OCR Physics Unit 4

Topic Questions from Papers

Circular Motion

2 **(a)** Fig. 2.1 shows the London Eye.

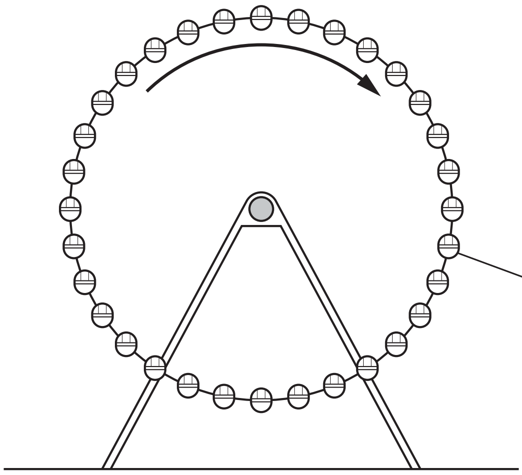

Fig. 2.1

It has 32 capsules equally spaced around the edge of a large vertical wheel of radius 60 m. The wheel rotates about a horizontal axis such that each capsule has a constant speed of 0.26 m s^{-1}.

(i) Calculate the time taken for the wheel to make one complete rotation.

time = ... s **[1]**

(ii) Each capsule has a mass of 9.7×10^3 kg. Calculate the centripetal force which must act on the capsule to make it rotate with the wheel.

centripetal force = ... N **[2]**

(b) Fig. 2.2 shows the drum of a spin-dryer as it rotates. A dry sock **S** is shown on the inside surface of the side of the rotating drum.

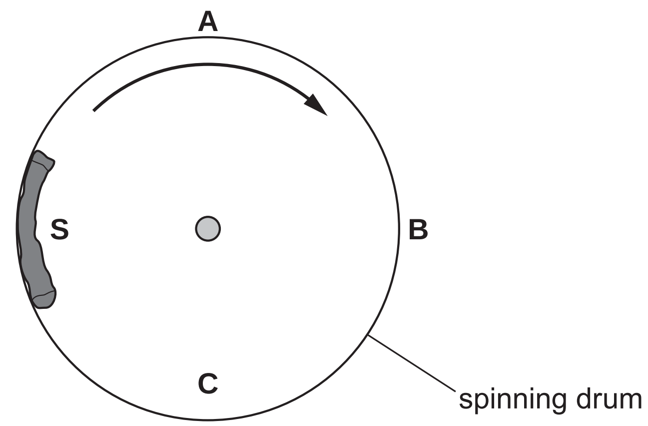

Fig. 2.2

(i) Draw arrows on Fig. 2.2 to show the direction of the centripetal force acting on **S** when it is at points **A**, **B** and **C**. **[1]**

(ii) State and explain at which position, **A**, **B** or **C** the normal contact force between the sock and the drum will be

1 the greatest

....

....

....

.... **[2]**

2 the least.

....

....

.... **[1]**

[Total: 7]

2 **(a)** Fig. 2.1 shows an aeroplane flying in a horizontal circle at constant speed. The weight of the aeroplane is W and L is the lift force acting at right angles to the wings.

Fig. 2.1

(i) Explain how the lift force L maintains the aeroplane flying in a **horizontal** circle.

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....

.... **[2]**

(ii) The aeroplane of mass 1.2×10^5 kg is flying in a horizontal circle of radius 2.0 km.

The centripetal force acting on the aeroplane is 1.8×10^6 N. Calculate the speed of the aeroplane.

speed = ... $m\,s^{-1}$ **[2]**

(b) Fig. 2.2 shows a satellite orbiting the Earth at a constant speed v. The radius of the orbit is r.

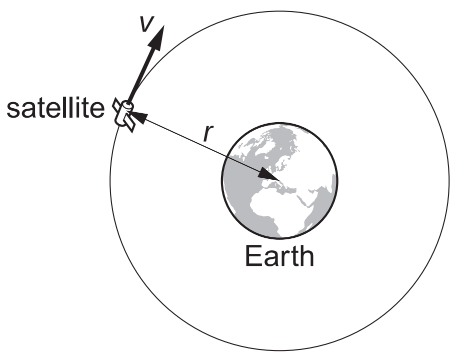

Fig. 2.2

2 **(a)** **(i)** State, in terms of force, the conditions necessary for an object to move in a circular path at constant speed.

....

.... **[1]**

(ii) Explain why this object is accelerating. State the direction of the acceleration.

....

.... **[2]**

(b) A satellite moves in a circular orbit around the Earth at a constant speed of 3700 m s^{-1}.

The mass M of the Earth is 6.0×10^{24} kg.

Calculate the radius of this orbit.

radius = ... m **[4]**

(c) In order to move the satellite in **(b)** into a new smaller orbit, a decelerating force is applied for a brief period of time.

(i) Suggest how the decelerating force could be applied.

....

.... **[1]**

(ii) The radius of this new orbit is 2.0×10^{7} m. Calculate the speed of the satellite in this orbit.

speed = ... m s^{-1} **[2]**

[Total: 10]

Answer **all** the questions.

1 **(a)** **(i)** State Newton's first law of motion.

....

....

.... **[1]**

(ii) Define the *newton*.

....

.... **[1]**

(b) A jet plane on the deck of an aircraft carrier is accelerated before take-off using a catapult. The mass of the plane is 3.2×10^4 kg and it is accelerated from rest to a velocity of $55\,\mathrm{m\,s^{-1}}$ in a time of 2.2 s. Calculate

(i) the mean acceleration of the plane

mean acceleration = ... $\mathrm{m\,s^{-2}}$ **[2]**

(ii) the distance over which the acceleration takes place

distance = ... m **[2]**

(iii) the mean force producing the acceleration.

mean force = ...N **[1]**

(c) The jet plane describes a **horizontal** circle of radius 870 m flying at a constant speed of 120 m s^{-1}.

(i) State the direction of the resultant horizontal force acting on the plane.

.... **[1]**

(ii) Calculate the magnitude of this horizontal force.

force = ... N **[2]**

(d) By changing the velocity of the plane it can be made to fly in a **vertical** circle of radius 1500 m. At a particular point in the vertical circle, the contact force between the pilot and his seat may be zero and the pilot experiences "weightlessness".

(i) State and explain at what point in the circle this weightlessness may occur.

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....

....

.... **[2]**

(ii) Calculate the speed of the plane at which weightlessness occurs.

speed = ... m s^{-1} **[2]**

[Total: 14]

3 Fig. 3.1 shows apparatus used to investigate circular motion. The bung is attached by a continuous nylon thread to a weight carrier supporting a number of slotted masses which may be varied. The thread passes through a vertical glass tube. The bung can be made to move in a nearly horizontal circle at a steady high speed by a suitable movement of the hand holding the glass tube. A constant radius *r* of rotation can be maintained by the use of a reference mark on the thread.

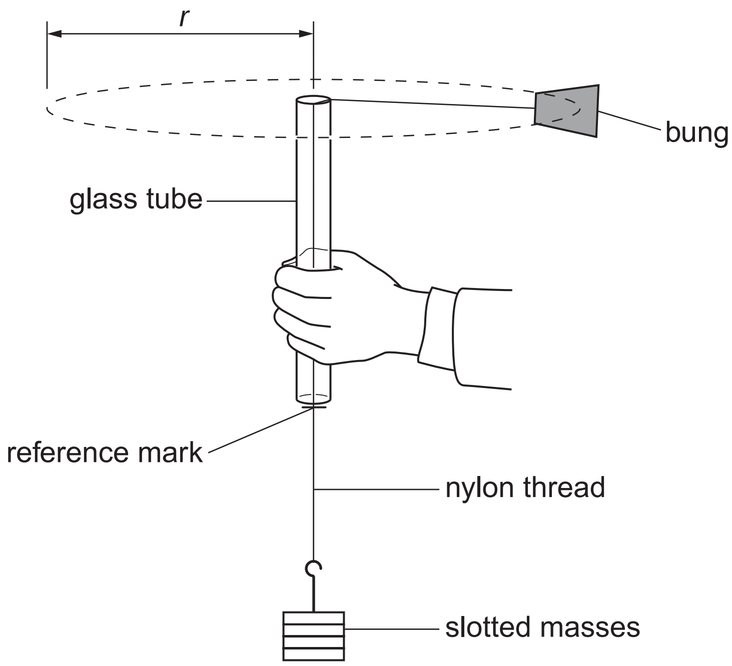

Fig. 3.1

(a) (i) Draw an arrow labelled **F** on Fig. 3.1 to indicate the direction of the resultant force on the bung.

[1]

(ii) Explain how the speed of the bung remains constant even though there is a resultant force *F* acting on it.

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.... **[2]**

(b) (i) Two students carry out an experiment using the apparatus in Fig. 3.1 to investigate the relationship between the force F acting on the bung and its speed v for a constant radius. Describe how they obtain the values of F and v.

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.... **[5]**

(ii) 1 Sketch, on Fig. 3.2, the expected graph of F against v^2.

[1]

Fig. 3.2

2 Explain how the graph can be used to determine the mass m of the bung.

....

....

....

.... **[2]**

[Total: 11]

Data

Values are given to three significant figures, except where more are useful.

speed of light in a vacuum	c	3.00×10^{8} m s^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^{2} N^{-1} m^{-2} (F m^{-1})
elementary charge	e	1.60×10^{-19} C
Planck constant	h	6.63×10^{-34} J s
gravitational constant	G	6.67×10^{-11} N m^{2} kg^{-2}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
electron rest mass	m_e	9.11×10^{-31} kg
proton rest mass	m_p	1.673×10^{-27} kg
neutron rest mass	m_n	1.675×10^{-27} kg
alpha particle rest mass	m_α	6.646×10^{-27} kg
acceleration of free fall	g	9.81 m s^{-2}

Conversion factors

unified atomic mass unit	$1\ \text{u} = 1.661 \times 10^{-27}$ kg
electron-volt	$1\ \text{eV} = 1.60 \times 10^{-19}$ J
	$1\ \text{day} = 8.64 \times 10^{4}$ s
	$1\ \text{year} \approx 3.16 \times 10^{7}$ s
	$1\ \text{light year} \approx 9.5 \times 10^{15}$ m

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

volume of cylinder = $\pi r^2 h$

surface area of sphere = $4\pi r^2$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

For small angle $\theta \Rightarrow \sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$

$\lg(AB) = \lg(A) + \lg(B)$

$\lg(\frac{A}{B}) = \lg(A) - \lg(B)$

$\ln(x^n) = n \ln(x)$

$\ln(e^{kx}) = kx$

Formulae and relationships

Unit 1 – Mechanics

$F_x = F\cos\theta$
$F_y = F\sin\theta$

$a = \dfrac{\Delta v}{\Delta t}$

$v = u + at$

$s = \dfrac{1}{2}(u + v)t$

$s = ut + \dfrac{1}{2}at^2$

$v^2 = u^2 + 2as$

$F = ma$

$W = mg$

moment = Fx

torque = Fd

$\rho = \dfrac{m}{V}$

$p = \dfrac{F}{A}$

$W = Fx\cos\theta$

$E_k = \dfrac{1}{2}mv^2$

$E_p = mgh$

efficiency = $\dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$

$F = kx$

$E = \dfrac{1}{2}Fx \qquad E = \dfrac{1}{2}kx^2$

stress = $\dfrac{F}{A}$

strain = $\dfrac{x}{L}$

Young modulus = $\dfrac{\text{stress}}{\text{strain}}$

Unit 2 – Electrons, Waves and Photons

$\Delta Q = I\Delta t$

$I = Anev$

$W = VQ$

$V = IR$

$R = \dfrac{\rho L}{A}$

$P = VI \qquad P = I^2R \qquad P = \dfrac{V^2}{R}$

$W = VIt$

e.m.f. = $V + Ir$

$V_{\text{out}} = \dfrac{R_2}{R_1 + R_2} \times V_{\text{in}}$

$v = f\lambda$

$\lambda = \dfrac{ax}{D}$

$d\sin\theta = n\lambda$

$E = hf \qquad E = \dfrac{hc}{\lambda}$

$hf = \phi + \text{KE}_{\text{max}}$

$\lambda = \dfrac{h}{mv}$

$R = R_1 + R_2 + \ldots$

$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

Unit 4 – Newtonian World

$$F = \frac{\Delta p}{\Delta t}$$

$$v = \frac{2\pi r}{T}$$

$$a = \frac{v^2}{r}$$

$$F = \frac{mv^2}{r}$$

$$F = -\frac{GMm}{r^2}$$

$$g = \frac{F}{m}$$

$$g = -\frac{GM}{r^2}$$

$$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$$

$$f = \frac{1}{T}$$

$$\omega = \frac{2\pi}{T} = 2\pi f$$

$$a = -(2\pi f)^2\, x$$

$$x = A\cos(2\pi f t)$$

$$v_{max} = (2\pi f)\, A$$

$$E = mc\Delta\theta$$

$$pV = NkT$$

$$pV = nRT$$

$$E = \frac{3}{2}\, kT$$

Unit 5 – Fields, Particles and Frontiers of Physics

$$E = \frac{F}{Q}$$

$$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

$$F = BIL\sin\theta$$

$$F = BQv$$

$$\phi = BA\cos\theta$$

induced e.m.f. = – rate of change of magnetic flux linkage

$$\frac{V_s}{V_p} = \frac{n_s}{n_p}$$

$$Q = VC$$

$$W = \frac{1}{2}\, QV \qquad W = \frac{1}{2}\, CV^2$$

time constant = CR

$$x = x_0 e^{-\frac{t}{CR}}$$

$$C = C_1 + C_2 + \ldots$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$$

$$A = \lambda N$$

$$A = A_0\, e^{-\lambda t}$$

$$N = N_0\, e^{-\lambda t}$$

$$\lambda t_{½} = 0.693$$

$$\Delta E = \Delta m c^2$$

$$I = I_0\, e^{-\mu x}$$