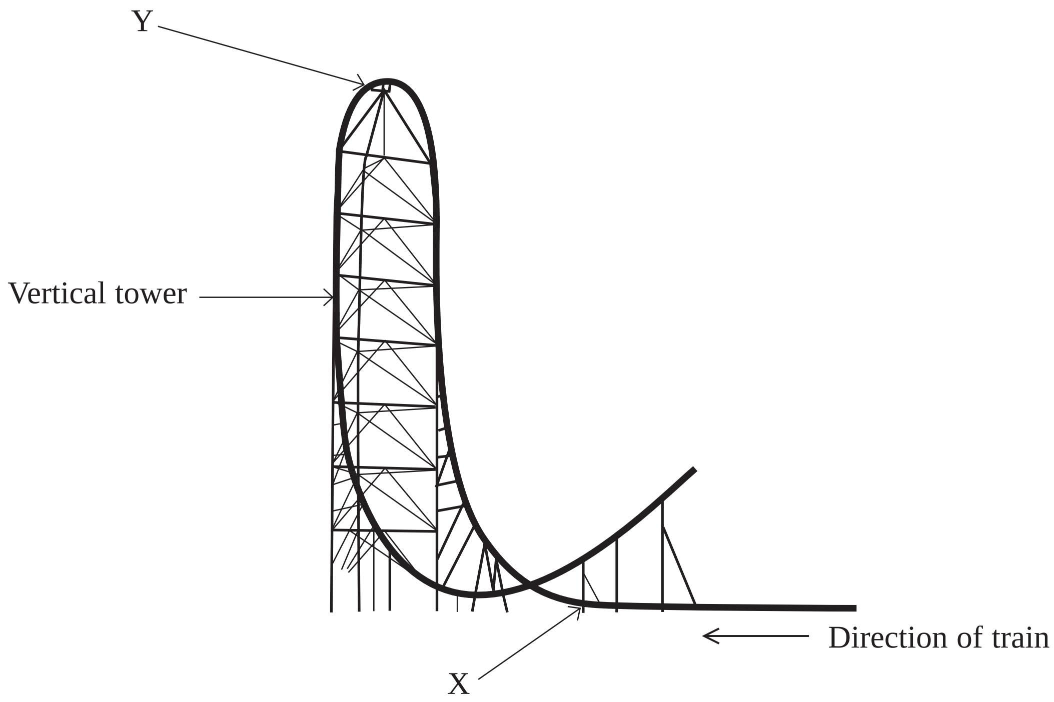
Edexcel Physics Unit 4

Topic Questions from Papers

Circular Motion

12 Kingda Ka was the highest roller coaster in the world in 2007. A train is initially propelled along a horizontal track by a hydraulic system. It reaches a speed of 57 m s^{-1} from rest in 3.5 s. It then climbs a vertical tower before falling back towards the ground.



(a) Calculate the average force used to accelerate a fully loaded train along the horizontal track.

Total mass of fully loaded train = 12 000 kg

(2)

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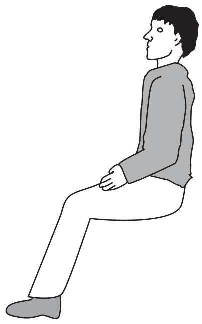
Force = ...

(b) Point X is just before the train leaves the horizontal track and moves into the first bend. Complete the free-body diagram below to show the two forces acting on a rider in the train at this point.

(3)



(c) The mass of the rider is m and g is the acceleration of free fall. Just after point X, the reaction force of the train on the rider is $4mg$ and can be assumed to be vertical. This is referred to as a g-force of $4g$.
Show that the radius of curvature of the track at this point is about 100 m.

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(d) Show that the speed of the train as it reaches the top of the vertical tower is about $20\ \text{m s}^{-1}$. Assume that resistance forces are negligible.

The height of the vertical tower is 139 m.

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(e) Riders will feel momentarily weightless if the vertical reaction force becomes zero. The track is designed so that this happens at point Y.

Calculate the radius of the track at point Y.

(2)

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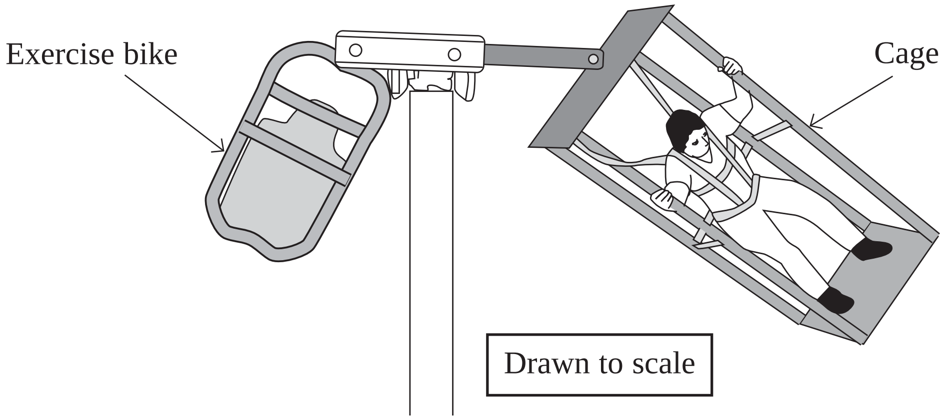
Radius = ...

(Total for Question 12 = 12 marks)

13 Astronauts can be weakened by the long-term effects of microgravity. To keep in shape it has been suggested that they can do some exercise using a Space Cycle: a horizontal beam from which an exercise bike and a cage are suspended. One astronaut sits on the exercise bike and pedals, which causes the whole Space Cycle to rotate around a pole. Another astronaut standing in the cage experiences artificial gravity. When rotated at 20 revolutions per minute, this is of similar strength to the gravitational field on Earth.

Space Cycle



(a) Calculate the angular velocity, in rad s^{-1}, corresponding to 20 revolutions per minute.

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Angular velocity = ...

(b) Use the diagram to estimate the radius of the path followed by the cage's platform and hence calculate the platform's acceleration.

(3)

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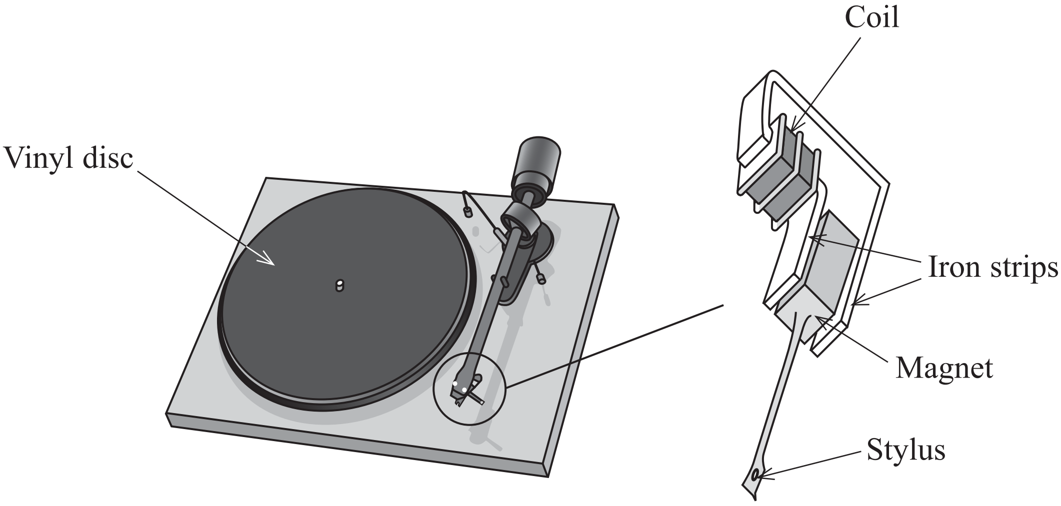
Acceleration = ...

(Total for Question 13 = 5 marks)

15 A vinyl disc is used to store music. When the disc is played, a stylus (needle) moves along in a groove in the disc. The disc rotates and bumps in the groove cause the stylus to vibrate.



The stylus is attached to a small magnet which is near to a coil of wire. When the stylus vibrates, there is a potential difference across the terminals of the coil.

(a) Explain the origin of this potential difference.

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(b) The potential difference is then amplified and sent to a loudspeaker. Long-playing vinyl discs (LPs) have to be rotated at 33 rpm (revolutions per minute) so that the encoded bumps in the groove lead to the correct sound frequencies.

(i) Calculate the angular velocity of an LP.

(2)

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Angular velocity = ...

(ii) As the stylus moves towards the centre of the LP the encoded bumps must be fitted into a shorter length of groove.

Explain why the encoding of bumps in the groove becomes more compressed as the stylus moves towards the centre.

(3)

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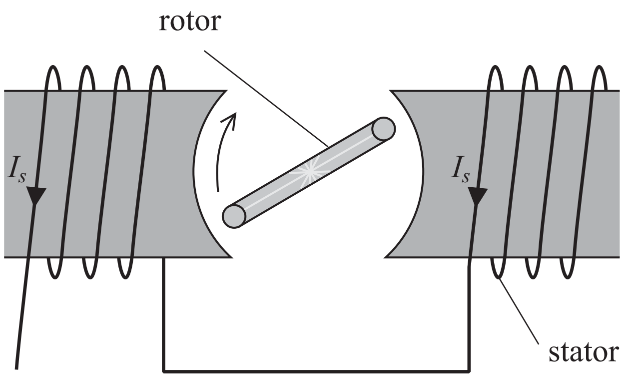
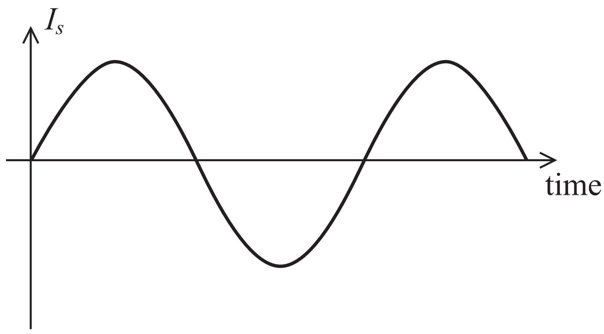
(Total for Question 15 = 9 marks)

15 The diagram represents a simple induction motor. An alternating current I_s is supplied to a stationary coil (stator). This coil is wrapped around an iron core.

A rotating coil (rotor) is shown end on in the diagram.



(a) The graph shows the variation of the alternating current I_s with time.



*(i) Explain how current is induced in the rotor coil.

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(ii) Explain why the rotor turns.

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(iii) State **two** ways of making the rotor turn faster.

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(b) An induction motor is used to rotate the turntable in a record deck. Long-play records require the turntable to rotate at 33 revolutions per minute.

(i) Calculate the angular velocity of the turntable.

(3)

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Angular velocity = ...

(ii) Calculate the acceleration of a speck of dust at the outside edge of a rotating record.

radius of record = 12.5 cm

(2)

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Acceleration = ...

(Total for Question 15 = 13 marks)

13 The London Eye consists of a large vertical circle with 32 equally-spaced passenger cabins attached to it. The wheel rotates so that each cabin has a constant speed of 0.26 m s^{-1} and moves around a circle of radius 61 m.

(a) Calculate the time taken for each cabin to make one complete revolution.

(2)

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Time = ...

(b) Calculate the centripetal force acting on each cabin.

mass of cabin = 9.7 × 10^3 kg

(2)

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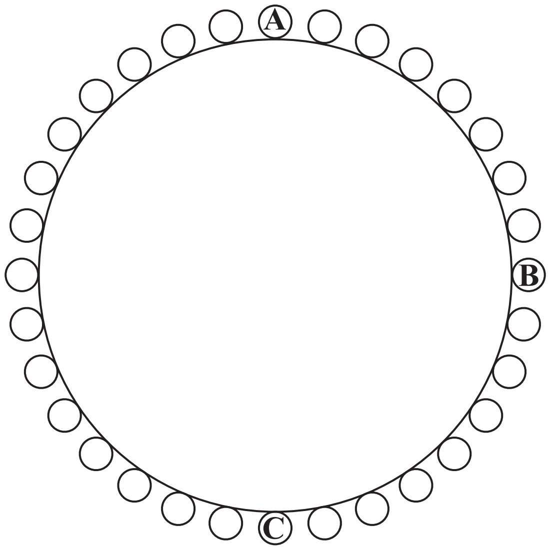
Centripetal force = ...

(c) (i) The diagram shows just the circle and the cabins.
Draw arrows to show the direction of the centripetal force acting on a person in a cabin when the person is at each of positions **A**, **B** and **C**.

(1)



*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

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(Total for Question 13 = 9 marks)

16 In order to make an object move around a circular path at a constant speed a resultant force must act on it.

(a) Explain why a resultant force is required and state the direction of this force.

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(b) When vehicles move around a bend on a level road, the resultant force is provided by friction between the tyres and the road. For a given vehicle and road surface there is a maximum value for this sideways frictional force.

Explain why roads designed for high-speed travel, such as motorways, do not have any sharp bends.

(2)

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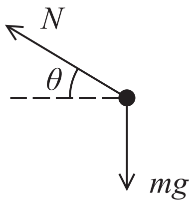
(c) Some cycling tracks are banked. When cornering, a cyclist moves up the track until the sideways frictional force is zero.

The free-body force diagram for a cyclist and bicycle is shown. The normal contact force exerted by the track is N and the weight of cyclist and bicycle is mg.



(i) By considering the vertical and horizontal motion, show that

$$\tan\theta = gr/v^2$$

where r is the radius of the cyclist's path and v is the cyclist's speed.

(3)

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(ii) Calculate the value of θ for a cyclist travelling at 11.0 m s^{-1} around a bend of radius 18.7 m.

(2)

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θ = ...

(Total for Question 16 = 9 marks)

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$ $= 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19} \text{ C}$	
Electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27} \text{ kg}$	

Unit 1

Mechanics

Kinematic equations of motion	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
Forces	$\Sigma F = ma$ $g = F/m$ $W = mg$
Work and energy	$\Delta W = F\Delta s$ $E_k = \frac{1}{2}mv^2$ $\Delta E_{grav} = mg\Delta h$

Materials

Stokes' law	$F = 6\pi\eta rv$
Hooke's law	$F = k\Delta x$
Density	$\rho = m/V$
Pressure	$p = F/A$
Young modulus	$E = \sigma/\varepsilon$ where Stress $\sigma = F/A$ Strain $\varepsilon = \Delta x/x$
Elastic strain energy	$E_{el} = \frac{1}{2}F\Delta x$

Unit 2

Waves

Wave speed	$v = f\lambda$
Refractive index	${}_1\mu_2 = \sin i/\sin r = v_1/v_2$

Electricity

Potential difference	$V = W/Q$
Resistance	$R = V/I$
Electrical power, energy and efficiency	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$
	$\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$
	$\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
Resistivity	$R = \rho l/A$
Current	$I = \Delta Q/\Delta t$ $I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Quantum physics

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$

Unit 4

Mechanics

Momentum	$p = mv$
Kinetic energy of a non-relativistic particle	$E_k = p^2/2m$
Motion in a circle	$v = \omega r$ $T = 2\pi/\omega$ $F = ma = mv^2/r$ $a = v^2/r$ $a = r\omega^2$

Fields

Coulomb's law	$F = kQ_1Q_2/r^2$ where $k = 1/4\pi\varepsilon_0$
Electric field	$E = F/Q$ $E = kQ/r^2$ $E = V/d$
Capacitance	$C = Q/V$
Energy stored in capacitor	$W = \frac{1}{2}QV$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$
In a magnetic field	$F = BIl \sin\theta$ $F = Bqv \sin\theta$ $r = p/BQ$
Faraday's and Lenz's Laws	$\varepsilon = -d(N\phi)/dt$

Particle physics

Mass-energy	$\Delta E = c^2 \Delta m$
de Broglie wavelength	$\lambda = h/p$