OCR A A Level Circular Motion worksheet

35-40 minutes independent practice + 15-20 minutes review | 41 marks

Specification points covered

- 5.2.1(a), 5.2.1(b) and 5.2.1(c) Use radians, period, frequency and angular velocity, with $\omega = 2\pi/T = 2\pi f$.
- 5.2.2(a) Explain that a constant net force perpendicular to velocity causes circular motion.
- 5.2.2(b) and 5.2.2(c) Use $v = r\omega$ and centripetal acceleration $a = v^2/r = r\omega^2$.
- 5.2.2(d)(i) and 5.2.2(d)(ii) Use $F = mv^2/r = mr\omega^2$ and investigate circular motion using a whirling bung.

Arcadia circular-motion test centre

Engineers test rotating sensors, sample centrifuges, inspection drones and habitat rings before deployment. Show working, use SI units and identify the real force or force component that provides the inward resultant.

1. Circular-motion kinematics

1. State what is meant by an angle of one radian. [1 mark]

2. A calibration arm of radius 0.280 m turns through 135°. Convert the angle to radians and calculate the arc length travelled by its tip. [2 marks]

3. An ocean-current sensor rotor completes 18 revolutions in 7.50 s. Calculate its frequency, period and angular velocity. [3 marks]

4. A blade tip on the rotor is 0.420 m from the axis. Calculate its linear speed when the rotor turns at 2.40 Hz. [1 mark]

2. Direction, acceleration and resultant force

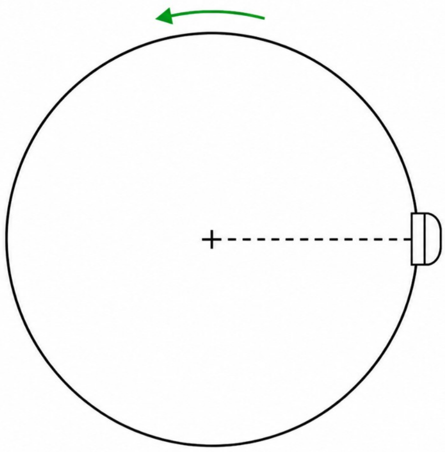

Figure 1: capsule on a circular guide rail

5. Figure 1 shows a sample capsule moving anticlockwise at constant speed. On Figure 1, draw and label an arrow for its velocity v and an arrow for the resultant force F. Explain why the capsule accelerates even though its speed is constant. [4 marks]

6. An asteroid-sample centrifuge moves a 0.180 kg capsule at 14.0 m s^{-1} in a circle of radius 0.650 m. Calculate its centripetal acceleration and the resultant force. State the factor by which the force changes if the speed increases by 20%. [3 marks]

3. Forces that provide the inward resultant

7. A 5.00 kg inspection drone flies in a horizontal circle of radius 32.0 m at 16.0 m s^{-1} while maintaining constant height. The vertical component of lift balances its weight and the horizontal component supplies the centripetal force. Calculate the horizontal component of lift, the total lift and the angle of the lift force to the vertical. Take g = 9.81 N kg^{-1}. [3 marks]

8. In a proton test ring, the speed increases from 4.20×10^6 m s^{-1} to 10.5×10^6 m s^{-1} as the frequency increases from 0.700×10^5 Hz to 1.75×10^5 Hz. Calculate the gradient of a v-against-f graph and hence determine the ring radius. [2 marks]

9. A rotating space-habitat ring has radius 95.0 m. Determine the angular velocity, period and rim speed required for the centripetal acceleration at the rim to be 9.81 m s^{-2}. [3 marks]

4. Vertical circles and proportional reasoning

10. A 120 kg carrier travels at 12.0 m s^{-1} around a vertical circular guide of radius 8.00 m. At both the top and bottom, state the direction of the resultant force. Calculate the normal contact force from the guide at the top and at the bottom. Take g = 9.81 N kg^{-1}. [4 marks]

11. A technician says, 'The capsule moves at constant speed, so it has no acceleration. The centripetal force is an extra force acting in addition to the real forces.' Explain both errors using precise physics language. [3 marks]

12. A tethered sensor rotates with constant angular velocity. Its radius is reduced from 12.0 m to 8.00 m. State the ratios new/old for its linear speed, centripetal acceleration and centripetal force. [2 marks]

5. Practical: validating $F = mv^2/r$

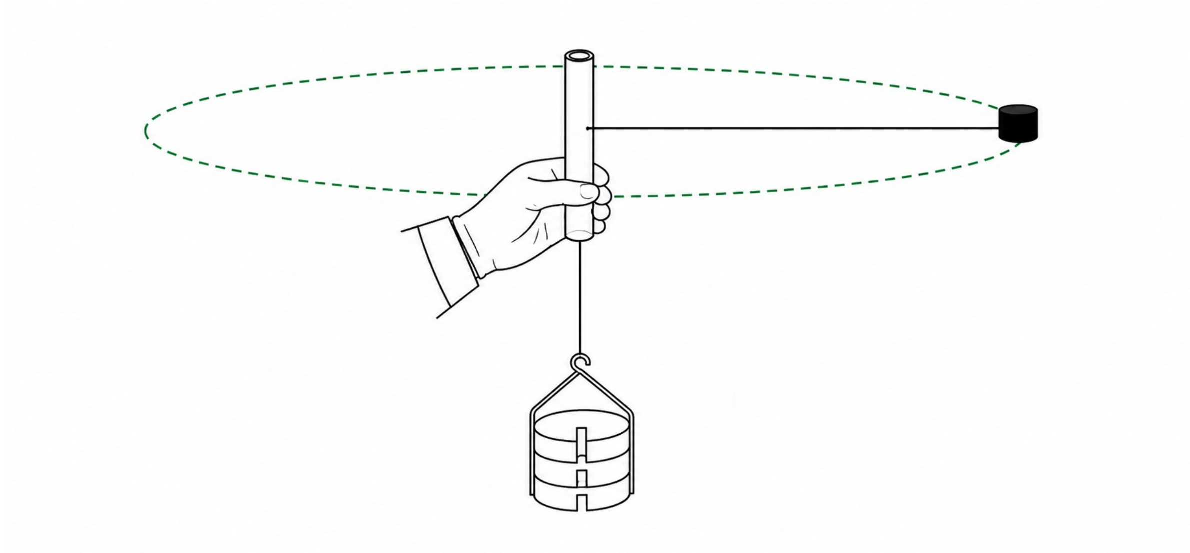

Figure 2: whirling-bung apparatus

13. Scaffolded six-mark practical. Figure 2 shows a whirling bung of mass m connected through a tube to a stationary hanging mass M. Describe how to validate $F = mv^2/r$. Organise your answer around: how F, r and v are measured; how M is varied while m and r are controlled; reliability and safety; the graph to plot; and how its gradient and intercept test the equation. [6 marks]

6. Unfamiliar application

14. In microgravity, a 0.800 kg debris-capture sensor moves on a 4.50 m tether at angular velocity 1.80 rad s^{-1}. Calculate its linear speed, centripetal acceleration and tether tension. The tether is rated to 15.0 N. Calculate the maximum safe angular velocity. **[4 marks]**

Review and improve

- ☐ I distinguish speed from velocity in circular motion.
- ☐ I identify centripetal force as the inward resultant of real forces.
- ☐ I can test $F \propto v^2$ with controlled variables, repeats and a graph.