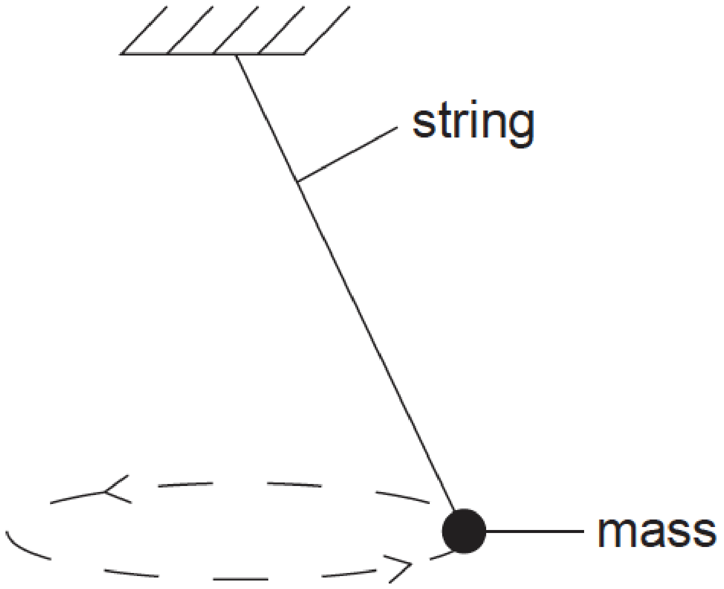
T6 *[200 marks]*

1. A mass is suspended by a string from a fixed point. The mass moves with constant speed along a circular path in a horizontal plane. *[1 mark]*



The resultant force acting on the mass is

A. zero.

B. directed upwards along the string.

C. directed towards the centre of the circular path.

D. in the same direction as the velocity of the mass.

2. Which single condition enables Newton's universal law of gravitation to be used to predict the force between the Earth and the Sun? *[1 mark]*

A. The Earth and the Sun both have a very large radius.

B. The distance between the Earth and the Sun is approximately constant.

C. The Earth and the Sun both have a very large mass.

D. The Earth and the Sun behave as point masses.

3. Which single condition enables Newton's universal law of gravitation to be used to predict the force between the Earth and the Sun? *[1 mark]*

A. The Earth and the Sun both have a very large radius.

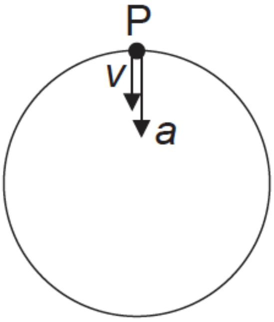
B. The distance between the Earth and the Sun is approximately constant.

C. The Earth and the Sun both have a very large mass.

D. The Earth and the Sun behave as point masses.

4. An electron moves with uniform circular motion in a region of magnetic field. Which diagram shows the acceleration *a* and velocity *v* of the electron at point P? *[1 mark]*

A.



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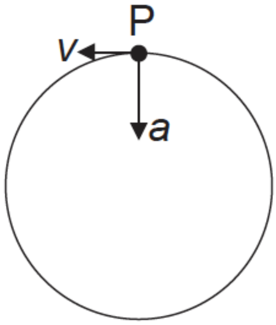

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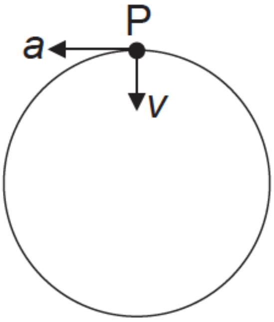
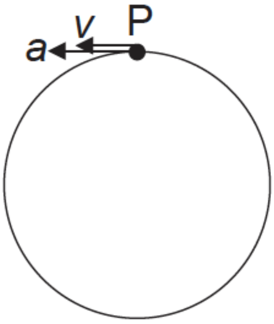


D.



5. A planet has half the mass and half the radius of the Earth. What is the gravitational field strength at the surface of the planet? The gravitational field strength at the surface of the Earth is 10 N kg^{-1}. *[1 mark]*

A. 2.5 N kg^{-1}

B. 5.0 N kg^{-1}

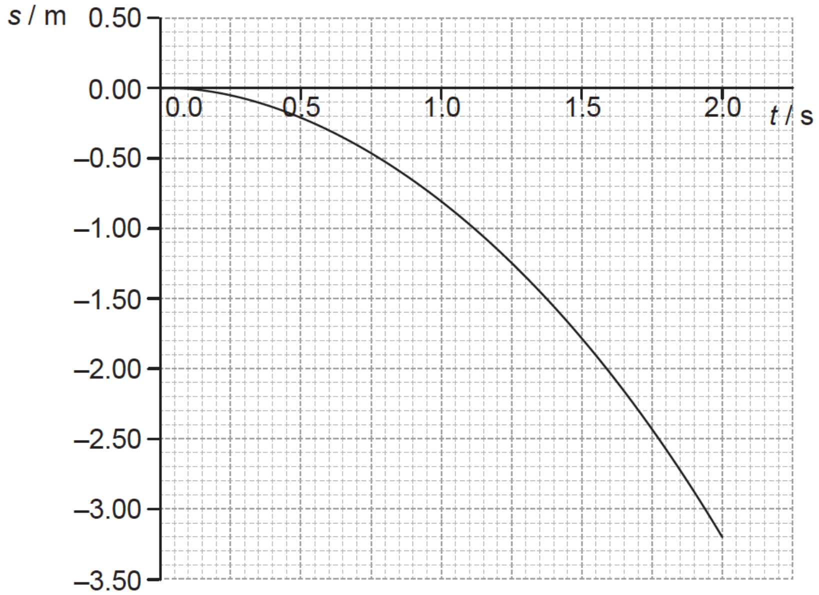
C. 10 N kg^{-1}

D. 20 N kg^{-1}

This question is in **two** parts. **Part 1** is about kinematics and gravitation. **Part 2** is about radioactivity.

Part 1 Kinematics and gravitation

A ball is released near the surface of the Moon at time t=0. The point of release is on a straight line between the centre of Earth and the centre of the Moon. The graph below shows the variation with time t of the displacement s of the ball from the point of release.



6a. State the significance of the negative values of s. *[1 mark]*

6b. Use the graph to *[6 marks]*

(i) estimate the velocity of the ball at $t = 0.80$ s.

(ii) calculate a value for the acceleration of free fall close to the surface of the Moon.

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6c. The following data are available. *[4 marks]*

Mass of the ball = 0.20 kg

Mean radius of the Moon = 1.74×10^6 m

Mean orbital radius of the Moon about the centre of Earth = 3.84×10^8 m

Mass of Earth = 5.97×10^{24} kg

Show that Earth has no significant effect on the acceleration of the ball.

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6d. Calculate the speed of an identical ball when it falls 3.0 m from rest close to the surface of Earth. Ignore air resistance. *[1 mark]*

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6e. Sketch, on the graph, the variation with time *t* of the displacement *s* from the point of release of the ball when the ball is dropped close to the surface of Earth. (For this sketch take the direction towards the Earth as being negative.) *[3 marks]*

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Part 2 Radioactivity

Two isotopes of calcium are calcium-40 $\left(^{40}_{20}\mathrm{Ca}\right)$ and calcium-47 $\left(^{47}_{20}\mathrm{Ca}\right)$. Calcium-40 is stable and calcium-47 is radioactive with a half-life of 4.5 days.

6f. Calculate the percentage of a sample of calcium-47 that decays in 27 days. *[3 marks]*

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6g. The nuclear equation for the decay of calcium-47 into scandium-47 $\left(^{47}_{21}\mathrm{Sc}\right)$ is given by *[4 marks]*

$$^{47}_{20}\mathrm{Ca} \rightarrow {}^{47}_{21}\mathrm{Sc} + {}^{0}_{-1}\mathrm{e} + \mathrm{X}$$

(i) Identify X.

(ii) The following data are available.

Mass of calcium-47 nucleus = 46.95455 u
Mass of scandium-47 nucleus = 46.95241 u

Using the data, determine the maximum kinetic energy, in MeV, of the products in the decay of calcium-47.

(iii) State why the kinetic energy will be less than your value in (h)(ii).

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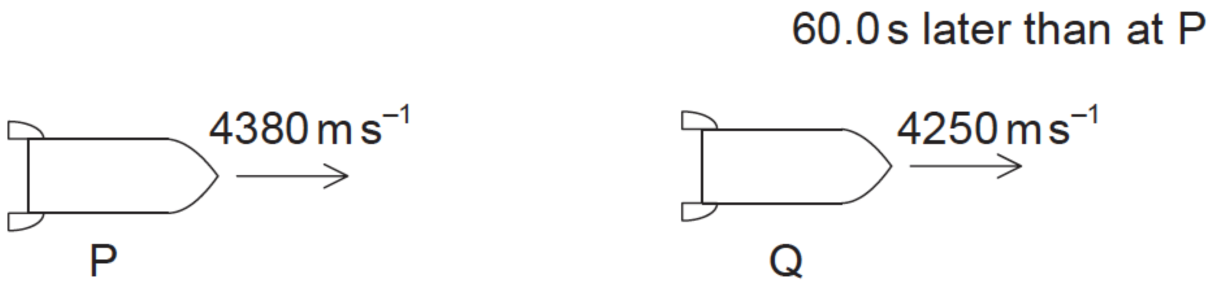
Part 2 Motion of a rocket

A rocket is moving away from a planet within the gravitational field of the planet. When the rocket is at position P a distance of 1.30×10^7m from the centre of the planet, the engine is switched off. At P, the speed of the rocket is 4.38×10^3ms^{-1}.



At a time of 60.0 s later, the rocket has reached position Q. The speed of the rocket at Q is 4.25×10^3ms^{-1}. Air resistance is negligible.

7a. Outline, with reference to the energy of the rocket, why the speed of the rocket is changing between P and Q. *[2 marks]*

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7b. Estimate the average gravitational field strength of the planet between P and Q. *[2 marks]*

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7c. A space station is in orbit at a distance *r* from the centre of the planet in (e)(i). A satellite is launched from the space station so as just to escape from the gravitational field of the planet. The launch takes place in the same direction as the velocity of the space station. Outline why the launch velocity relative to the space station can be less than your answer to (e)(i). *[1 mark]*

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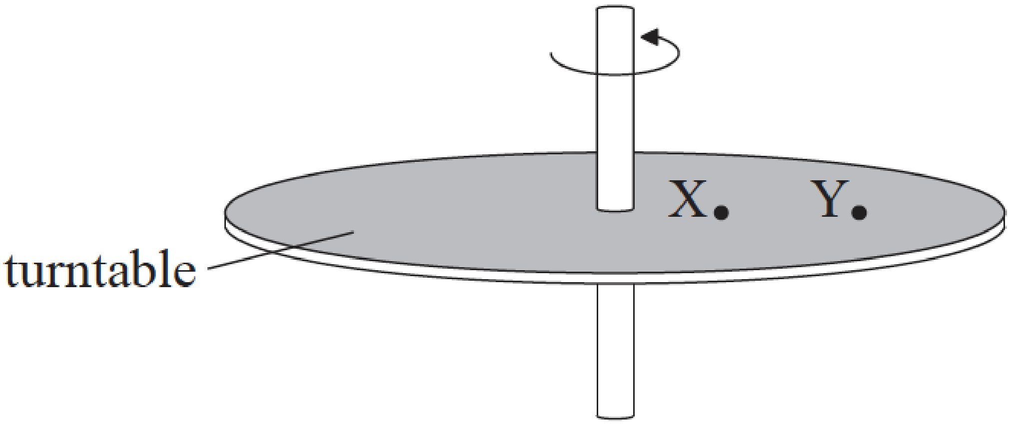
8. The maximum speed with which a car can take a circular turn of radius *R* is *v*. The maximum speed with which the same car, under the same conditions, can take a circular turn of radius 2*R* is *[1 mark]*

A. $2v$.
B. $v\sqrt{2}$.
C. $4v$.
D. $2v\sqrt{2}$.

9. The magnitude of the potential at the surface of a planet is *V*. What is the escape speed from the surface of the planet? *[1 mark]*

A. $\sqrt{V}$
B. $\sqrt{2V}$
C. $\sqrt{VR}$
D. $\sqrt{2VR}$

10. Two particles, X and Y, are attached to the surface of a horizontally mounted turntable. *[1 mark]*



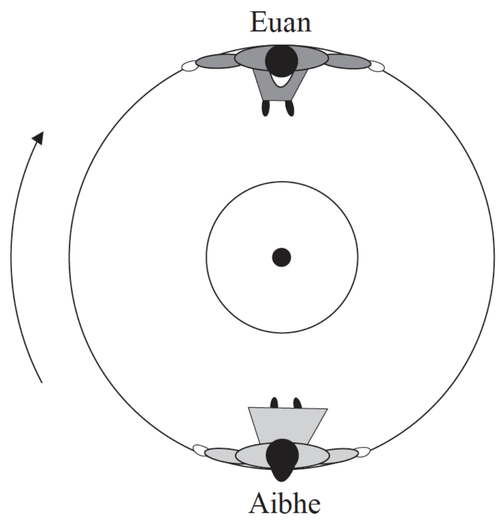
The turntable rotates uniformly about a vertical axis. The magnitude of the linear velocity of X is *v* and the magnitude of its acceleration is *a*. Which of the following correctly compares the magnitude of the velocity of Y and the magnitude of the acceleration of Y with *v* and *a* respectively?

	Magnitude of velocity of Y	Magnitude of acceleration of Y
A.	equal to *v*	less than *a*
B.	greater than *v*	less than *a*
C.	equal to *v*	greater than *a*
D.	greater than *v*	greater than *a*

This question is in **two** parts. **Part 1** is about two children on a merry-go-round. **Part 2** is about electric circuits.

Part 1 Two children on a merry-go-round

Aibhe and Euan are sitting on opposite sides of a merry-go-round, which is rotating at constant speed around a fixed centre. The diagram below shows the view from above.



Aibhe is moving at speed $1.0 ms^{-1}$ relative to the ground.

11a. Determine the magnitude of the velocity of Aibhe relative to *[2 marks]*

(i) Euan.

(ii) the centre of the merry-go-round.

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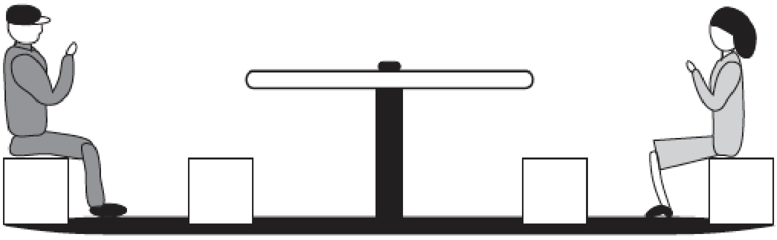
11b. (i) Outline why Aibhe is accelerating even though she is moving at constant speed. *[6 marks]*

(ii) Draw an arrow on the diagram on page 22 to show the direction in which Aibhe is accelerating.

(iii) Identify the force that is causing Aibhe to move in a circle.

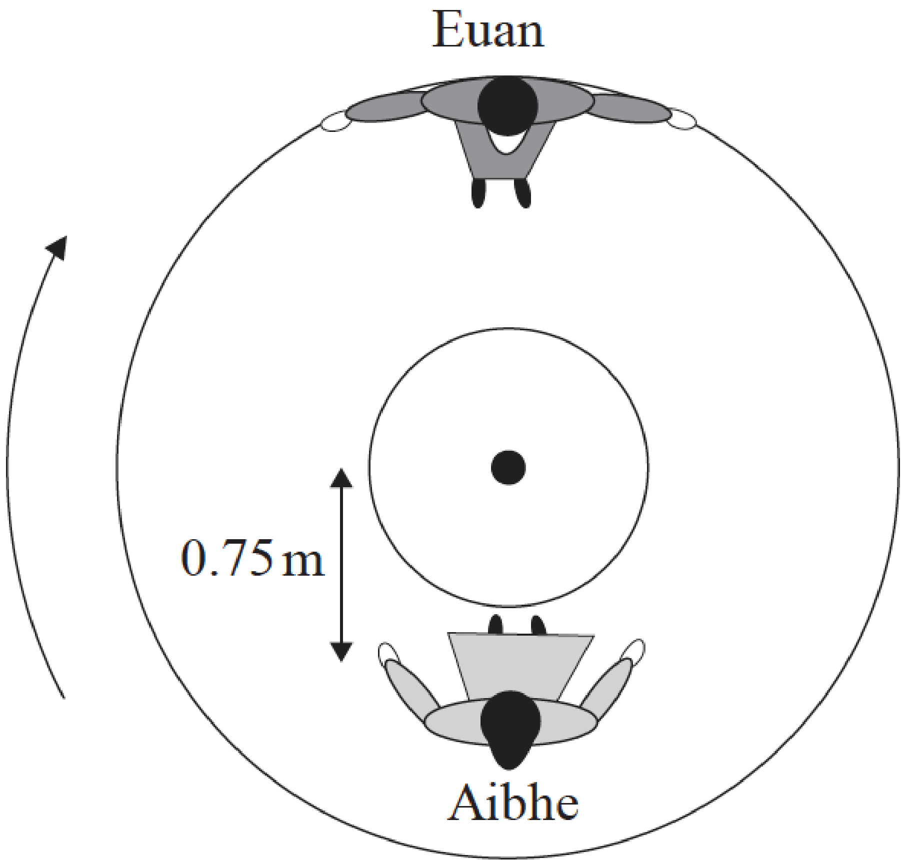
(iv) The diagram below shows a side view of Aibhe and Euan on the merry-go-round.



Explain why Aibhe feels as if her upper body is being "thrown outwards", away from the centre of the merry-go-round.

11c. Euan is rotating on a merry-go-round and drags his foot along the ground to act as a brake. The merry-go-round comes to a stop after 4.0 rotations. The radius of the merry-go-round is 1.5 m. The average frictional force between his foot and the ground is 45 N. Calculate the work done. *[2 marks]*

11d. Aibhe moves so that she is sitting at a distance of 0.75 m from the centre of the merry-go-round, as shown below. *[5 marks]*



Euan pushes the merry-go-round so that he is again moving at 1.0 ms^{-1} relative to the ground.

(i) Determine Aibhe's speed relative to the ground.

(ii) Calculate the magnitude of Aibhe's acceleration.

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This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about orbital motion.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	7.0×10^{8} m
Surface temperature of Sun	T	5.8×10^{3} K
Distance from Sun to Earth	d	1.5×10^{11} m
Stefan-Boltzmann constant	σ	5.7×10^{-8} W m^{-2} K^{-4}

12a. State the Stefan-Boltzmann law for a black body. *[2 marks]*

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12b. Deduce that the solar power incident per unit area at distance *d* from the Sun is given by $\frac{\sigma R^2 T^4}{d^2}$. *[2 marks]*

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12c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2 marks]*

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12d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

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12e. The average power absorbed per unit area at the Earth's surface is $240 Wm^{-2}$. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*

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12f. Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3 marks]*

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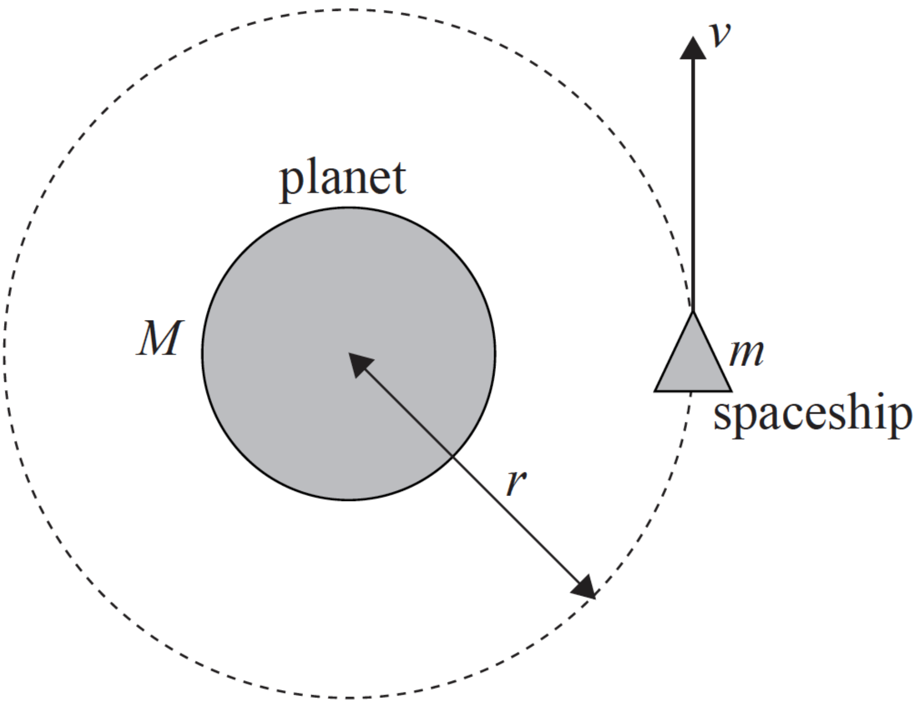
Part 2 Orbital motion

A spaceship of mass *m* is moving at speed *v* in a circular orbit of radius *r* around a planet of mass *M*.



(not to scale)

12g. (i) Identify the force that causes the centripetal acceleration of the spaceship. *[4 marks]*

(ii) Explain why astronauts inside the spaceship would feel “weightless”, even though there is a force acting on them.

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12h. Deduce that the speed of the spaceship is $v = \sqrt{\frac{GM}{r}}$. *[2 marks]*

12i. The table gives equations for the forms of energy of the orbiting spaceship. *[4 marks]*

Form of Energy	**Equation**
Kinetic	$E_K = \frac{GMm}{2r}$
Gravitational potential	$E_P = -\frac{GMm}{r}$
Total (kinetic + potential)	$E = -\frac{GMm}{2r}$

The spaceship passes through a cloud of gas, so that a small frictional force acts on the spaceship.

(i) State and explain the effect that this force has on the total energy of the spaceship.

(ii) Outline the effect that this force has on the speed of the spaceship.

13. An object rotates in a horizontal circle when acted on by a centripetal force *F*. What is the centripetal force acting on the object when the radius of the circle doubles and the kinetic energy of the object halves? *[1 mark]*

A. $\frac{F}{4}$

B. $\frac{F}{2}$

C. *F*

D. 4*F*

14. What is the definition of gravitational field strength at a point? *[1 mark]*

A. Force acting per unit mass on a small mass placed at the point.

B. Work done per unit mass on any mass moved to the point.

C. Force acting on a small mass placed at the point.

D. Work done on any mass moved to the point.

15. An object rotates in a horizontal circle when acted on by a centripetal force *F*. What is the centripetal force acting on the object when the radius of the circle doubles and the kinetic energy of the object halves? *[1 mark]*

A. $\frac{F}{4}$

B. $\frac{F}{2}$

C. *F*

D. 4*F*

16. A body moves with uniform speed around a circle of radius *r*. The period of the motion is *T*. What is the speed of the body? *[1 mark]*

A. $\frac{2\pi r}{T}$

B. $\frac{2\pi T}{r}$

C. Zero

D. $\frac{\pi r^2}{T}$

17. The force *F* between particles in gravitational and electric fields is related to the separation *r* of the particles by an equation of the form *[1 mark]*

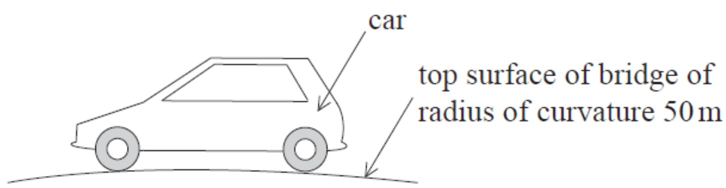
$F = a\frac{bc}{r^2}$.

Which of the following identifies the units for the quantities *a*, *b* and *c* for a gravitational field?

	a	***b* and *c***
A.	$N\,m^2\,C^{-2}$	C
B.	$N\,m^2\,C^{-2}$	kg
C.	$N\,m^2\,kg^{-2}$	C
D.	$N\,m^2\,kg^{-2}$	kg

This question is about circular motion.

The diagram shows a car moving at a constant speed over a curved bridge. At the position shown, the top surface of the bridge has a radius of curvature of 50 m.



18a. Explain why the car is accelerating even though it is moving with a constant speed. *[2 marks]*

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18b. On the diagram, draw and label the vertical forces acting on the car in the position shown. *[2 marks]*

18c. Calculate the maximum speed at which the car will stay in contact with the bridge. *[3 marks]*

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This question is in **two** parts. **Part 1** is about gravitational force fields. **Part 2** is about properties of a gas.

Part 1 Gravitational force fields

19a. State Newton's universal law of gravitation. *[2 marks]*

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19b. A satellite of mass *m* orbits a planet of mass *M*. Derive the following relationship between the period of the satellite *T* and the radius of its orbit *R* (Kepler's third law). *[3 marks]*

$$T^2 = \frac{4\pi^2 R^3}{GM}$$

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19c. A polar orbiting satellite has an orbit which passes above both of the Earth’s poles. One polar orbiting satellite used for Earth observation has an orbital period of 6.00×10^3 s. *[8 marks]*

Mass of Earth = 5.97×10^{24} kg
Average radius of Earth = 6.37×10^6 m

(i) Using the relationship in (b), show that the average height above the surface of the Earth for this satellite is about 800 km.

(ii) The satellite moves from an orbit of radius 1200 km above the Earth to one of radius 2500 km. The mass of the satellite is 45 kg.

Calculate the change in the gravitational potential energy of the satellite.

(iii) Explain whether the gravitational potential energy has increased, decreased or stayed the same when the orbit changes, as in (c)(ii).

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This question is in two parts. **Part 1** is about electric charge and electric circuits. **Part 2** is about momentum.

Part 1 Electric charge and electric circuits

20a. State Coulomb’s law. *[2 marks]*

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20b. In a simple model of the hydrogen atom, the electron can be regarded as being in a circular orbit about the proton. The radius of the orbit is 2.0×10^{-10} m. *[7 marks]*

(i) Determine the magnitude of the electric force between the proton and the electron.

(ii) Calculate the magnitude of the electric field strength *E* and state the direction of the electric field due to the proton at a distance of 2.0×10^{-10} m from the proton.

(iii) The magnitude of the gravitational field due to the proton at a distance of 2.0×10^{-10} m from the proton is *H*. Show that the ratio $\frac{H}{E}$ is of the order 10^{-28}C kg^{-1}.

(iv) The orbital electron is transferred from its orbit to a point where the potential is zero. The gain in potential energy of the electron is 5.4×10^{-19}J. Calculate the value of the potential difference through which the electron is moved.

20c. An electric cell is a device that is used to transfer energy to electrons in a circuit. A particular circuit consists of a cell of emf ε and internal resistance r connected in series with a resistor of resistance 5.0 Ω. *[6 marks]*

(i) Define *emf of a cell.*

(ii) The energy supplied by the cell to one electron in transferring it around the circuit is 5.1×10^{-19}J. Show that the emf of the cell is 3.2V.

(iii) Each electron in the circuit transfers an energy of 4.0×10^{-19} J to the 5.0 Ω resistor. Determine the value of the internal resistance *r.*

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21. A car on a road follows a horizontal circular path at constant speed. Which of the following correctly identifies the origin and the direction of the net force on the car? *[1 mark]*

	Origin	Direction
A.	car engine	toward centre of circle
B.	car engine	away from centre of circle
C.	friction between car tyres and road	away from centre of circle
D.	friction between car tyres and road	toward centre of circle

22. The magnitude of the gravitational field strength at the surface of a planet of mass M and radius R is g. What is the magnitude of the gravitational field strength at the surface of a planet of mass $2M$ and radius $2R$? *[1 mark]*

A. $\frac{g}{4}$

B. $\frac{g}{2}$

C. g

D. $2g$

23. A car travels in a horizontal circle at constant speed. At any instant the resultant horizontal force acting on the car is *[1 mark]*

A. zero.
B. in the direction of travel of the car.
C. directed out from the centre of the circle.
D. directed towards the centre of the circle.

24. What is the acceleration of an object rotating with constant speed v in a circle of radius r? *[1 mark]*

A. Zero

B. $\frac{v^2}{r}$ towards the centre of the circle

C. $\frac{v^2}{r}$ away from the centre of the circle

D. $\frac{v^2}{r}$ along a tangent to the circle

25. The centres of two planets are separated by a distance R. The gravitational force between the two planets is F. What will be the force between the planets when their separation increases to $3R$? *[1 mark]*

A. $\frac{F}{9}$

B. $\frac{F}{3}$

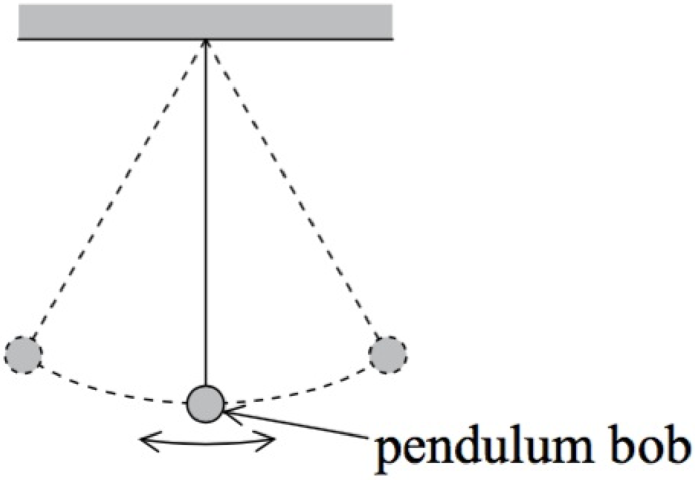
C. F

D. $3F$

26. The acceleration of free fall of a mass of 2.0 kg close to the surface of Mars is 3.6 ms^{-2}. What is the gravitational field strength at the surface of Mars in N kg^{-1}? *[1 mark]*

A. 1.8
B. 3.6
C. 7.2
D. 9.8

27. A pendulum bob is attached to a light string and is swinging in a vertical plane. *[1 mark]*

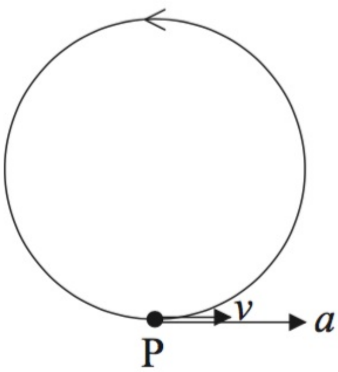


At the lowest point of the motion, the magnitude of the tension in the string is

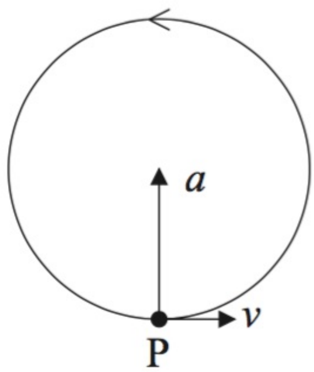
A. less than the weight of the mass of the pendulum bob.
B. zero.
C. greater than the weight of the mass of the pendulum bob.
D. equal to the weight of the mass of the pendulum bob.

28. Particle P is moving with uniform speed in a horizontal circle. Which of the following shows the correct directions of the acceleration *a* and the velocity *v* of P at the position shown? *[1 mark]*

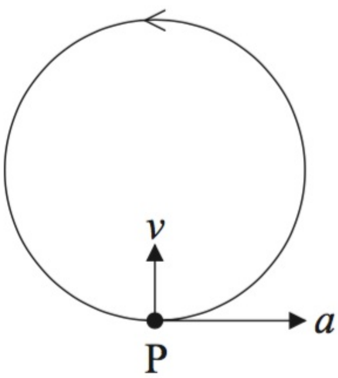
A.



B.



C.



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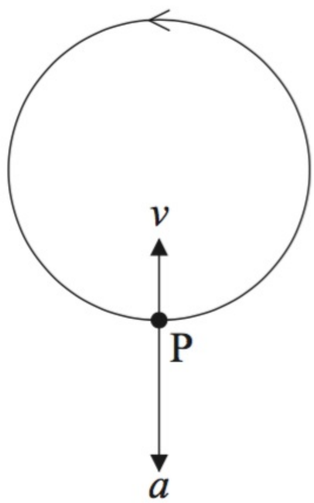

29. A car moves at constant speed around a horizontal circular track. The resultant force on the car is always equal to *[1 mark]*

A. the forward force from the engine.

B. the sideways friction between the tires and the track.

C. the weight of the car.

D. zero.

30. A mass at point *X* gives rise to a gravitational field strength *g* at point *P* as shown below. *[1 mark]*

An identical mass is placed at point *Y* as shown below.

The resultant gravitational field strength at *P* is now

A. greater than 2*g*.

B. between 2*g* and *g*.

C. between *g* and zero.

D. zero.

31. A spacecraft travels away from Earth in a straight line with its motors shut down. At one instant the speed of the spacecraft is 5.4 km s^{-1}. After a time of 600 s, the speed is 5.1 km s^{-1}. The average gravitational field strength acting on the spacecraft during this time interval is *[1 mark]*

A. 5.0×10^{-4} N kg^{-1}

B. 3.0×10^{-2} N kg^{-1}

C. 5.0×10^{-1} N kg^{-1}

D. 30 N kg^{-1}

32. An astronaut of mass 60 kg is on board the International Space Station, which is in low orbit around the Earth. The gravitational force of attraction between the Earth and astronaut is approximately *[1 mark]*

A. zero.
B. 6 N.
C. 60 N.
D. 600 N.

Part 2 Gravitational fields and electric fields

33. The magnitude of gravitational field strength g is defined from the equation shown below. *[4 marks]*

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

The magnitude of electric field strength E is defined from the equation shown below.

$$E = \frac{F_E}{q}$$

For each of these defining equations, state the meaning of the symbols

(i) F_g.

(ii) F_E.

(iii) m.

(iv) q.

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Part 2 Gravitational fields

34a. State Newton's universal law of gravitation. *[3 marks]*

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34b. Deduce that the gravitational field strength g at the surface of a spherical planet of uniform density is given by *[2 marks]*

$$g = \frac{GM}{R^2}$$

where M is the mass of the planet, R is its radius and G is the gravitational constant. You can assume that spherical objects of uniform density act as point masses.

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34c. The gravitational field strength at the surface of Mars g_M is related to the gravitational field strength at the surface of the Earth g_E by *[2 marks]*

$$g_M = 0.38 \times g_E.$$

The radius of Mars R_M is related to the radius of the Earth R_E by

$$R_M = 0.53 \times R_E.$$

Determine the mass of Mars M_M in terms of the mass of the Earth M_E.

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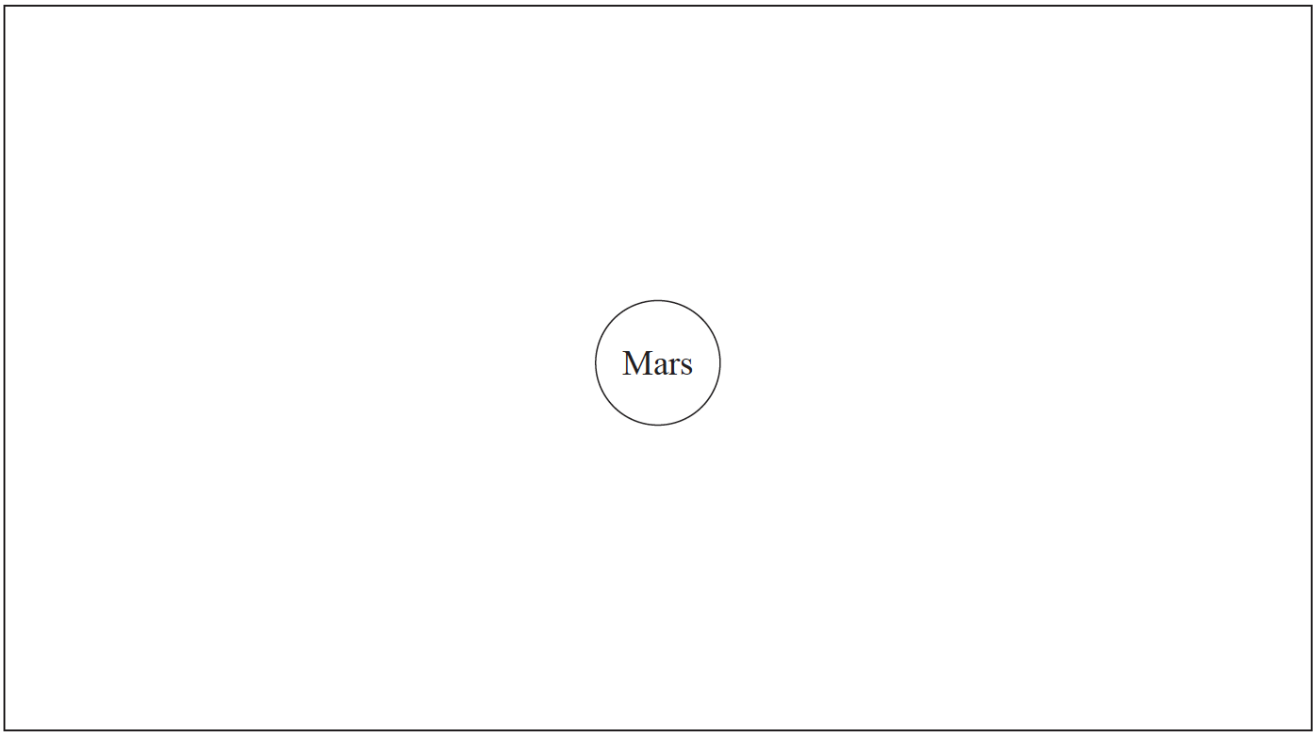
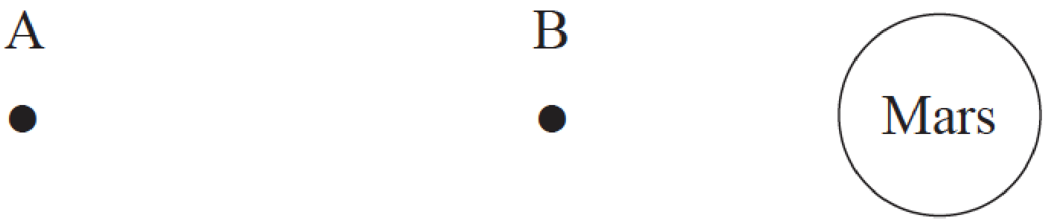
34d. (i) On the diagram below, draw lines to represent the gravitational field around the planet Mars. *[3 marks]*



(ii) An object falls freely in a straight line from point A to point B in time t. The speed of the object at A is u and the speed at B is v. A student suggests using the equation $v=u+g_M t$ to calculate v. Suggest **two** reasons why it is not appropriate to use this equation.



This question is in **two** parts. **Part 1** is about fields, electric potential difference and electric circuits. **Part 2** is about thermodynamic cycles.

Part 1 Fields, electric potential difference and electric circuits

35a. The magnitude of gravitational field strength g is defined from the equation shown below. *[4 marks]*

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

The magnitude of electric field strength E is defined from the equation shown below.

$$E = \frac{F_E}{q}$$

For each of these defining equations, state the meaning of the symbols

(i) F_g.

(ii) F_E.

(iii) m.

(iv) q.

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35b. In a simple model of the hydrogen atom, the electron is regarded as being in a circular orbit about the proton. *[3 marks]* The magnitude of the electric field strength at the electron due to the proton is E_p . The magnitude of the gravitational field strength at the electron due to the proton is g_p.

Determine the order of magnitude of the ratio shown below.

$$\frac{E_p}{g_p}$$

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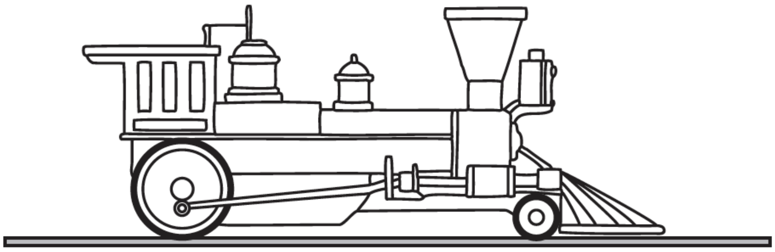
This question is in two parts. **Part 1** is about forces. **Part 2** is about internal energy.

Part 1 Forces

A railway engine is travelling along a horizontal track at a constant velocity.



36a. On the diagram above, draw labelled arrows to represent the vertical forces that act on the railway engine. *[3 marks]*

36b. Explain, with reference to Newton's laws of motion, why the velocity of the railway engine is constant. *[2 marks]*

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36c. The constant horizontal velocity of the railway engine is 16 ms^{-1}. A total horizontal resistive force of 76 kN acts on the railway engine. *[2 marks]*

Calculate the useful power output of the railway engine.

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36d. The power driving the railway engine is switched off. The railway engine stops, from its speed of 16 ms^{-1}, without braking in a distance of 1.1 km. A student hypothesizes that the horizontal resistive force is constant. *[2 marks]*

Based on this hypothesis, calculate the mass of the railway engine.

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36e. Another hypothesis is that the horizontal force in (c) consists of two components. One component is a constant frictional force of 19 kN. The other component is a resistive force F that varies with speed v where F is proportional to v^3. *[5 marks]*

(i) State the value of the magnitude of F when the railway engine is travelling at 16 ms^{-1}.

(ii) Determine the **total** horizontal resistive force when the railway engine is travelling at 8.0 ms^{-1}.

36f. On its journey, the railway engine now travels around a curved track at constant speed. Explain whether or not the railway engine is accelerating. *[3 marks]*

Part 2 Satellite

37a. State, in words, Newton’s universal law of gravitation. *[2 marks]*

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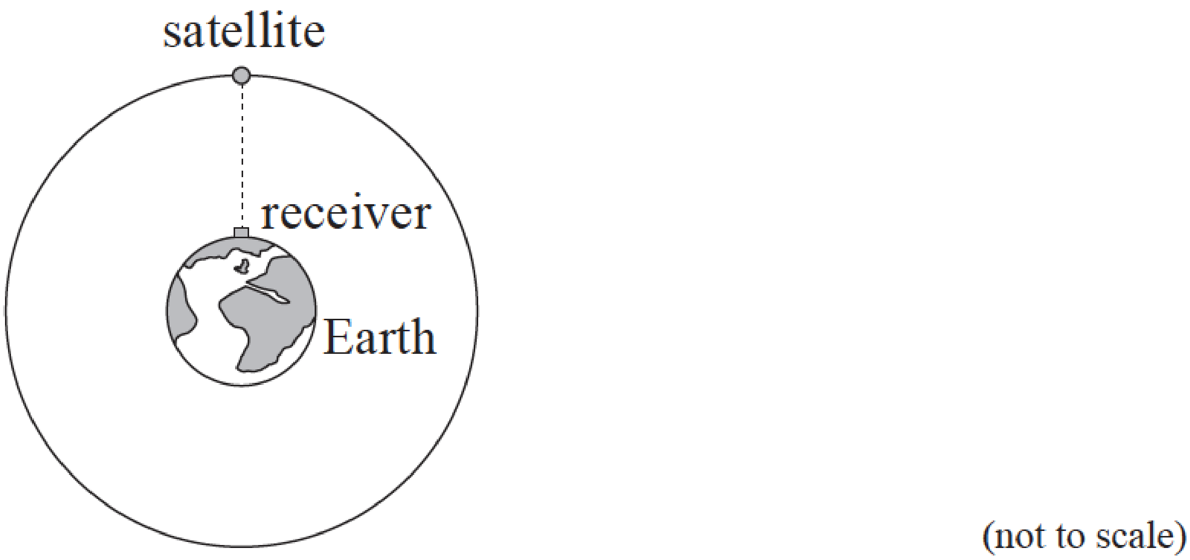
37b. The diagram shows a satellite orbiting the Earth. The satellite is part of the network of global-positioning satellites (GPS) that transmit radio signals used to locate the position of receivers that are located on the Earth. *[3 marks]*



When the satellite is directly overhead, the microwave signal reaches the receiver 67ms after it leaves the satellite.

(i) State the order of magnitude of the wavelength of microwaves.

(ii) Calculate the height of the satellite above the surface of the Earth

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37c. (i) Explain why the satellite is accelerating towards the centre of the Earth even though its orbital speed is constant. *[8 marks]*

(ii) Calculate the gravitational field strength due to the Earth at the position of the satellite.

Mass of Earth = 6.0×10^{24}kg
Radius of Earth = 6.4×10^{6}m

(iii) Determine the orbital speed of the satellite.

(iv) Determine, in hours, the orbital period of the satellite.

38. A cyclist rides around a circular track at a uniform speed. Which of the following correctly gives the net horizontal force on the cyclist at any given instant of time? *[1 mark]*

	Net horizontal force along direction of motion	Net horizontal force normal to direction of motion
A.	zero	zero
B.	zero	non zero
C.	non zero	zero
D.	non zero	non zero

39. A spherical planet of uniform density has three times the mass of the Earth and twice the average radius. The magnitude of the gravitational field strength at the surface of the Earth is *g*. What is the gravitational field strength at the surface of the planet? *[1 mark]*

A. 6 g

B. $\frac{2}{3}g$

C. $\frac{3}{4}g$

D. $\frac{3}{2}g$

40. A particle of mass *m* is moving with constant speed *v* in uniform circular motion. What is the total work done by the centripetal force during one revolution? *[1 mark]*

A. Zero

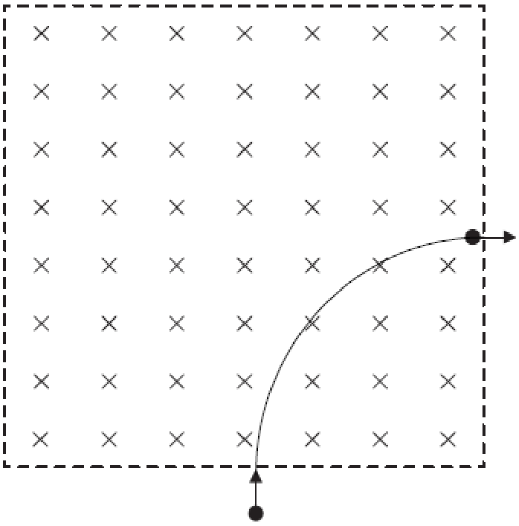
B. $\frac{mv^2}{2}$

C. mv^2

D. $2\pi mv^2$

This question is about motion in a magnetic field.

An electron, that has been accelerated from rest by a potential difference of 250 V, enters a region of magnetic field of strength 0.12 T that is directed into the plane of the page.



41a. The electron’s path while in the region of magnetic field is a quarter circle. Show that the *[4 marks]*

(i) speed of the electron after acceleration is $9.4\times10^{6}\,\text{ms}^{-1}$.

(ii) radius of the path is $4.5\times10^{-4}\,\text{m}$.

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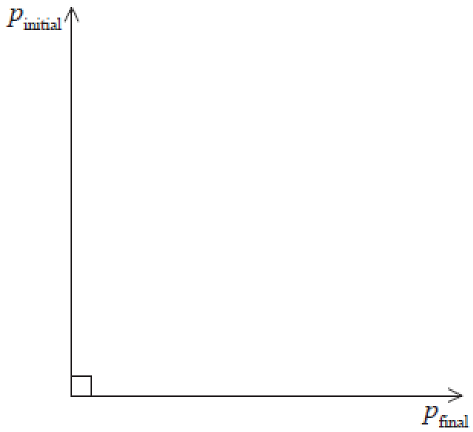
41b. The diagram below shows the momentum of the electron as it enters and leaves the region of magnetic field. *[3 marks]*
The magnitude of the initial momentum and of the final momentum is 8.6×10^{-24}Ns.



(i) On the diagram above, draw an arrow to indicate the vector representing the change in the momentum of the electron.

(ii) Show that the magnitude of the change in the momentum of the electron is 1.2×10^{-23}Ns.

(iii) The time the electron spends in the region of magnetic field is 7.5×10^{-11}s. Estimate the magnitude of the average force on the electron.

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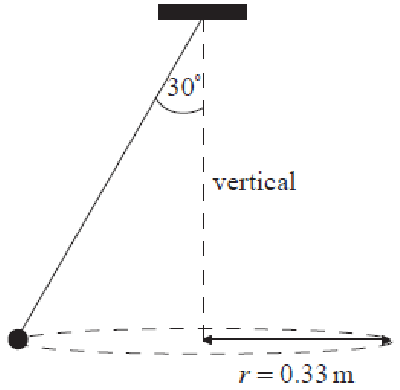
This question is about circular motion.

A ball of mass 0.25 kg is attached to a string and is made to rotate with constant speed *v* along a horizontal circle of radius *r* = 0.33m. The string is attached to the ceiling and makes an angle of 30° with the vertical.



42a. (i) On the diagram above, draw and label arrows to represent the forces on the ball in the position shown. *[4 marks]*

(ii) State and explain whether the ball is in equilibrium.

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42b. Determine the speed of rotation of the ball. *[3 marks]*

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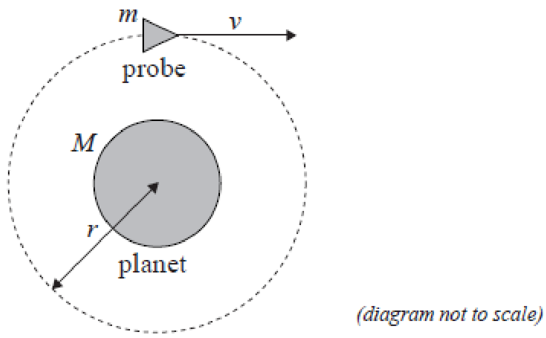
This question is about a probe in orbit.

A probe of mass *m* is in a circular orbit of radius *r* around a spherical planet of mass *M*.



43a. State why the work done by the gravitational force during one full revolution of the probe is zero. *[1 mark]*

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43b. Deduce for the probe in orbit that its *[4 marks]*

(i) speed is $v = \sqrt{\frac{GM}{r}}$.

(ii) total energy is $E = -\frac{GMm}{2r}$.

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43c. It is now required to place the probe in another circular orbit further away from the planet. To do this, the probe's engines will be fired for a very short time. *[2 marks]*

State and explain whether the work done on the probe by the engines is positive, negative **or** zero.

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