Motion-practice-1-ShortA *[173 marks]*

A girl rides a bicycle that is powered by an electric motor. A battery transfers energy to the electric motor. The emf of the battery is 16 V and it can deliver a charge of 43 kC when discharging completely from a full charge.

The maximum speed of the girl on a horizontal road is 7.0 m s^{-1} with energy from the battery alone. The maximum distance that the girl can travel under these conditions is 20 km.

1a. Show that the time taken for the battery to discharge is about 3×10^3 s. *[1 mark]*

1b. Deduce that the average power output of the battery is about 240 W. *[2 marks]*

1c. Friction and air resistance act on the bicycle and the girl when they move. Assume that all the energy is transferred from the battery to the electric motor. Determine the total average resistive force that acts on the bicycle and the girl. *[2 marks]*

The bicycle and the girl have a total mass of 66 kg. The girl rides up a slope that is at an angle of 3.0° to the horizontal.

1d. Calculate the component of weight for the bicycle and girl acting down the slope. *[1 mark]*

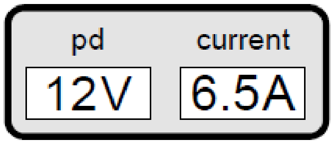
1e. The battery continues to give an output power of 240 W. Assume that the resistive forces are the same as in (a)(iii). *[2 marks]*

Calculate the maximum speed of the bicycle and the girl up the slope.

1f. On another journey up the slope, the girl carries an additional mass. *[2 marks]*

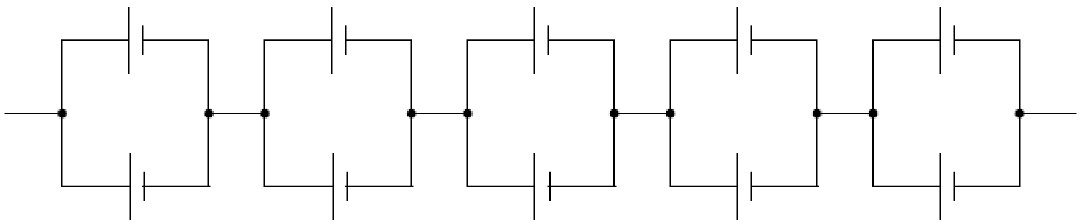
Explain whether carrying this mass will change the maximum distance that the bicycle can travel along the slope.

The bicycle has a meter that displays the current and the terminal potential difference (pd) for the battery when the motor is running. The diagram shows the meter readings at one instant. The emf of the cell is 16 V.



1g. Determine the internal resistance of the battery. *[2 marks]*

The battery is made from an arrangement of 10 identical cells as shown.

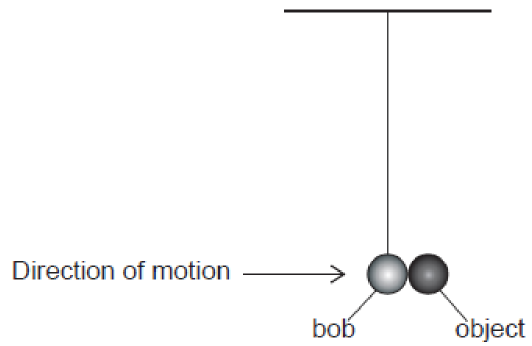


1h. Calculate the emf of **one** cell. *[1 mark]*

1i. Calculate the internal resistance of **one** cell. *[2 marks]*

A small metal pendulum bob of mass 75 g is suspended at rest from a fixed point with a length of thread of negligible mass. Air resistance is negligible. The bob is then displaced to the left.

At time $t = 0$ the bob is moving horizontally to the right at 0.8 m s^{-1}. It collides with a small stationary object also of mass 75 g. Both objects then move together with motion that is simple harmonic.

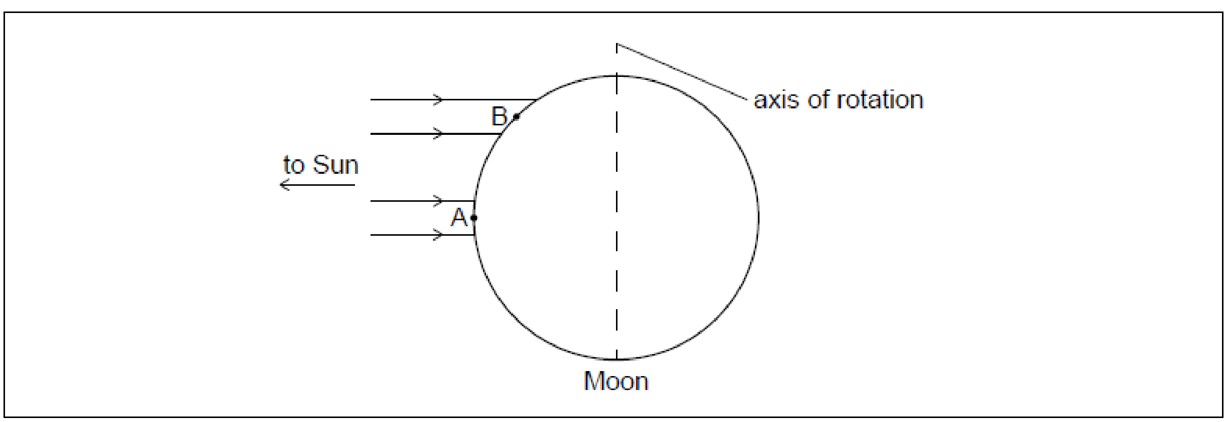


2a. Calculate the speed of the combined masses immediately after the collision. *[1 mark]*

2b. Show that the collision is inelastic. *[3 marks]*

2c. Describe the changes in gravitational potential energy of the oscillating system from $t = 0$ as it oscillates through one cycle of its motion. *[1 mark]*

The Moon has no atmosphere and orbits the Earth. The diagram shows the Moon with rays of light from the Sun that are incident at 90° to the axis of rotation of the Moon.



3a. A black body is on the Moon's surface at point A. Show that the maximum temperature that this body can reach is 400 K. Assume that the Earth and the Moon are the same distance from the Sun. *[2 marks]*

3b. Another black body is on the Moon’s surface at point B. *[2 marks]*

Outline, without calculation, why the aximum temperature of the black body at point B is less than at point A.

3c. The albedo of the Earth’s atmosphere is 0.28. Outline why the maximum temperature of a black body on the Earth when the Sun is overhead is less than that at point A on the Moon. *[1 mark]*

3d. Outline why a force acts on the Moon. *[1 mark]*

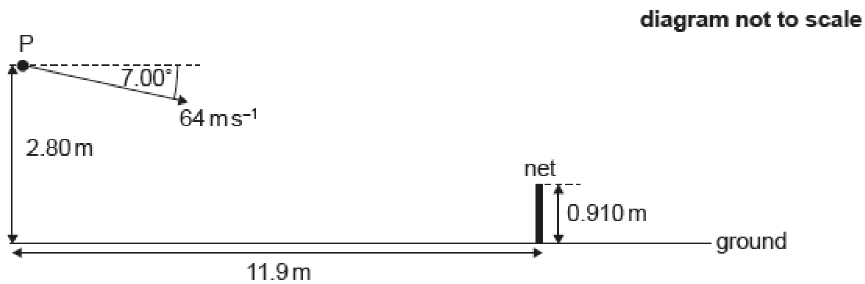
3e. Outline why this force does no work on the Moon. *[1 mark]*

A student strikes a tennis ball that is initially at rest so that it leaves the racquet at a speed of 64 m s^{-1}. The ball has a mass of 0.058 kg and the contact between the ball and the racquet lasts for 25 ms.

4a. Calculate the average force exerted by the racquet on the ball. *[2 marks]*

4b. Calculate the average power delivered to the ball during the impact. *[2 marks]*

The student strikes the tennis ball at point P. The tennis ball is initially directed at an angle of 7.00° to the horizontal.



The following data are available.

Height of P = 2.80 m

Distance of student from net = 11.9 m

Height of net = 0.910 m

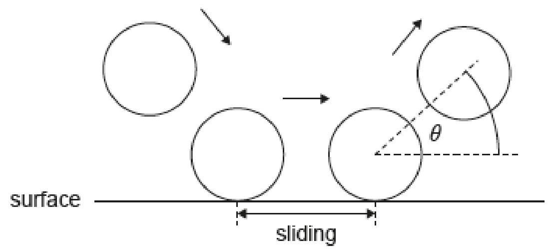
Initial speed of tennis ball = 64 m s^{-1}

4c. Calculate the time it takes the tennis ball to reach the net. *[2 marks]*

4d. Show that the tennis ball passes over the net. *[3 marks]*

4e. Determine the speed of the tennis ball as it strikes the ground. *[2 marks]*

4f. The student models the bounce of the tennis ball to predict the angle *θ* at which the ball leaves a surface of clay and a surface of grass. *[3 marks]*

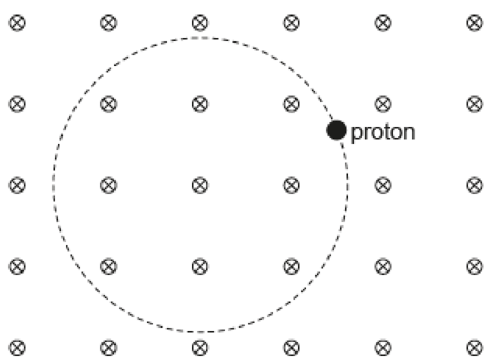


The model assumes

- during contact with the surface the ball slides.
- the sliding time is the same for both surfaces.
- the sliding frictional force is greater for clay than grass.
- the normal reaction force is the same for both surfaces.

Predict for the student's model, without calculation, whether θ is greater for a clay surface or for a grass surface.

A proton moves along a circular path in a region of a uniform magnetic field. The magnetic field is directed into the plane of the page.

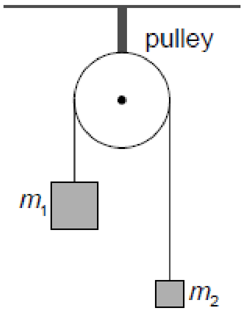


5a. Label with arrows on the diagram the magnetic force *F* on the proton. *[1 mark]*

5b. Label with arrows on the velocity vector *v* of the proton. *[1 mark]*

5c. The speed of the proton is 2.16×10^{6} m s^{-1} and the magnetic field strength is 0.042 T. For this proton, determine, in m, the radius of the circular path. Give your answer to an appropriate number of significant figures. *[3 marks]*

In an experiment to measure the acceleration of free fall a student ties two different blocks of masses m_1 and m_2 to the ends of a string that passes over a frictionless pulley.



The student calculates the acceleration a of the blocks by measuring the time taken by the heavier mass to fall through a given distance. Their theory predicts that $a = g\frac{m_1 - m_2}{m_1 + m_2}$ and this can be re-arranged to give $g = a\frac{m_1 + m_2}{m_1 - m_2}$.

In a particular experiment the student calculates that a = (0.204 ±0.002) ms^{-2} using m_1 = (0.125 ±0.001) kg and m_2 = (0.120 ±0.001) kg.

6a. Calculate the percentage error in the measured value of g. *[3 marks]*

6b. Deduce the value of g and its absolute uncertainty for this experiment. *[2 marks]*

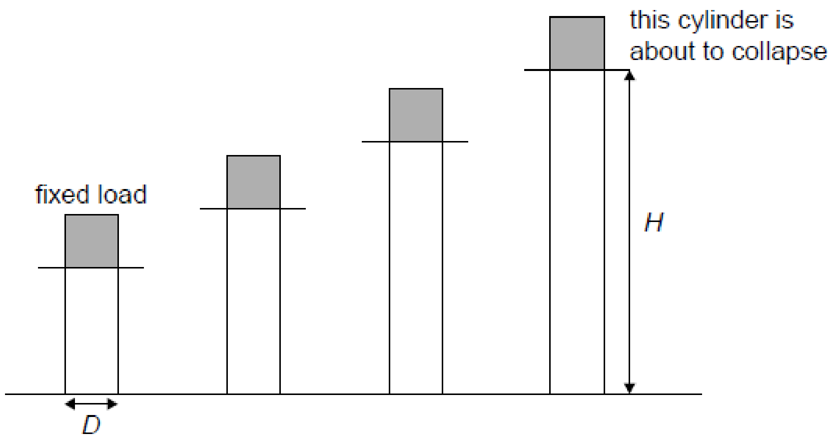
6c. There is an advantage and a disadvantage in using two masses that are almost equal. *[2 marks]*

State and explain the advantage with reference to the magnitude of the acceleration that is obtained.

6d. There is an advantage and a disadvantage in using two masses that are almost equal. *[2 marks]*

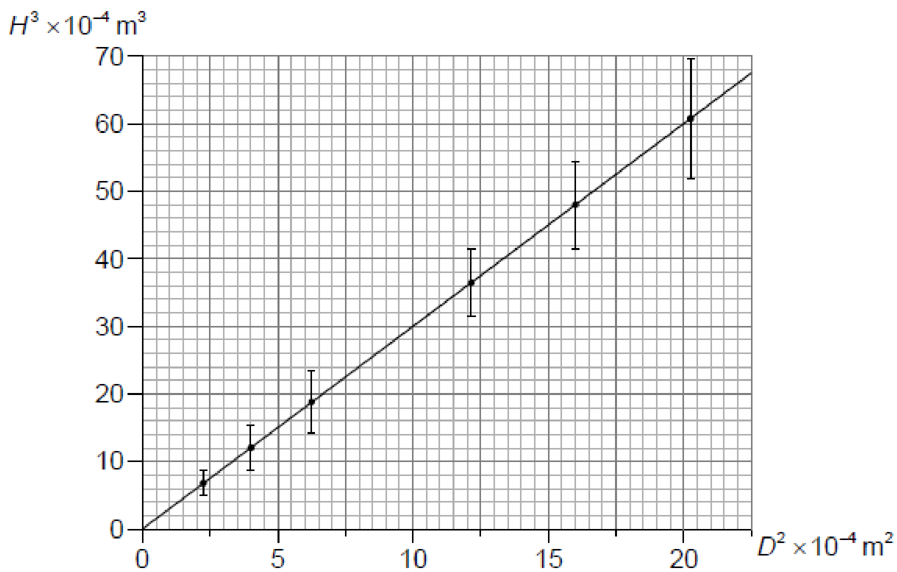
State and explain the disadvantage with reference to your answer to (a)(ii).

In an investigation a student folds paper into cylinders of the same diameter *D* but different heights. Beginning with the shortest cylinder they applied the same fixed load to each of the cylinders one by one. They recorded the height *H* of the first cylinder to collapse.



They then repeat this process with cylinders of different diameters.

The graph shows the data plotted by the student and the line of best fit.



Theory predicts that $H = cD^{\frac{2}{3}}$ where *c* is a constant.

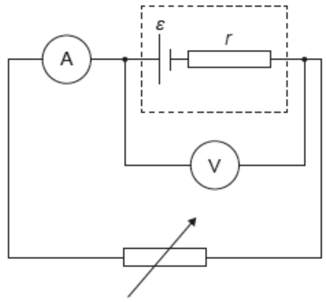
7a. Suggest why the student's data supports the theoretical prediction. *[2 marks]*

7b. Determine *c*. State an appropriate unit for *c*. *[3 marks]*

7c. Determine *c*. State an appropriate unit for *c*. *[3 marks]*

7d. Identify **one** factor that determines the value of *c*. *[1 mark]*

A student investigates the electromotive force (emf) ε and internal resistance r of a cell.



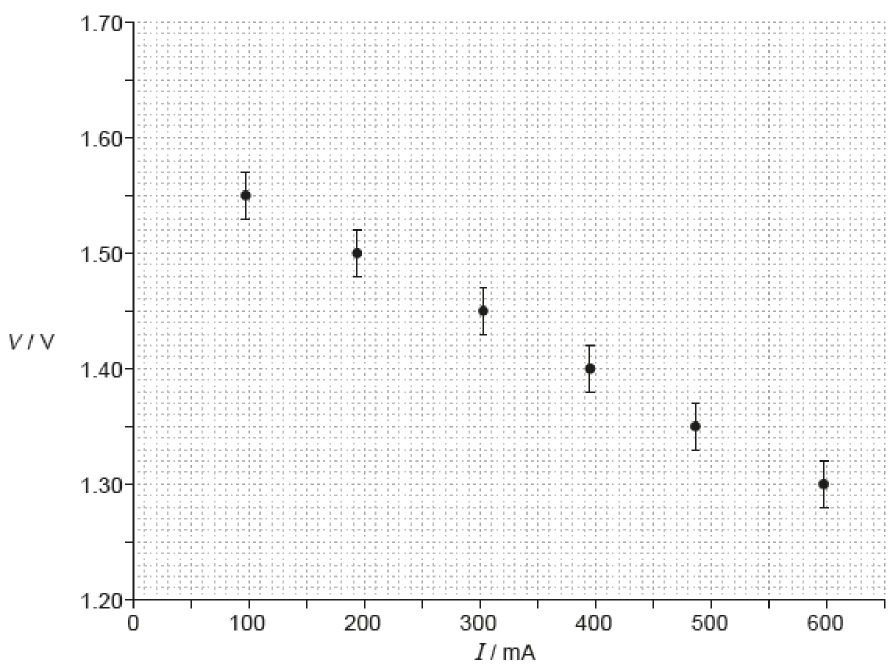
The current I and the terminal potential difference V are measured.

For this circuit $V = \varepsilon - Ir$.

The table shows the data collected by the student. The uncertainties for each measurement
are shown.

I / mA ± 1 mA	V / V ± 0.02 V
97	1.55
193	1.50
304	1.45
395	1.40
487	1.35
598	1.30

The graph shows the data plotted.



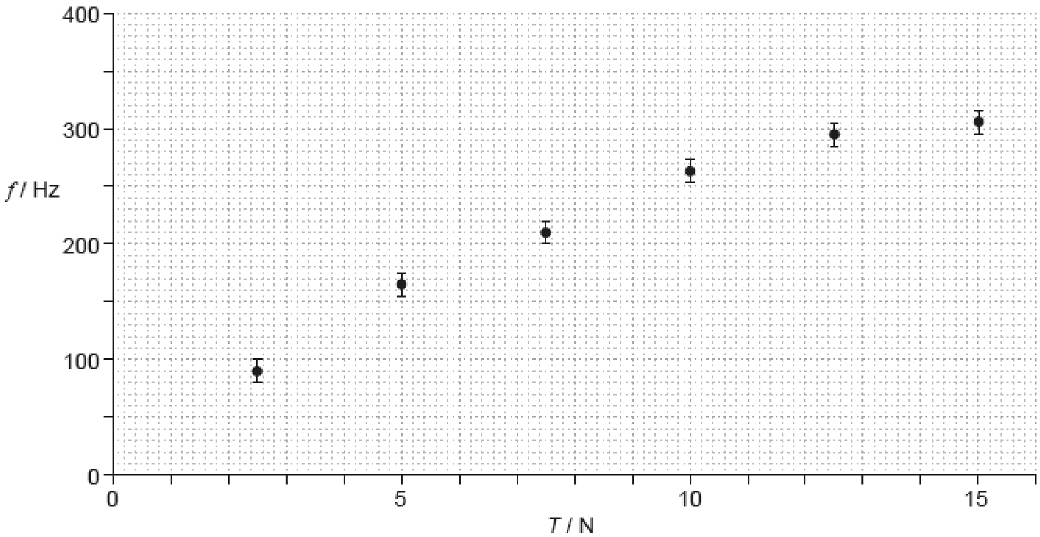
8a. The student has plotted error bars for the potential difference. Outline why no error bars are shown for the current. *[1 mark]*

8b. Determine, using the graph, the emf of the cell including the uncertainty for this value. Give your answer to the correct number of significant figures. *[3 marks]*

8c. Outline, **without** calculation, how the internal resistance can be determined from this graph. *[2 marks]*

An experiment is conducted to determine how the fundamental frequency *f* of a vibrating wire varies with the tension *T* in the wire.

The data are shown in the graph, the uncertainty in the tension is not shown.



9a. Draw the line of best fit for the data. *[1 mark]*

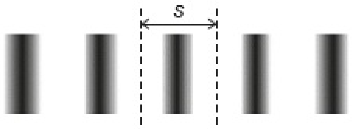
It is proposed that the frequency of oscillation is given by $f^2 = kT$ where *k* is a constant.

9b. Determine the fundamental SI unit for *k*. *[1 mark]*

9c. Write down a pair of quantities that, when plotted, enable the relationship $f^2 = kT$ to be verified. *[1 mark]*

9d. Describe the key features of the graph in (b)(ii) if it is to support this relationship. *[2 marks]*

A student uses a Young's double-slit apparatus to determine the wavelength of light emitted by a monochromatic source. A portion of the interference pattern is observed on a screen.



The distance *D* from the double slits to the screen is measured using a ruler with a smallest scale division of 1 mm.

The fringe separation s is measured with uncertainty ± 0.1 mm.

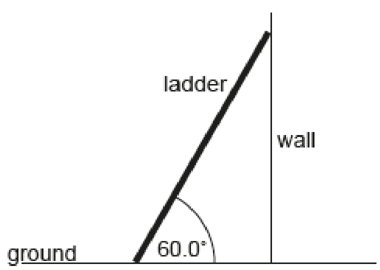
The slit separation d has negligible uncertainty.

The wavelength is calculated using the relationship $\lambda = \frac{sd}{D}$.

10a. When d = 0.200 mm, s = 0.9 mm and D = 280 mm, determine the percentage uncertainty in the wavelength. *[2 marks]*

10b. Explain how the student could use this apparatus to obtain a more reliable value for λ. *[2 marks]*

A uniform ladder of weight 50.0 N and length 4.00 m is placed against a frictionless wall making an angle of 60.0° with the ground.

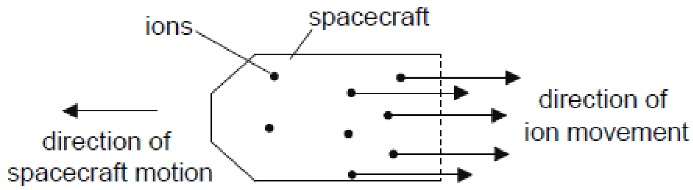


11a. Outline why the normal force acting on the ladder at the point of contact with the wall is equal to the frictional force *F* between the ladder and the ground. *[1 mark]*

11b. Calculate *F.* *[2 marks]*

11c. The coefficient of friction between the ladder and the ground is 0.400. Determine whether the ladder will slip. *[2 marks]*

Ion-thrust engines can power spacecraft. In this type of engine, ions are created in a chamber and expelled from the spacecraft. The spacecraft is in outer space when the propulsion system is turned on. The spacecraft starts from rest.



The mass of ions ejected each second is 6.6×10^{-6} kg and the speed of each ion is 5.2×10^{4} m s^{-1}. The initial total mass of the spacecraft and its fuel is 740 kg. Assume that the ions travel away from the spacecraft parallel to its direction of motion.

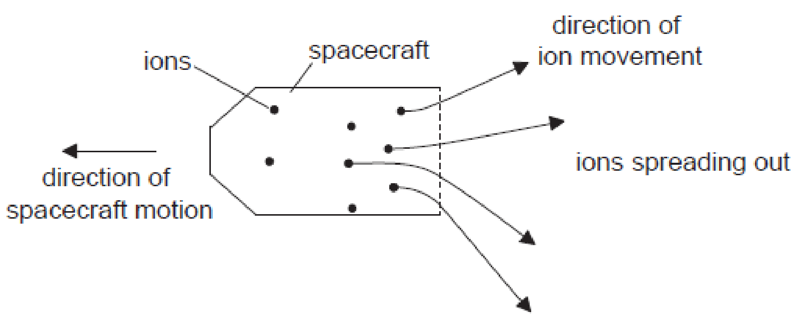
12a. Determine the initial acceleration of the spacecraft. *[2 marks]*

An initial mass of 60 kg of fuel is in the spacecraft for a journey to a planet. Half of the fuel will be required to slow down the spacecraft before arrival at the destination planet.

12b. Estimate the maximum speed of the spacecraft. *[2 marks]*

12c. Outline why scientists sometimes use estimates in making calculations. *[1 mark]*

In practice, the ions leave the spacecraft at a range of angles as shown.



12d. Outline why the ions are likely to spread out. *[2 marks]*

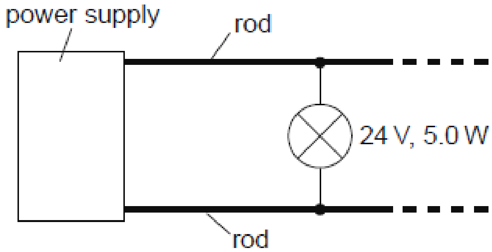
12e. Explain what effect, if any, this spreading of the ions has on the acceleration of the spacecraft. *[2 marks]*

On arrival at the planet, the spacecraft goes into orbit as it comes into the gravitational field of the planet.

12f. Outline what is meant by the gravitational field strength at a point. *[2 marks]*

12g. Newton's law of gravitation applies to point masses. Suggest why the law can be applied to a satellite orbiting a spherical planet of uniform density. *[1 mark]*

A lighting system consists of two long metal rods with a potential difference maintained between them. Identical lamps can be connected between the rods as required.



The following data are available for the lamps when at their working temperature.

Lamp specifications 24 V, 5.0 W

Power supply emf 24 V

Power supply maximum current 8.0 A

Length of each rod 12.5 m

Resistivity of rod metal 7.2×10^{-7} Ω m

13a. Each rod is to have a resistance no greater than 0.10 Ω. Calculate, in m, the minimum radius of each rod. Give your answer to an appropriate number of significant figures. *[3 marks]*

13b. Calculate the maximum number of lamps that can be connected between the rods. Neglect the resistance of the rods. *[2 marks]*

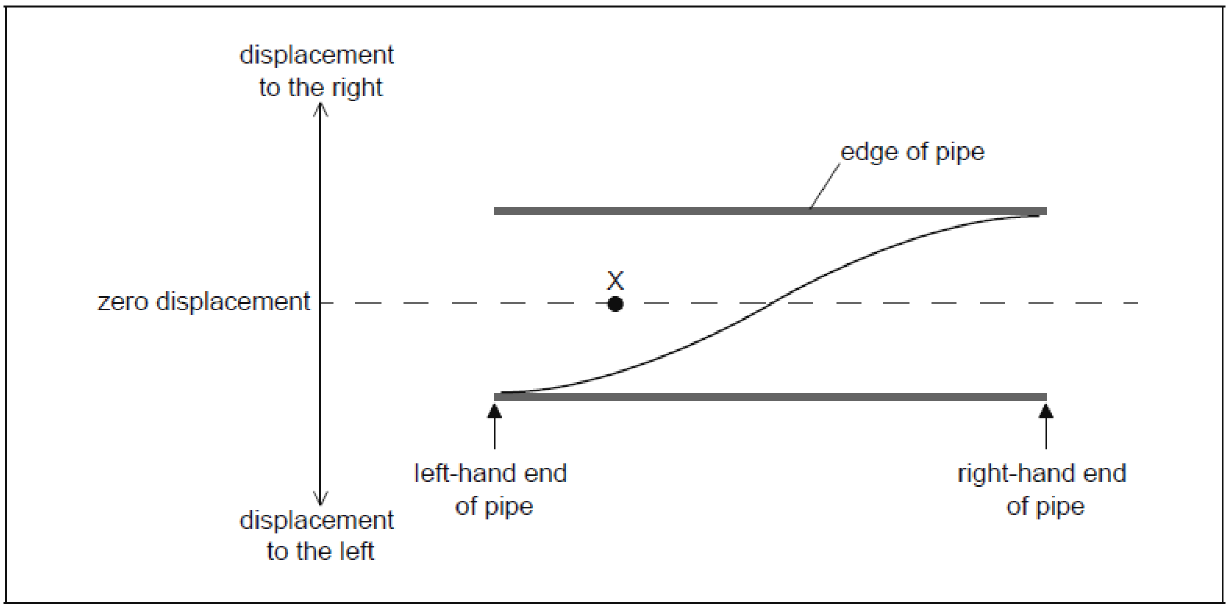
13c. One advantage of this system is that if one lamp fails then the other lamps in the circuit remain lit. Outline **one** other electrical advantage of this system compared to one in which the lamps are connected in series. *[1 mark]*

A chicken's egg of mass 58 g is dropped onto grass from a height of 1.1 m. The egg comes to rest in a time of 55 ms. Assume that air resistance is negligible and that the egg does not bounce or break.

14a. Determine the magnitude of the average decelerating force that the ground exerts on the egg. *[4 marks]*

14b. Explain why the egg is likely to break when dropped onto concrete from the same height. *[2 marks]*

A pipe is open at both ends. A first-harmonic standing wave is set up in the pipe. The diagram shows the variation of displacement of air molecules in the pipe with distance along the pipe at time $t = 0$. The frequency of the first harmonic is f.



15a. An air molecule is situated at point X in the pipe at $t = 0$. Describe the motion of this air molecule during one complete cycle of the standing wave beginning from $t = 0$. *[2 marks]*

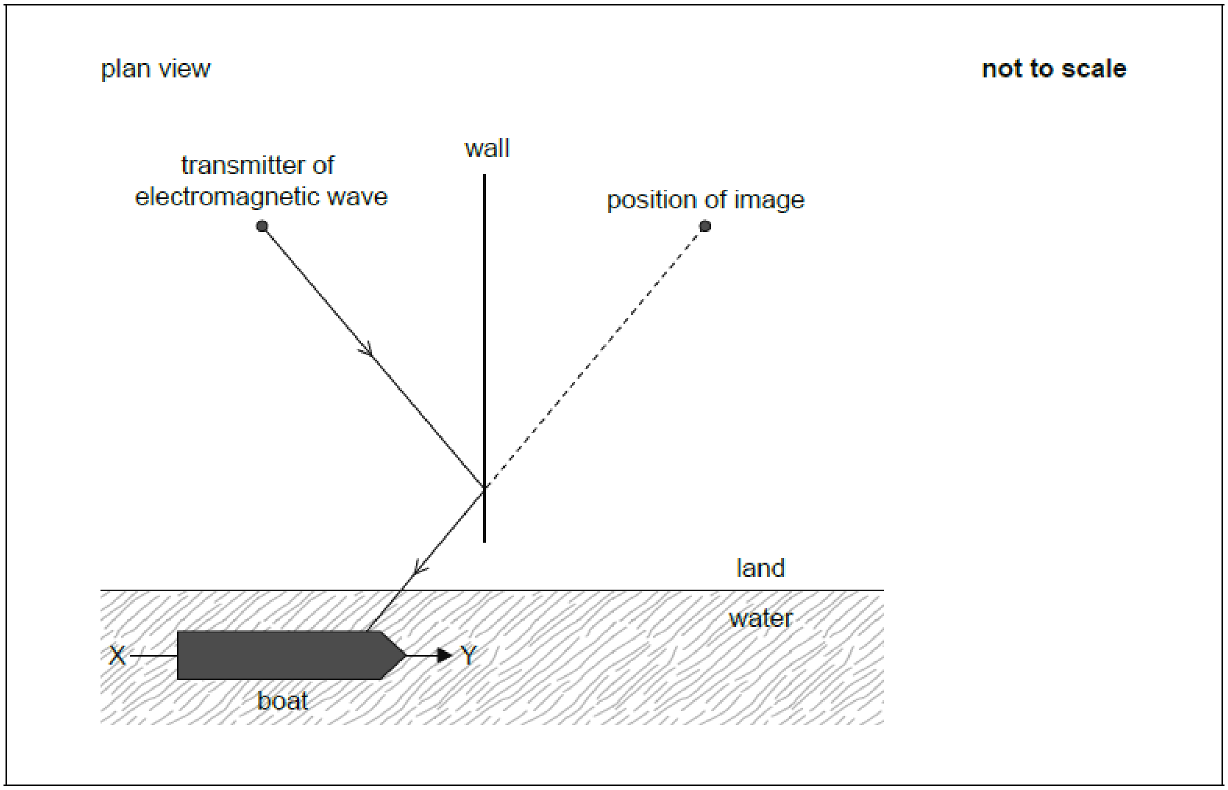
15b. The speed of sound c for longitudinal waves in air is given by *[3 marks]*

$$c = \sqrt{\frac{K}{\rho}}$$

where ρ is the density of the air and K is a constant.

A student measures f to be 120 Hz when the length of the pipe is 1.4 m. The density of the air in the pipe is 1.3 kg m^{-3}. Determine, in kg m^{-1} s^{-2}, the value of K for air.

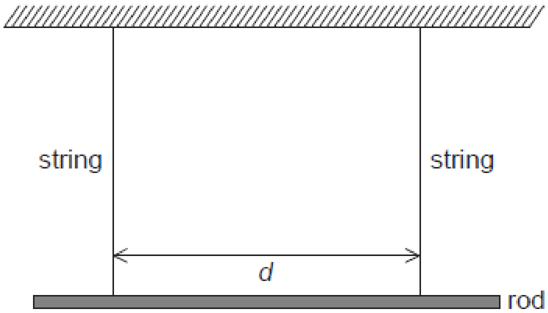
A transmitter of electromagnetic waves is next to a long straight vertical wall that acts as a plane mirror to the waves. An observer on a boat detects the waves both directly and as an image from the other side of the wall. The diagram shows one ray from the transmitter reflected at the wall and the position of the image.



15c. Demonstrate, using a second ray, that the image appears to come from the position indicated. *[1 mark]*

15d. Outline why the observer detects a series of increases and decreases in the intensity of the received signal as the boat moves along the line XY. *[2 marks]*

In an investigation to measure the acceleration of free fall a rod is suspended horizontally by two vertical strings of equal length. The strings are a distance *d* apart.



When the rod is displaced by a small angle and then released, simple harmonic oscillations take place in a horizontal plane.

The theoretical prediction for the period of oscillation *T* is given by the following equation

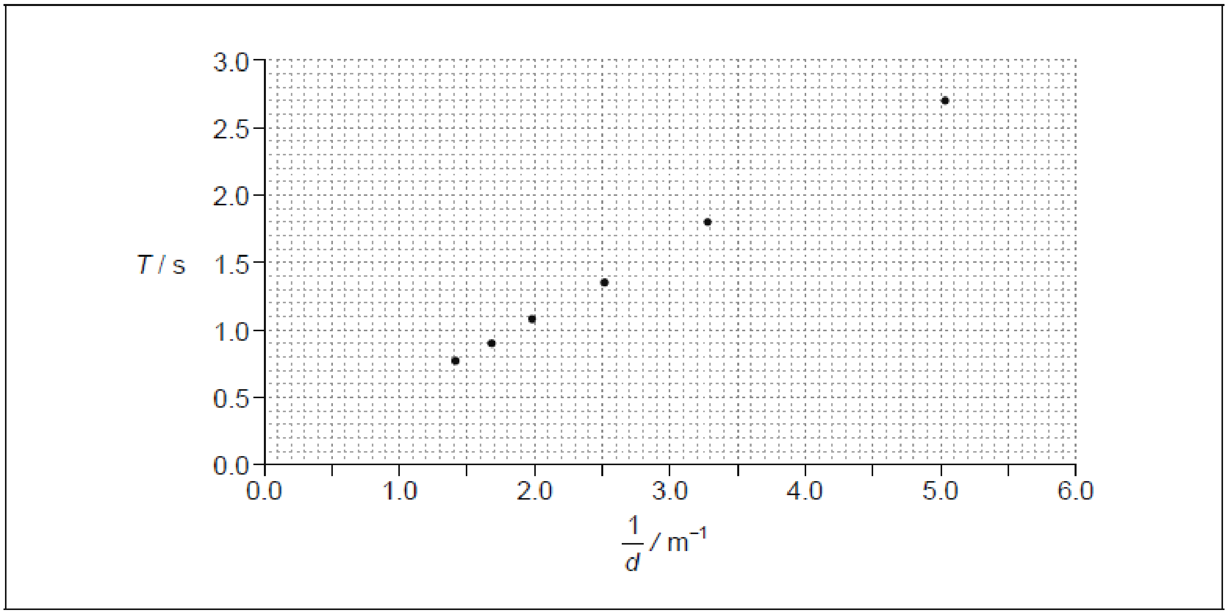
$$T = \frac{c}{d\sqrt{g}}$$

where *c* is a known numerical constant.

16a. State the unit of *c*. *[1 mark]*

16b. A student records the time for 20 oscillations of the rod. Explain how this procedure leads to a more precise measurement of the time for **one** oscillation *T*. *[2 marks]*

In one experiment *d* was varied. The graph shows the plotted values of *T* against $\frac{1}{d}$. Error bars are negligibly small.



16c. Draw the line of best fit for these data. *[1 mark]*

16d. Suggest whether the data are consistent with the theoretical prediction. *[2 marks]*

16e. The numerical value of the constant *c* in SI units is 1.67. Determine *g*, using the graph. *[4 marks]*

In an experiment to measure the specific latent heat of vaporization of water L_v, a student uses an electric heater to boil water. A mass *m* of water vaporizes during time *t*. L_v may be calculated using the relation

$$L_v = \frac{VIt}{m}$$

where *V* is the voltage applied to the heater and *I* the current through it.

17a. Outline why, during the experiment, *V* and *I* should be kept constant. *[1 mark]*

17b. Outline whether the value of L_v calculated in this experiment is expected to be larger or smaller than the actual value. *[2 marks]*

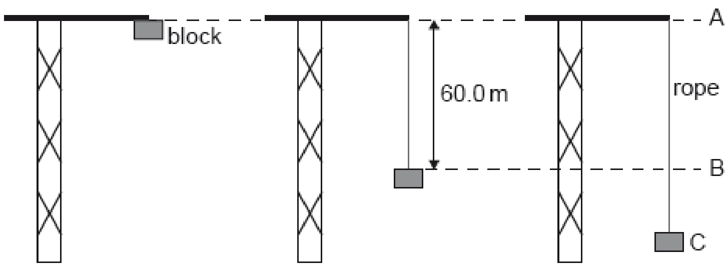
17c. A student suggests that to get a more accurate value of L_v the experiment should be performed twice using different heating rates. *[2 marks]*

With voltage and current V_1, I_1 the mass of water that vaporized in time t is m_1.
With voltage and current V_2, I_2 the mass of water that vaporized in time t is m_2.
The student now uses the expression

$$L_v = \frac{(V_1 I_1 - V_2 I_2)\, t}{m_1 - m_2}$$

to calculate L_v. Suggest, by reference to heat losses, why this is an improvement.

An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.



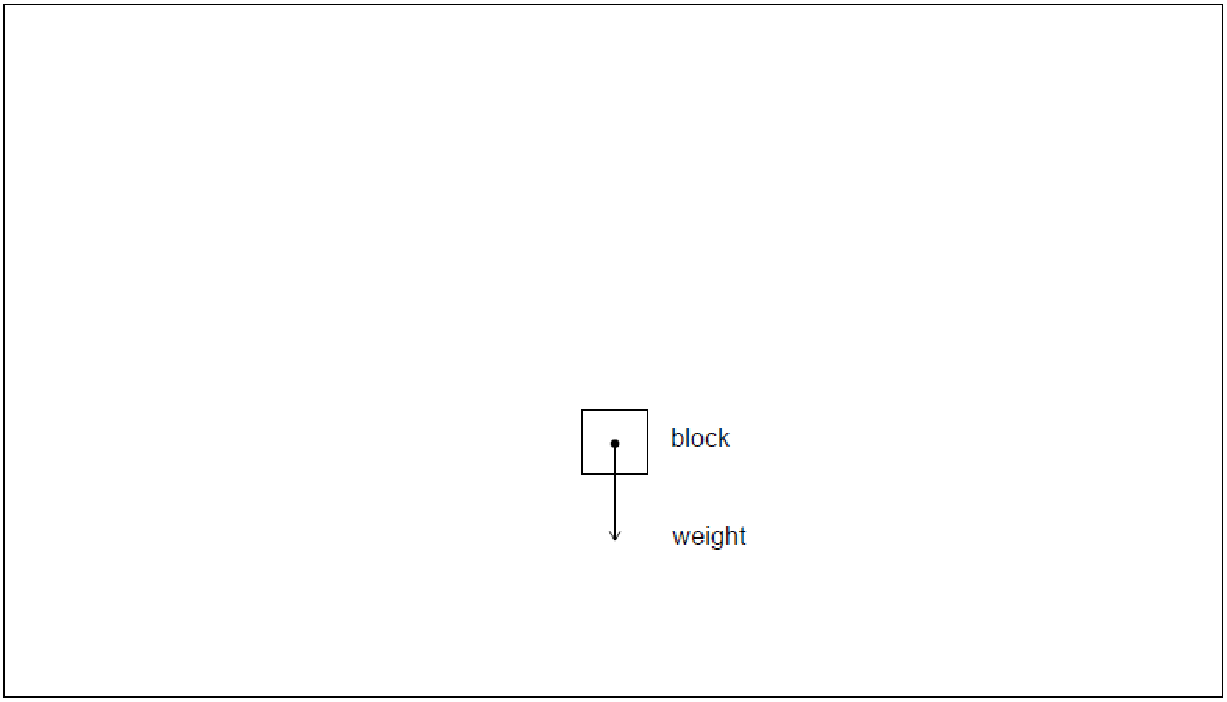
The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

18a. At position B the rope starts to extend. Calculate the speed of the block at position B. *[2 marks]*

At position C the speed of the block reaches zero. The time taken for the block to fall between B and C is 0.759 s. The mass of the block is 80.0 kg.

18b. Determine the magnitude of the average resultant force acting on the block between B and C. *[2 marks]*

18c. Sketch on the diagram the average resultant force acting on the block between B and C. The arrow on the diagram represents the weight of the block. *[2 marks]*



18d. Calculate the magnitude of the average force exerted by the rope on the block between B and C. *[2 marks]*

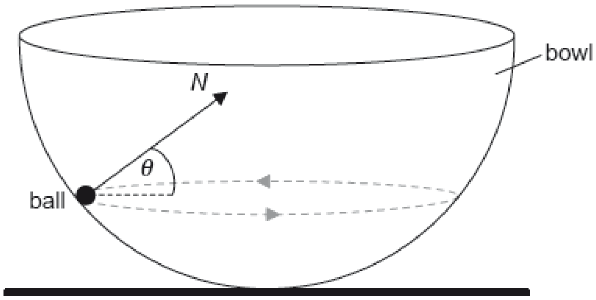
For the rope and block, describe the energy changes that take place

18e. between A and B. *[1 mark]*

18f. between B and C. *[1 mark]*

18g. The length reached by the rope at C is 77.4 m. Suggest how energy considerations could be used to determine the elastic constant of the rope. *[2 marks]*

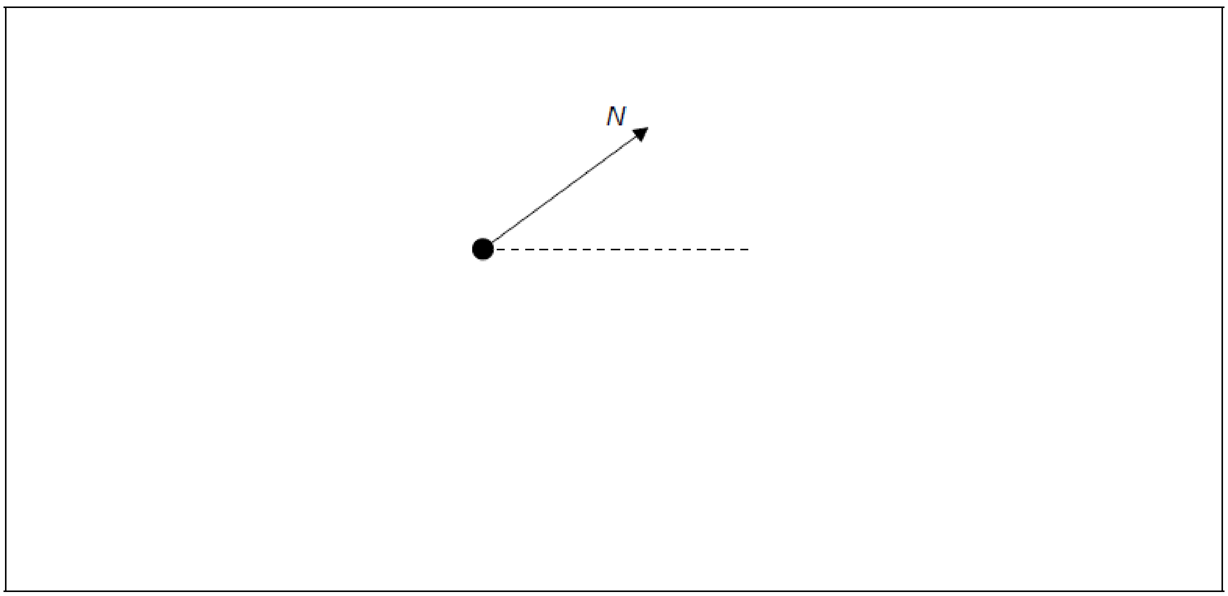
A small ball of mass *m* is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.



The normal reaction force *N* makes an angle θ to the horizontal.

19a. State the direction of the resultant force on the ball. *[1 mark]*

19b. On the diagram, construct an arrow of the correct length to represent the weight of the ball. *[2 marks]*



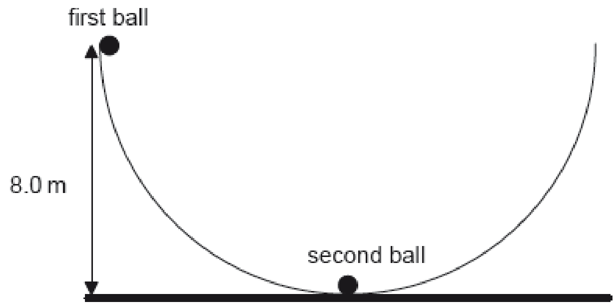
19c. Show that the magnitude of the net force *F* on the ball is given by the following equation. *[3 marks]*

$$F = \frac{mg}{\tan\theta}$$

19d. The radius of the bowl is 8.0 m and $\theta = 22°$. Determine the speed of the ball. *[4 marks]*

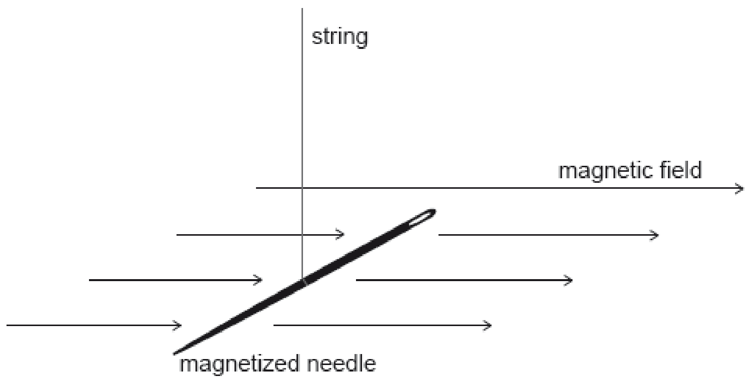
19e. Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. *[2 marks]*

19f. A second identical ball is placed at the bottom of the bowl and the first ball is displaced so that its height from the horizontal is equal to 8.0 m. *[3 marks]*

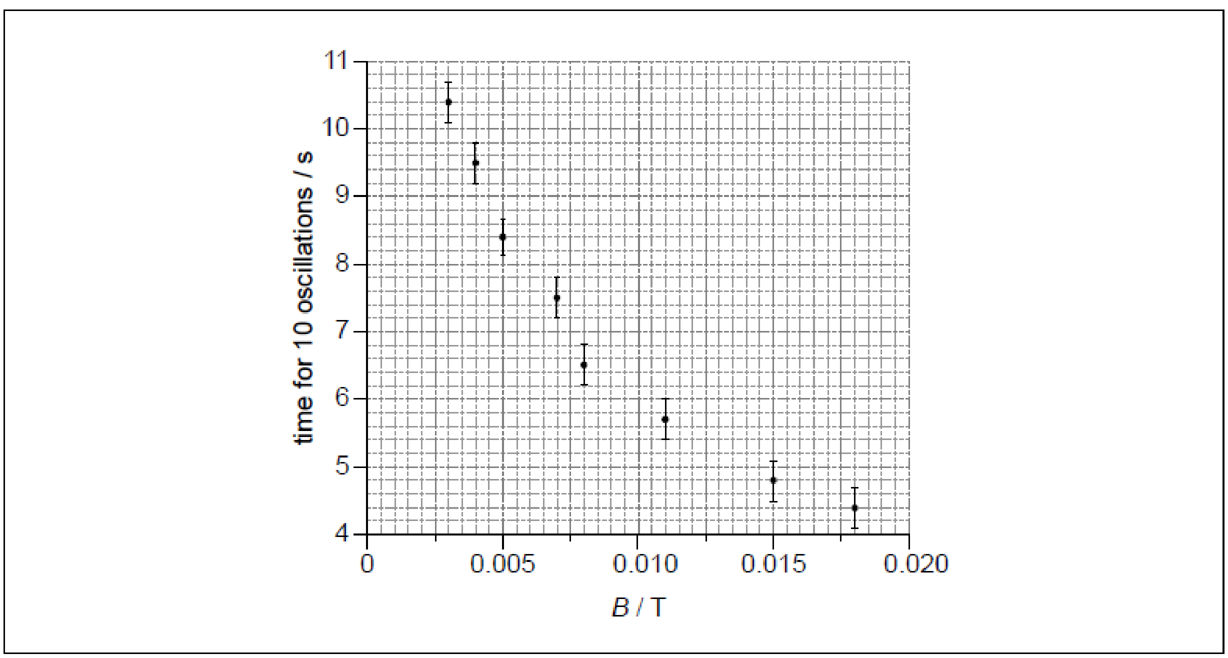


The first ball is released and eventually strikes the second ball. The two balls remain in contact. Determine, in m, the maximum height reached by the two balls.

A magnetized needle is oscillating on a string about a vertical axis in a horizontal magneticfield *B*. The time for 10 oscillations is recorded for different values of *B*.



The graph shows the variation with *B* of the time for 10 oscillations together with the uncertainties in the time measurements. The uncertainty in *B* is negligible.



20a. Draw on the graph the line of best fit for the data. *[1 mark]*

20b. Write down the time taken for one oscillation when B = 0.005 T with its absolute uncertainty. *[1 mark]*

20c. A student forms a hypothesis that the period of one oscillation P is given by: *[3 marks]*

$$P = \frac{K}{\sqrt{B}}$$

where K is a constant.

Determine the value of K using the point for which B = 0.005 T.

State the uncertainty in K to an appropriate number of significant figures.

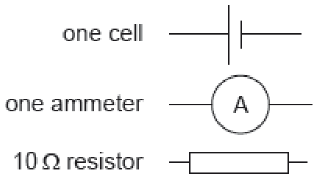
20d. State the unit of K. *[1 mark]*

20e. The student plots a graph to show how P^2 varies with $\frac{1}{B}$ for the data. *[2 marks]*

Sketch the shape of the expected line of best fit on the axes below assuming that the relationship $P = \frac{K}{\sqrt{B}}$ is verified. You do **not** have to put numbers on the axes.

20f. State how the value of K can be obtained from the graph. *[1 mark]*

An experiment to find the internal resistance of a cell of known emf is to be set. The following equipment is available:



21a. Draw a suitable circuit diagram that would enable the internal resistance to be determined. *[1 mark]*

21b. It is noticed that the resistor gets warmer. Explain how this would affect the calculated value of the internal resistance. *[3 marks]*

21c. Outline how using a variable resistance could improve the accuracy of the value found for the internal resistance. *[2 marks]*