Rigid Body Mechanics

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Course	HL IB Physics
Section	Space, Time & Motion
Topic	Rigid Body Mechanics
Difficulty	Medium

Exam Papers Practice

To be used by all students preparing for HL IB Physics
Students of other boards may also find this useful

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The correct answer is **A** because:

- List the known quantities:
  - Radius of rotation, $r = 8$ cm = 0.08 m
  - Mass of blu-tac, $m = 2$ g = 2×10^{-3} kg
- Calculate the moment of inertia for the blu-tac:
  - $I = mr^2$
  - $I = (2 \times 10^{-3}) \times 0.08^2$
  - $I = 1.28 \times 10^{-5}$ kg m^2

B is incorrect because the radius has not been squared in the calculation

C is incorrect because this is the angular acceleration calculated using a linear acceleration of $g = 9.81$ m s^{-2}

D is incorrect because the radius and the mass have not been converted into the standard units of kg and metres

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The correct answer is **B** because:

- List the known quantities:
  - Mass, $m = 55$ kg
  - Radius of boy as a ball, $r = 67$ cm = 0.67 m
  - Linear Velocity, $v = 7.1$ m s^{-1}
- Calculate the moment of inertia of the boy, I:
  - $I = mr^2$
  - $I = 55 \times 0.67^2$
  - $I = 24.69$ kg m^2
- Calculate the angular velocity of the boy, ω:
  - $\omega = \frac{v}{r}$
  - $\omega = \frac{7.1}{0.67}$
  - $\omega = 10.60$ rad s^{-1}

- Calculate the boy's angular momentum:
  - From the data booklet: $L = I\omega$
  - $L = 24.69 \times 10.60$
  - $L = 261.7 = 262$ kg m^2 rad s^{-1} (3 s.f.)

A is incorrect because 7.1 m s^{-1} has been used as the angular velocity when it is the linear velocity

C is incorrect because this is the value of the linear momentum, $p = mv$ and not the angular momentum

D is incorrect because the radius has not been converted from cm into m

The method shown uses the equation given in the data booklet. You can answer this question in one method step by remembering that angular momentum can also be given by the equation:

$$L = mvr$$

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The correct answer is **C** because:

- Consider the situation in the diagram:
  - The performers apply a couple of forces to the pole
- List the known quantities:
  - Force, $F = 15$ N
  - Angle of force to pole, $\theta = 60°$
  - Total torque of couple, $\tau = 45$ N m
- State the equation for calculating the total torque of a couple:
  - $\tau = 2Fr\sin\theta$
- Rearrange the equation to make radius, r the subject:
  - $r = \dfrac{\tau}{2F\sin\theta}$
- Substitute in the known quantities to calculate r:
  - $r = \dfrac{45}{2 \times 15\sin(60)}$
  - $r = \sqrt{3}$

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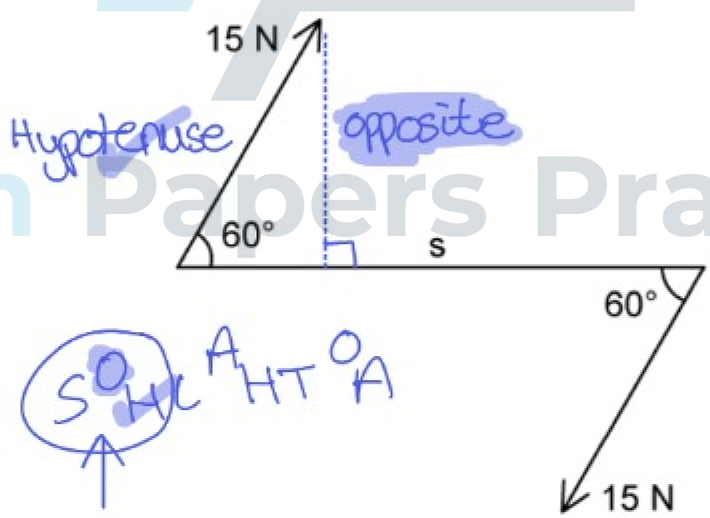
- Calculate the length of *S*:
  - $S = 2r$
  - $S = 2 \times \sqrt{3}$
  - $S = 2\sqrt{3}$ m

A is incorrect because the radius used is *S* and not ½*S*.

B is incorrect because the angle of the forces to the pole has not been considered. The torque is the force x perpendicular distance. The force needs to be resolved to find the opposite side.

D is incorrect because the incorrect equation for calculating the torque has been used. The equation $\tau = 2Fr\sin\theta$ is needed to calculate the **total** torque of the couple.

Create and label a triangle on the diagram to check you are finding the opposite and not the adjacent component. The opposite component is at right angles to the perpendicular distance between the forces in a couple.



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The correct answer is **D** because:

- If the system is in equilibrium, the moment due to tension *T* must **equal** the moment of the couple formed by the **two** 50 N forces, i.e.
  - Moment due to *T* = Moment of the couple

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- Since the force on the couple is 50 N and the separation is 0.80 m:
  - Moment of the couple = Force × Perpendicular distance between forces
  - Moment of the couple = 50 × 0.80
  - Moment of the couple = 40 N m

- Therefore, the moment due to T = 40 N m
  - Moment due to $T = T \times r$ where r = 20 cm = 0.2 m
  - Hence, $T = \frac{40}{0.2}$
  - T = 200 N

A is incorrect because this is the torque of the couple or the torque of the tension and not the value of the tension T

B is incorrect because this is the sum of the magnitude of the forces in the couple and not the value of the tension T calculated due to the torque created by the couple

C is incorrect because the distance of 20 cm + 40 cm = 60 cm has been used as the perpendicular distance between the forces in the couple instead of the actual distance of 40 cm + 40 cm = 80 cm

This is a tricky moments question as it can take a while to figure out what is going on! Many students forget to use the total distance between the **two** 50 N forces and end up with a moment of a couple that is half as large as it should be!

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The correct answer is **A** because:

- List the known quantities:
  - Radius, r = 60 mm = 60×10^{-3} m
  - Revolutions per minute = 500
  - Time, Δt = 3 minutes = 3 × 60 = 180 s

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- Recall the equation linking angular and linear acceleration:
  - $\alpha = \frac{\Delta\omega}{\Delta t} = \frac{a}{r}$
- First, calculate the angular velocity, ω:
  - 500 revolutions per minute = 500 × 2π radians in 60 seconds
  - So, $\omega = \frac{1000\pi}{60}$
  - $\omega = \frac{50}{3}\pi$
- Second, calculate angular acceleration, α:
  - $\alpha = \frac{\Delta\omega}{\Delta t}$
  - $\alpha = \frac{50}{3}\pi \div 180$
  - $\alpha = 0.29$ rad s^{-2}
- Third, calculate the linear acceleration, a:
  - $\alpha = \frac{a}{r}$
  - $a = \alpha r$
  - $a = 0.29 \times (60 \times 10^{-3})$
  - $a = 0.0174$ m s^{-2}

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B is incorrect because the number of revolutions per minute has been used instead of calculating the angular velocity

C is incorrect because this is the angular acceleration, α and not the linear acceleration, a as required

D is incorrect because none of the times have been converted into the standard units of seconds. They have been substituted into the equations in minutes