Access Tuition

A-Level Physics

Angular Momentum

Mark Scheme

Time available: 78 minutes
Marks available: 44 marks

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1. (a) Attempt at calculating area above or below t axis or both ✓
(Ang displacement =) 2.80 + 2.10 − 3.15 = 1.75 rad
($\frac{1.75}{12.0}$ =) 0.15 (rad s^{-1}) ✓

Method must be valid

MP2: correct answer only

(calculator value = 0.145833)

MAX1 if counting square method used and answer rounds to 0.15 (rad s^{-1})

2

(b) $P = T\omega$ giving 546 (W) ✓

Allow ecf for 590 (W) from

using ω_1 = 1.5 rad s^{-1}

1

(c) Selects steepest part of graph and

determines gradient $\alpha = \frac{1.40 - -0.90}{5.0}$ = 0.46 (rad s^{-2}) ✓$_1$

$T = I\alpha$ = 9660 N m ✓$_2$

Adds friction torque to give 10 100 (N m) ✓$_3$

Accept any correct calculation of steepest graph slope: eg from 2 s to 5 s

$a = \frac{1.4}{3.0}$ *= 0.467 giving T = 9800 N m*

or 5 s to 7 s

$a = \frac{0.9}{2.0}$ *= 0.45 giving T = 9450 N m*

Allow ECF from MP2 to MP3

Treat 10 000 (Nm) as a 2 sf answer if consistent with their working.

3

(d) (net) $T \times t$ = 9660 × 5.0 = 4.8 × 10^4 (N m s) ✓

OR

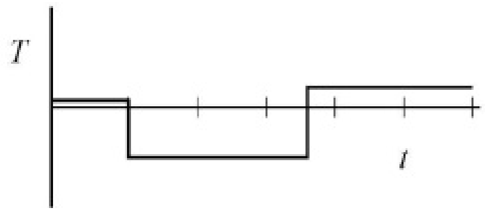
$\Delta(I\omega)$ = 2.1 × 10^4 (1.40 –(–0.90)) = 4.8 × 10^4 (N m s) ✓

*For first method allow ECF for torque ✓$_2$ from **(c)**, but not for ✓$_3$ value*

(calculator value = 48300)

1

(e)



✓

Tick (✓) against 3rd box

1

[8]

2. (a) (The M of I decreases) because more mass closer to axis of rotation ✓$_1$
$I\omega$/angular momentum constant since no external torque ✓$_2$
since I decreases, ω must increase ✓$_3$

For ✓$_1$ must have the idea of mass distribution around axis of rotation. Do not accept answers which give only decrease in radius as reason for lower M of I.

For ✓$_2$ condone answers which do not mention the condition of no external torque. ✓$_3$ cannot be awarded if conservation of rotational kinetic energy used.

3

(b) $I_1\omega_1 = I_2\omega_2$ $\quad \omega_1 = 4.3$ rad s^{-1} ✓

Accept the answer 4.3 rad s^{-1} if no working shown.

1

(c) Finds time for one rotation ✓
Divides 1.2 by time
AND
gives answer for complete rotations, not rounded up. ✓

time for 1 rotation = 2π/14.2 = 0.442 s

1.2/0.442 = 2.7 rotations/turns/somersaults.

OR Angle turned through = 14.2 × 1.2 = 17.04 rad

17.04/2π = 2.7 rotations

OR

Finds angle turned through in 1.2 s ✓
Divides by 2π
AND
gives answer for complete rotations, not rounded up. ✓

Expect to see 2 complete

rotations/turns/somersaults.

For MP2 give CE for time or angle from MP1

2

(d) Any 2 from:

- build up a greater initial angular speed around the bar ✓
  so reaches a greater height/will rotate faster in tuck ✓
- release at a greater angle from the horizontal ✓
  so will rise to greater height giving more time for somersaults ✓
- get into tuck position earlier/get out of tuck position later ✓
  so turning for more time ✓
- get into tighter tuck position ✓ reducing I_2, and increasing ω_2 ✓

Any 2

statement ✓ and correct reason ✓ scores 2 marks for each.

4

[10]

3. (a) The (total) <u>angular</u> momentum (of a system) remains constant provided no external <u>torque</u> acts (on the system) ✓

Must see 'angular'. Condone 'is conserved' for 'is constant'

Allow ang momtm before equals/is same as ang momtm after OR initial ang momtm = final ang momtm

Allow $I\omega$ is constant if symbols explained

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

1

(b) Use of $I = I_{BODY} + 2 \times mr^2$ ✓

$I_1 = (71 + 2 \times 5.0 \times 4.1^2) = 239$ kg m^2 ✓

(≈ 240 kg m^2)

For 2 marks 239 must be seen

2

(c) M of I decreases ✓

Because more mass closer to axis **OR** (for pods) <u>$I = (\sum)mr^2$</u> with r less ✓

$I\omega$ / angular momentum remains constant/is conserved

(So as I decreases) ω must increase ✓

Condone 'inertia' for 'moment of inertia'

2nd mark is for the reason why I is decreasing. Answer must relate to pods or masses getting closer to the axis. 'radius decreasing' on its own is not enough. Accept: pods get closer to axis/body as this implies mass is getting closer.

Both points needed for 3rd mark

3

(d) (Applies conservation of angular momentum/ $I_1\omega_1 = I_2\omega_2$)

$I_1\omega_1 = 240 \times 1.3 = (312 \text{ (N m s)})$ ✓

$312 = (71 + 2 \times 5.0 \times 0.74^2)\ \omega_2$

$\omega_2 = 4.08 \text{ rad s}^{-1}$ ✓

Therefore max speed not reached OR arms can be retracted safely✓

OR

$I_1\omega_1 = 240 \times 1.3 = (312 \text{ (N m s)})$ ✓

$312 = (71 + 2 \times 5.0 \times r_2^2)\ 4.2$

$r_2 = 0.57$ m ✓

So with *r* at circumference max speed not reached OR arms can be retracted safely✓

OR

$I_1\omega_1 = 240 \times 1.3 = (312 \text{ (N m s)})$ ✓

$312 = 4.2\ I_2$ at safety limit

$I_2 = 74(.3) \text{ kg m}^2$ ✓

Actual $I_2 = 76.5 \text{ kg m}^2$

Therefore max speed not reached OR arms can be retracted safely✓

Using 239 kg m^2 instead of 240 kg m^2 leads to

$\omega^2 = 4.06$ rad s^{-1}

Useful: $I_2 = 76.5$ kg m^2

Only credit last mark if conservation of angular momentum is used

Allow a judgement based on incorrect working (eg AE) provided conservation of angular momentum is used

Using 239 kg m^2 instead of 240 kg m^2 leads to

$r_2 = 0.55$ m

3

[9]

4. (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

ω_2 = 572 / 230 = 2.49 rad s^{-1} ✓

1

[8]

5. (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]