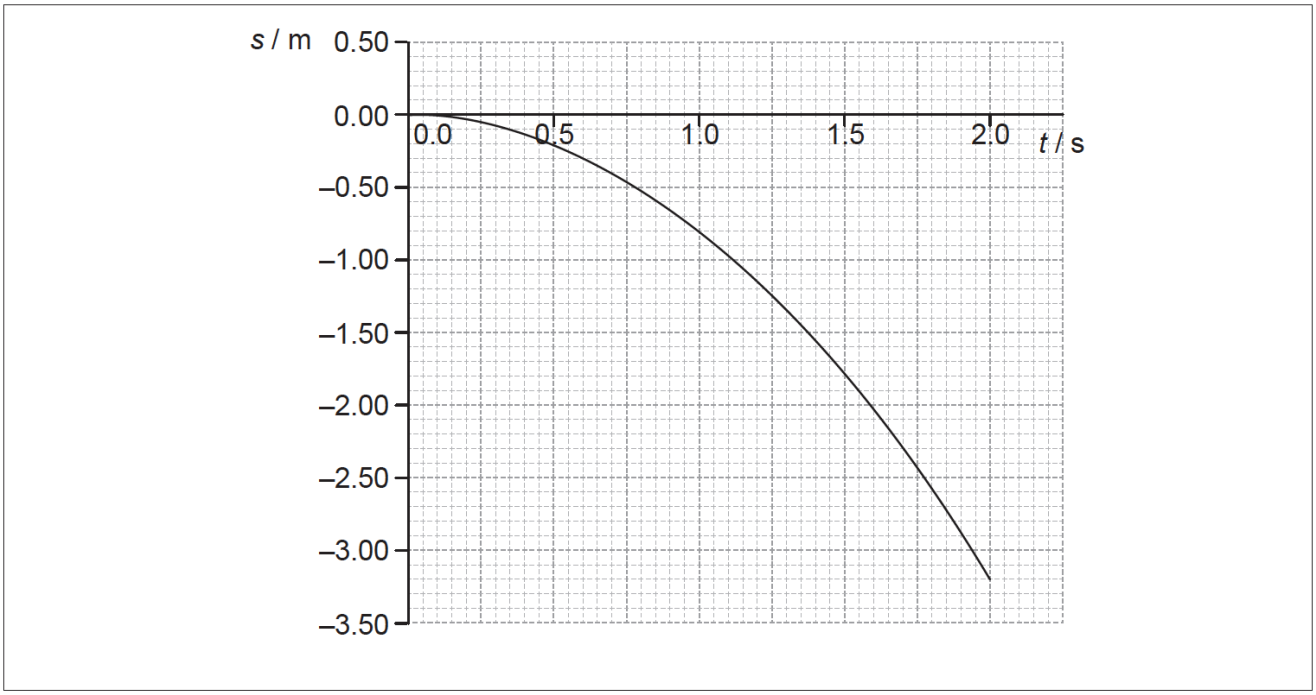
Circular-practice-1-Extended

[99 marks]

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.



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

1b. 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.

1c. 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.

1d. 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]*

1e. 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]*

Part 2 Radioactivity

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

1f. Calculate the percentage of a sample of calcium-47 that decays in 27 days. *[3 marks]*

1g. 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

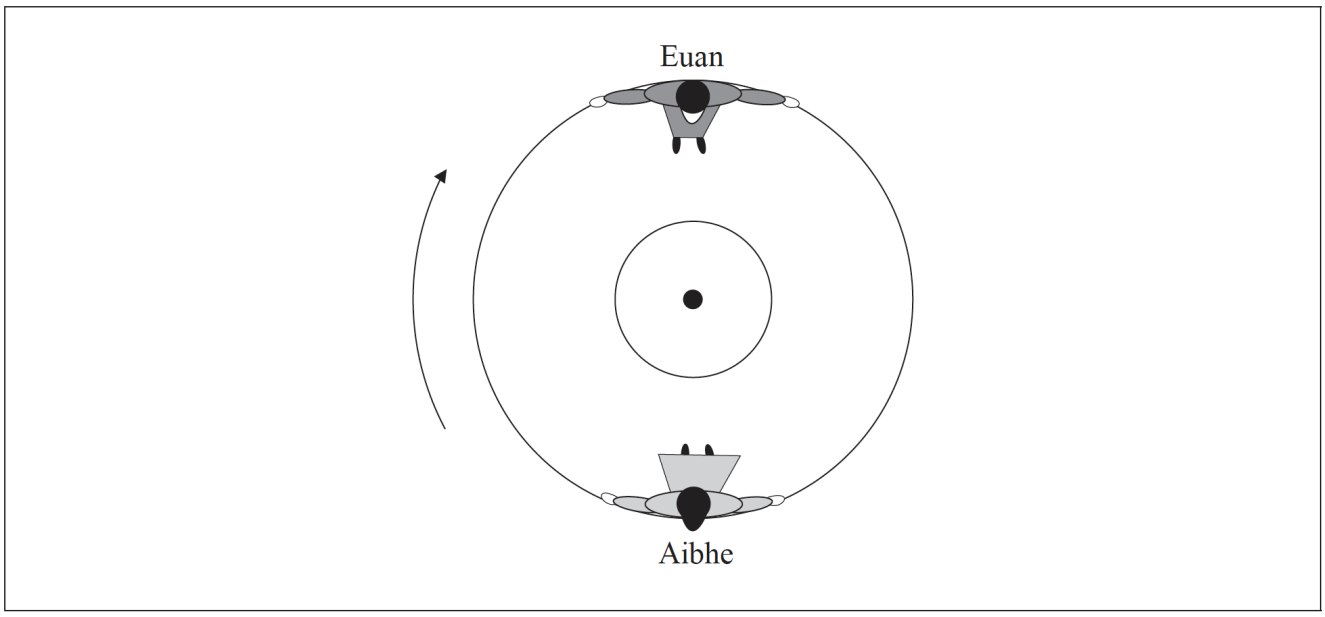
Using the data, determine the maximum kinetic energy, in MeV, of the products in the decay of calcium-47.

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

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.

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

(i) Euan.

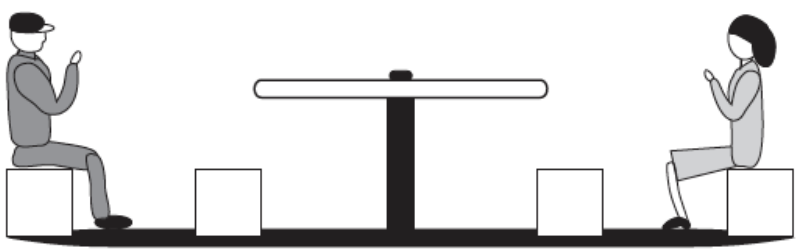
(ii) the centre of the merry-go-round.

2b. (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.

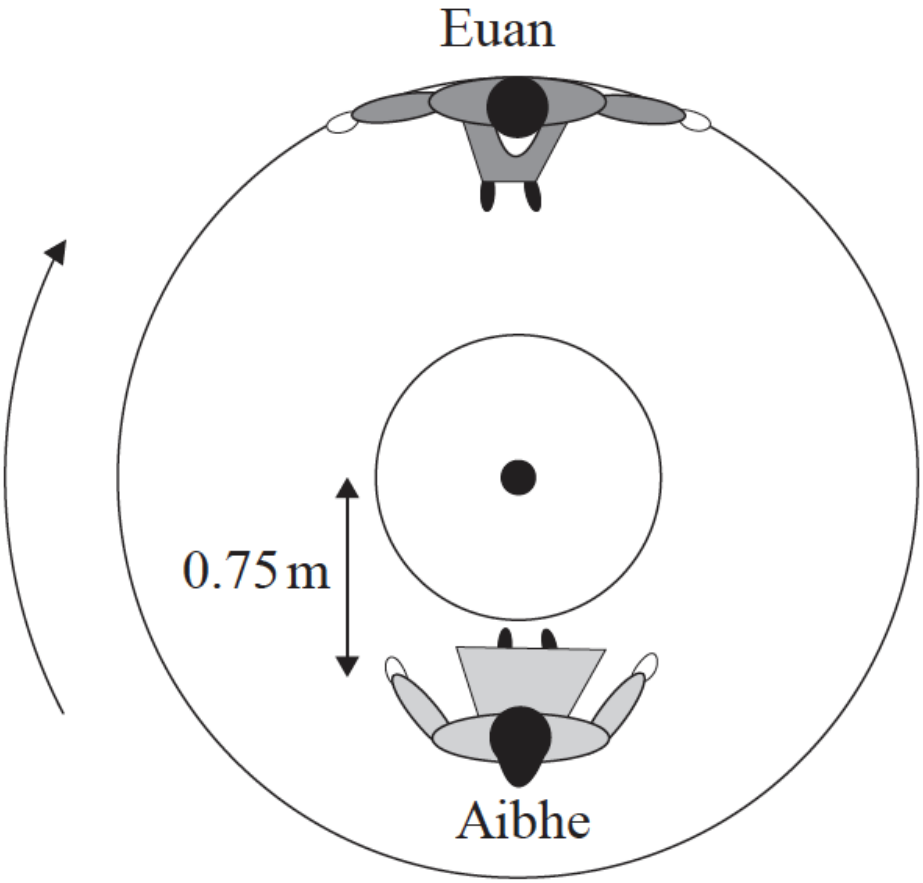
(iv) The diagram below shows a side view of Aibhe and Euan on the merry-go-round.



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

2c. 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]*

2d. 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.

This question is in **two** parts. **Part 1** is about the motion of a car. **Part 2** is about electricity.

Part 1 Motion of a car

3a. A car accelerates uniformly along a straight horizontal road from an initial speed of $12\ \mathrm{m\,s^{-1}}$ to a final speed of $28\ \mathrm{m\,s^{-1}}$ in a distance of 250 m. The mass of the car is 1200 kg. Determine the rate at which the engine is supplying kinetic energy to the car as it accelerates. *[4 marks]*

A car is travelling along the straight horizontal road at its maximum speed of $56\ \mathrm{m\,s^{-1}}$. The power output required at the wheels is 0.13 MW.

3b. A car is travelling along a straight horizontal road at its maximum speed of $56\ \mathrm{m\,s^{-1}}$. The power output required at the wheels is 0.13 MW. *[5 marks]*

(i) Calculate the total resistive force acting on the car when it is travelling at a constant speed of $56\ \mathrm{m\,s^{-1}}$.

(ii) The mass of the car is 1200 kg. The resistive force F is related to the speed v by $F \propto v^2$. Using your answer to (b)(i), determine the maximum theoretical acceleration of the car at a speed of $28\ \mathrm{m\,s^{-1}}$.

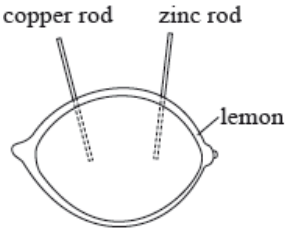
A driver moves the car in a horizontal circular path of radius 200 m. Each of the four tyres will not grip the road if the frictional force between a tyre and the road becomes less than 1500 N.

3c. (i) Calculate the maximum speed of the car at which it can continue to move in the circular path. Assume that the radius of the path is the same for each tyre. *[6 marks]*

(ii) While the car is travelling around the circle, the people in the car have the sensation that they are being thrown outwards. Outline how Newton's first law of motion accounts for this sensation.

Part 2 Electricity

A lemon can be used to make an electric cell by pushing a copper rod and a zinc rod into the lemon.



A student constructs a lemon cell and connects it in an electrical circuit with a variable resistor. The student measures the potential difference *V* across the lemon and the current *I* in the lemon.

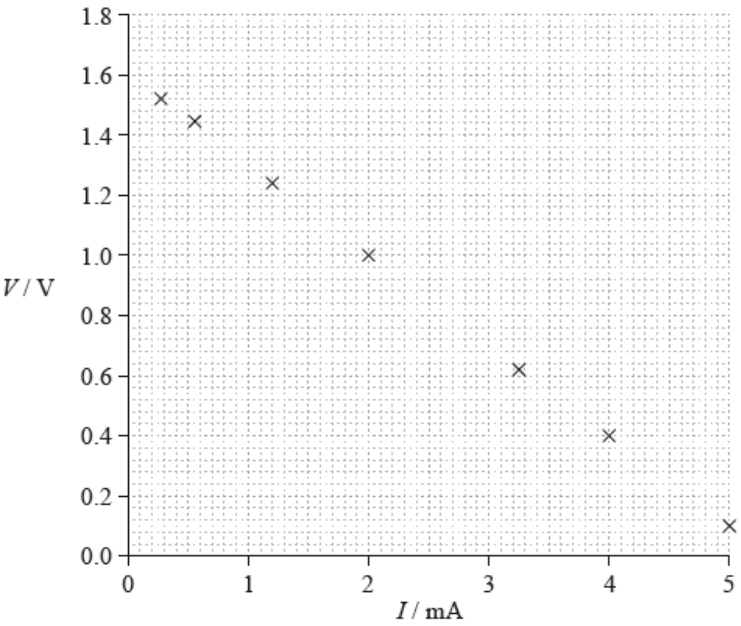
3d. (i) Draw a circuit diagram of the experimental arrangement that will enable the student to collect the data for the graph. *[10 marks]*

(ii) Show that the potential difference V across the lemon is given by

$$V = E - Ir$$

where E is the emf of the lemon cell and r is the internal resistance of the lemon cell.

(iii) The graph shows how V varies with I.



Using the graph, estimate the emf of the lemon cell.

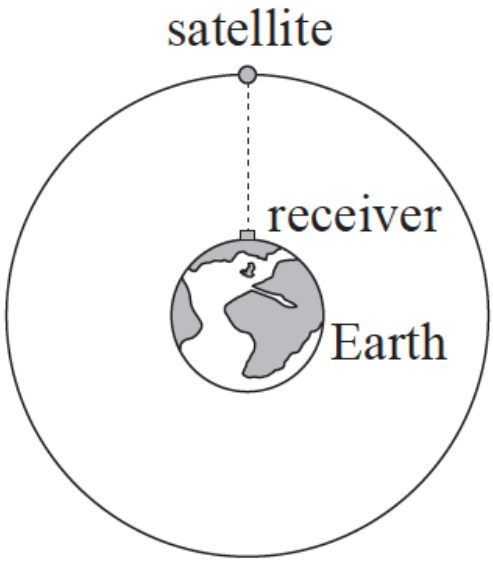
(iv) Determine the internal resistance of the lemon cell.

(v) The lemon cell is used to supply energy to a digital clock that requires a current of $6.0\ \mu\text{A}$. The clock runs for 16 hours. Calculate the charge that flows through the clock in this time.

Part 2 Satellite

4a. State, in words, Newton's universal law of gravitation. *[2 marks]*

4b. 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]*



(not to scale)

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

4c. (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.

Part 2 Gravitational fields

5a. State Newton's universal law of gravitation. *[3 marks]*

5b. 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.

5c. 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]*

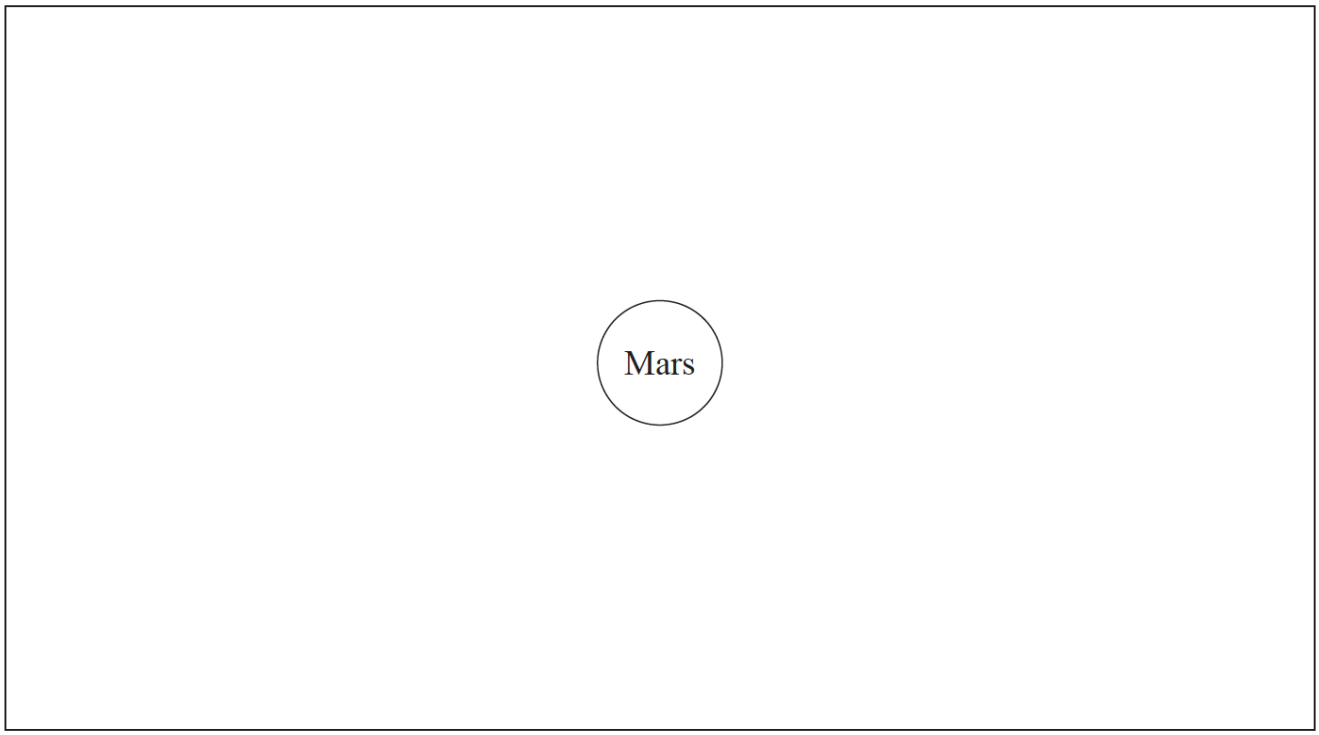
$g_M = 0.38 \times g_E$.

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

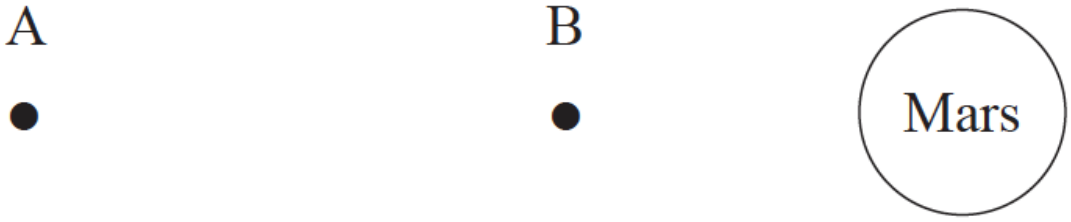
$R_M = 0.53 \times R_E$.

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

5d. (i) On the diagram below, draw lines to represent the gravitational field around the planet Mars. *[3 marks]*



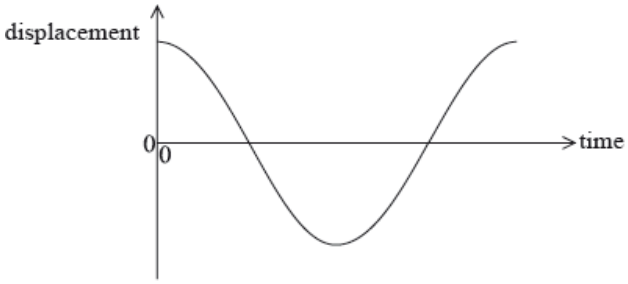
(ii) An object falls freely in a straight line from point A to point B in time t. The speed of the object at A is u and the speed at B is v. A student suggests using the equation $v = u + g_M t$ to calculate v. Suggest **two** reasons why it is not appropriate to use this equation.



This question is in **two** parts. **Part 1** is about a simple pendulum. **Part 2** is about the Rutherford model of the atom.

Part 1 Simple pendulum

A pendulum consists of a bob suspended by a light inextensible string from a rigid support. The pendulum bob is moved to one side and then released. The sketch graph shows how the displacement of the pendulum bob undergoing simple harmonic motion varies with time over one time period.



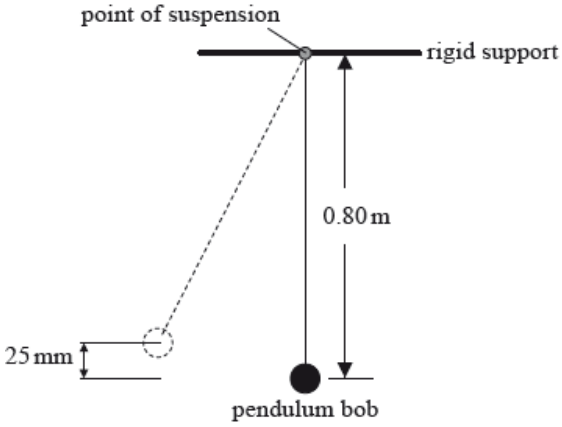
On the sketch graph above,

6a. (i) label with the letter A a point at which the acceleration of the pendulum bob is a maximum. *[2 marks]*

(ii) label with the letter V a point at which the speed of the pendulum bob is a maximum.

6b. Explain why the magnitude of the tension in the string at the midpoint of the oscillation is greater than the weight of the pendulum bob. *[3 marks]*

A pendulum bob is moved to one side until its centre is 25 mm above its rest position and then released.



6c. (i) Show that the speed of the pendulum bob at the midpoint of the oscillation is $0.70\ \mathrm{m\,s^{-1}}$. *[5 marks]*

(ii) The mass of the pendulum bob is 0.057 kg. The centre of the pendulum bob is 0.80 m below the support. Calculate the magnitude of the tension in the string when the pendulum bob is vertically below the point of suspension.

Part 2 Rutherford model of the atom

The isotope gold-197 $\left({}^{197}_{79}Au\right)$ is stable but the isotope gold-199 $\left({}^{199}_{79}Au\right)$ is not.

6d. (i) Outline, in terms of the forces acting between nucleons, why, for large stable nuclei such as gold-197, the number of neutrons exceeds the number of protons. *[4 marks]*

(ii) A nucleus of ${}^{199}_{79}\mathrm{Au}$ decays to a nucleus of ${}^{199}_{80}\mathrm{Hg}$ with the emission of an electron and another particle. State the name of this other particle.