) ✓

$6.4 \times \omega_{max} = 48$ leading to

$\omega_{max} = 7.5$ rad s^{-1} ✓

3

(Total 8 marks)