

OCR A-LEVEL PHYSICS A • H556

PHYSICS



EXAM QUESTION PACK

3.3 WORK, ENERGY AND POWER

SCORE

/197

PERCENTAGE

%

STEMUP

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1(a) On Fig. 21.3 sketch a graph showing the variation of kinetic energy with time. Add a scale to the kinetic energy axis.

[2]

(b) A stabilising mechanism for electrical equipment on board a high-speed train is modelled using a 5.0 g mass and two springs, as shown in Fig. 21.1. For testing purposes, the springs are horizontal and attached to two fixed supports in a laboratory.

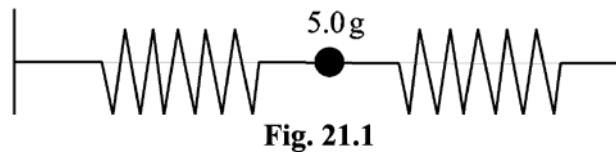
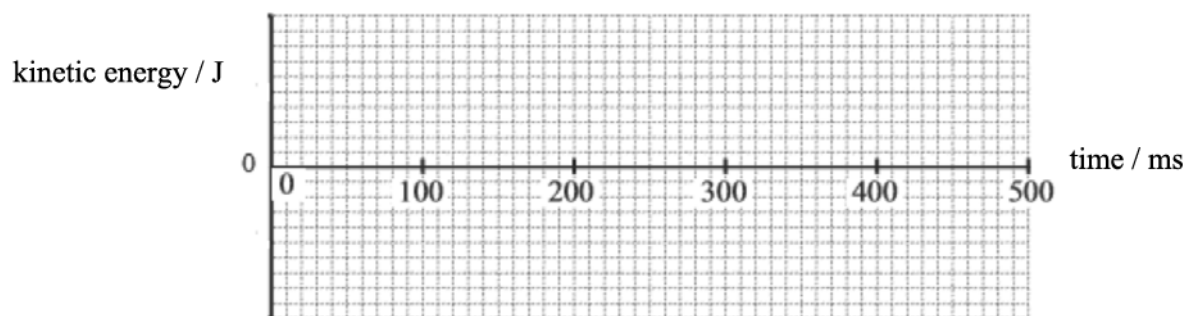
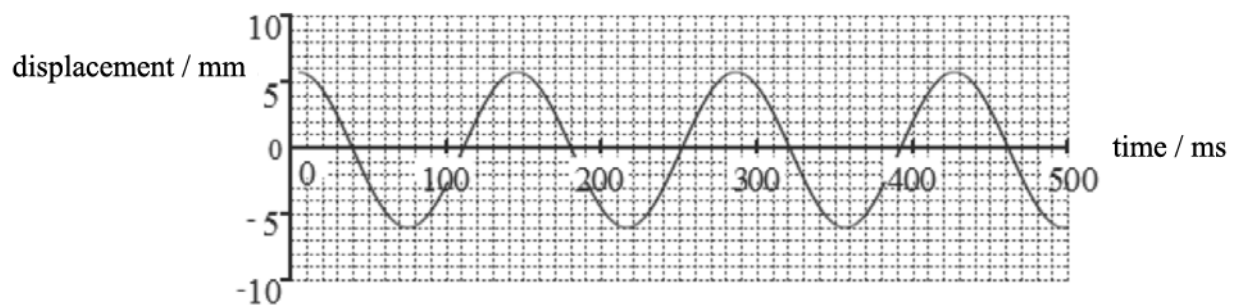


Fig. 21.2 shows the graph of displacement against time for the oscillating mass.



(i) Determine the maximum acceleration of the mass during the oscillations.

maximum acceleration = _____ ms^{-2} [2]

(ii) Calculate the maximum kinetic energy of the mass during the oscillations.

maximum kinetic energy = _____ J [2]

- 2 A 6.0 N force is applied to a spring which extends vertically downwards by a distance 5.0 cm. The force is suddenly removed so that the spring flies vertically upwards. The spring has mass 9.0 g.

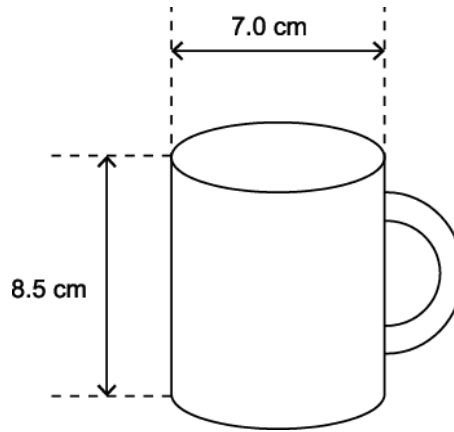
What is the maximum height reached by the spring?

- A 0.085 m
- B 0.17 m
- C 1.7 m
- D 3.4 m

Your answer

[1]

3(a) A cylindrical cup of internal diameter 7.0 cm and height 8.5 cm is filled to the top with water.



The density of water is 1000 kg m^{-3} . The mass of one mole of water is 18 g. The specific heat capacity of water is $4200 \text{ J kg}^{-1} \text{ K}^{-1}$.

Show that the minimum time taken for a 0.50 kW camping kettle to bring a cup of water at 20°C to boiling point is about 200 s.

[3]

(b) In a laboratory test, the camping kettle was found to bring a cup of water to the boil in 320 seconds.

Explain why your previous answer is an underestimate and suggest **two** ways that you can refine the test to ensure that the time to boil is closer to 200 s.

[3]

4(a) Define the *work done* by a force.

[1]

- (b) Fig. 19 shows a crane lifting a car of mass 850 kg at constant velocity through a height of 12 m in a time of 40 s. The crane has a working efficiency of 60 %.

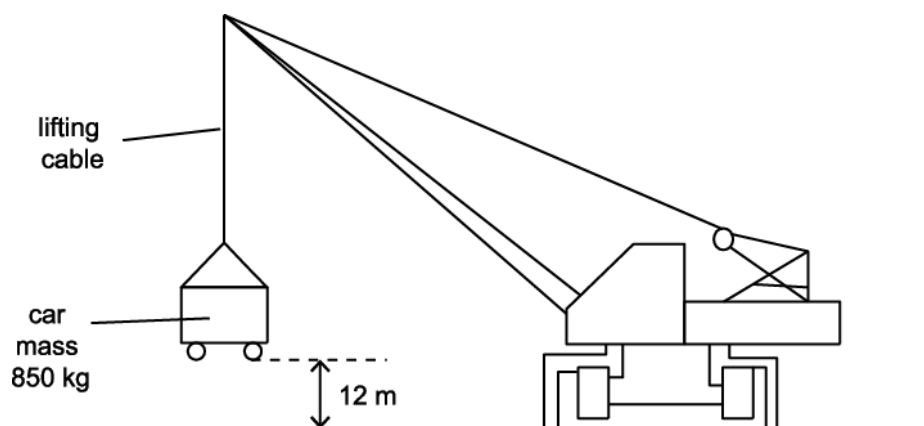


Fig. 19

- (i) Calculate the tension in the lifting cable.

tension = ... N [1]

- (ii) Calculate the total input power required by the crane to lift the car.

total input power = ... W [4]

- (iii) Suggest and explain **two** ways the crane can be modified to improve its efficiency.

----- [2]

5 A cyclist moves along a horizontal road. She pushes on the pedals with a constant power of 250 W. The mass of the cyclist and bicycle is 85 kg. The total drag force is $0.4v^2$, where v is the speed of the cyclist.

(i) Calculate the energy provided by the cyclist each minute when the overall efficiency of the cyclist's muscles is 65%.

energy = _____ J [2]

(ii) Calculate the drag force and hence the instantaneous acceleration of the cyclist when the speed is 6.0 ms^{-1} .

acceleration = _____ ms^{-2} [3]

6 A sodium lamp is rated at 40 W. About 12% of the power is emitted as yellow light of wavelength $5.9 \times 10^{-7} \text{ m}$.

How many photons of yellow light are emitted per second from this lamp?

- A $1.4 \times 10^{19} \text{ s}^{-1}$
- B $1.2 \times 10^{20} \text{ s}^{-1}$
- C $3.6 \times 10^{27} \text{ s}^{-1}$
- D $1.0 \times 10^{40} \text{ s}^{-1}$

Your answer

[1]

- 7 A metal plate is placed in an evacuated chamber. Electromagnetic radiation of wavelength 380 nm is incident on the plate. The work function of the metal is 1.1 eV.

(i) Calculate the maximum speed of the photoelectrons emitted from the plate.

speed = _____ m s⁻¹ [3]

(ii) State the change, if any, to the maximum speed of the emitted photoelectrons when the intensity of the incident electromagnetic radiation on the metal plate is doubled.

----- [1]

8 Fig. 21.2 shows two parallel vertical metal plates connected to a battery.

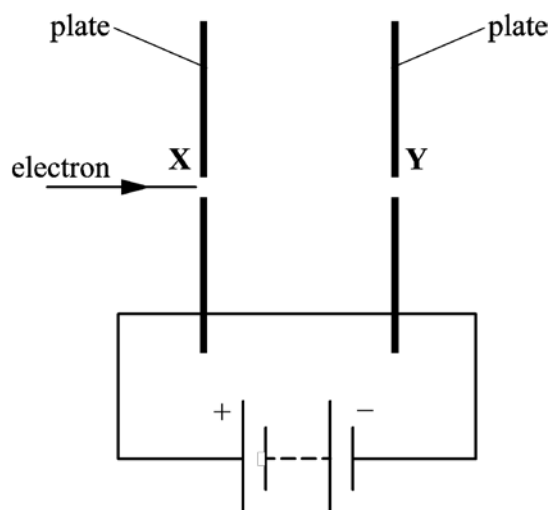


Fig. 21.2

The plates are placed in a vacuum and have a separation of 1.2 cm. The uniform electric field strength between the plates is 1500 V m^{-1} . An electron travels through holes X and Y in the plates. The electron has a horizontal velocity of $5.0 \times 10^6 \text{ m s}^{-1}$ when it enters hole X.

- (i) Draw five lines on Fig. 21.2 to represent the electric field between the parallel plates.

[2]

- (ii) Calculate the final speed of the electron as it leaves hole Y.

speed = _____ m s^{-1} [3]

9 Fig. 22.1 shows the circular track of a positron moving in a uniform magnetic field.

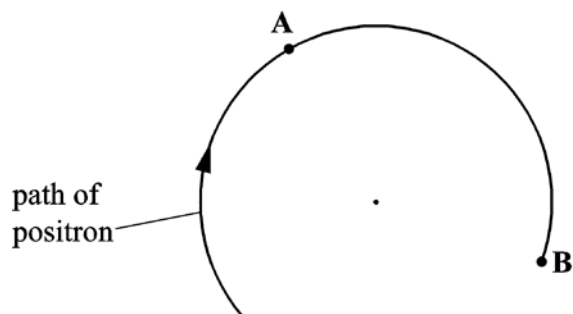


Fig. 22.1

The magnetic field is perpendicular to the plane of Fig. 22.1.

The speed of the positron is $5.0 \times 10^7 \text{ m s}^{-1}$ and the radius of the track is 0.018 m.

State the direction of the force acting on the positron when at point A and explain why this force does not change the speed of the positron.

----- [2]

10(a) The kilogram, metre and second are SI base units.

Determine the unit for *power* in terms of these SI units.

unit for power = _____ [1]

- (b) When riding at a steady speed on the flat, a cyclist provides a constant power of 200 W to the rear wheel of his bicycle. The total mass of bicycle and rider is 120 kg.

The total resistive forces R acting against the motion of the bicycle and the rider vary with the velocity v of the bicycle as shown in Fig. 1.

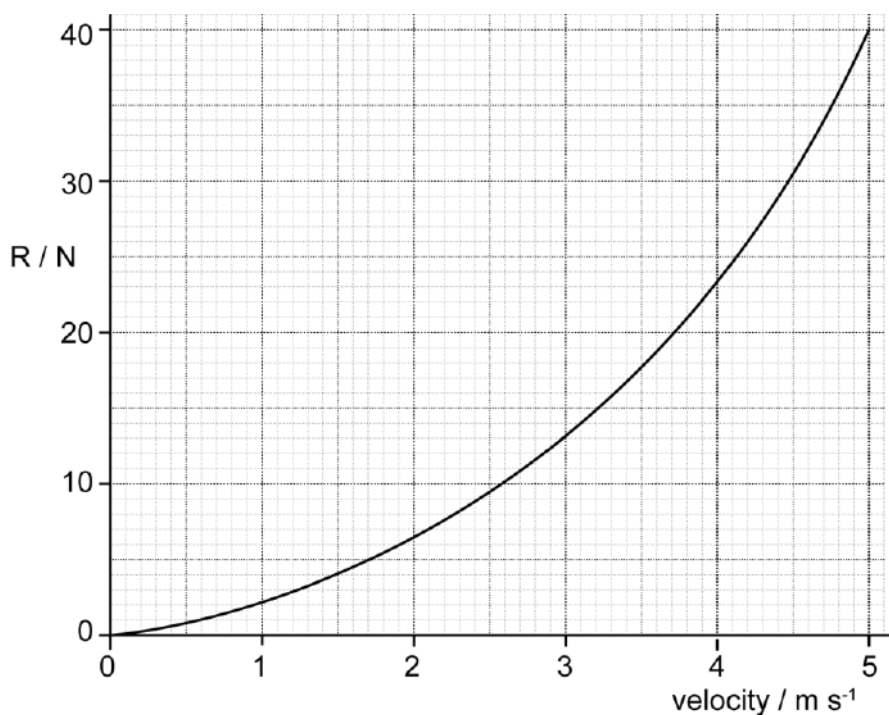


Fig.1

- (i) The cyclist starts from rest. He pedals steadily along a horizontal road. This exerts a constant forward force of 40 N on the bicycle.

Use Fig. 1 to state and explain how the acceleration and velocity of the bicycle vary as the cyclist travels along the road.

----- [3]

(ii) Calculate

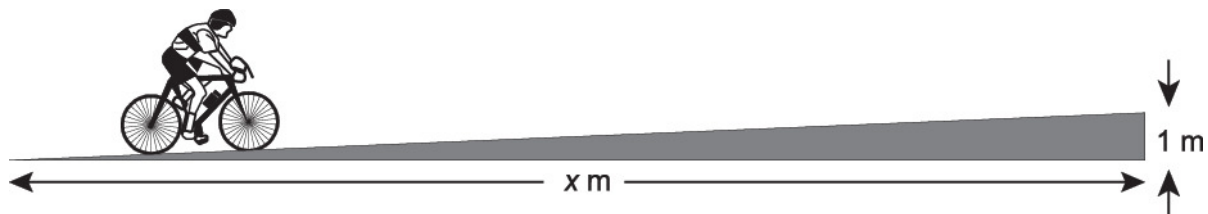
1 the initial acceleration of the bicycle

acceleration = _____ m s^{-2} [1]

2 the maximum speed of the cyclist.

maximum speed = _____ m s^{-1} [2]

(c) The cyclist reaches a hill.



The cyclist has to double the power provided to the rear wheel to maintain the same maximum speed reached on the flat road.

Assume that the total resistive force is unchanged.

The gradient of the hill is 1 in x .

Calculate x .

$x = \text{-----} \text{ m [3]}$

- 11 Fig. 6.1 shows a tube containing small pellets of lead. When the tube is inverted the pellets of lead fall freely through a vertical height equal to the length of the tube. The pellets are warm after the tube has been inverted many times.

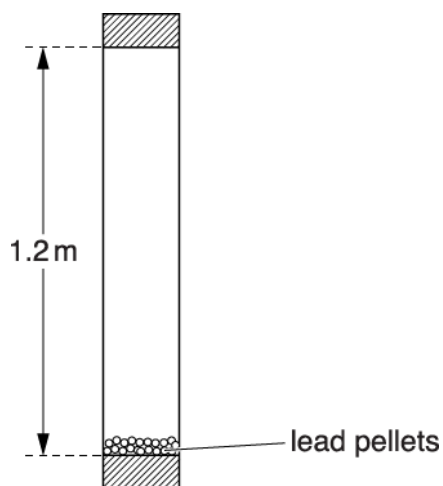


Fig. 6.1

Describe the energy changes that take place to the lead pellets following one inversion of the tube.

----- [2]

- 12 A ball is thrown vertically upwards with a speed of 5.0 m s^{-1} .
Ignore air resistance.

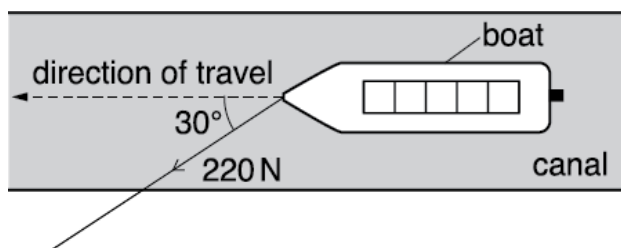
What is the maximum height reached by the ball?

- A 0.3 m
- B 0.8 m
- C 1.3 m
- D 2.5 m

Your answer

[1]

- 13 A canal boat is pulled by a single rope.
The tension in the rope is 220 N. The rope makes an angle of 30° to the direction of travel.
The speed of the boat is 1.8 m s^{-1} .



What is the work done per second by the 220 N force in the direction of travel?

- A 61 J s^{-1}
- B 200 J s^{-1}
- C 340 J s^{-1}
- D 400 J s^{-1}

Your answer

[1]

14(a) The ball-release mechanism of a pinball machine is shown in Fig. 17.1.

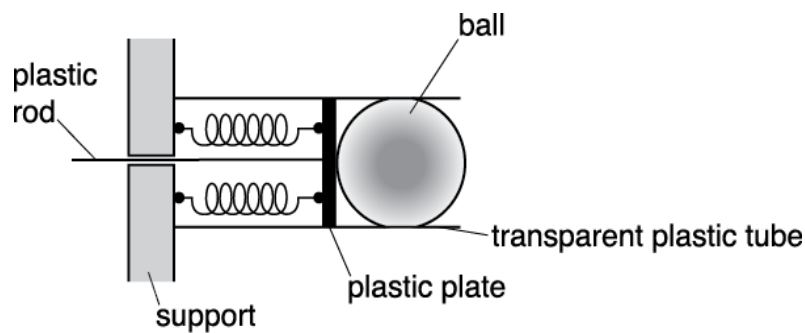


Fig. 17.1

A pair of identical compressible springs are fixed between a plastic plate and a support. The springs are in parallel. A plastic rod attached to the plate is pulled to the left to compress the springs. A ball, initially at rest, is fired when the plate is released.

A group of students are conducting an experiment to investigate the ball-release mechanism shown in Fig. 17.1. The students apply a force F and measure the compression x of the springs. The table below shows the results.

F / N	x / cm
1.1 ± 0.2	2.0
2.0 ± 0.2	4.0
2.9 ± 0.2	6.0
4.0 ± 0.2	8.0
5.1 ± 0.2	10.0

Fig. 17.2 shows four data points from the table plotted on a F against x graph.

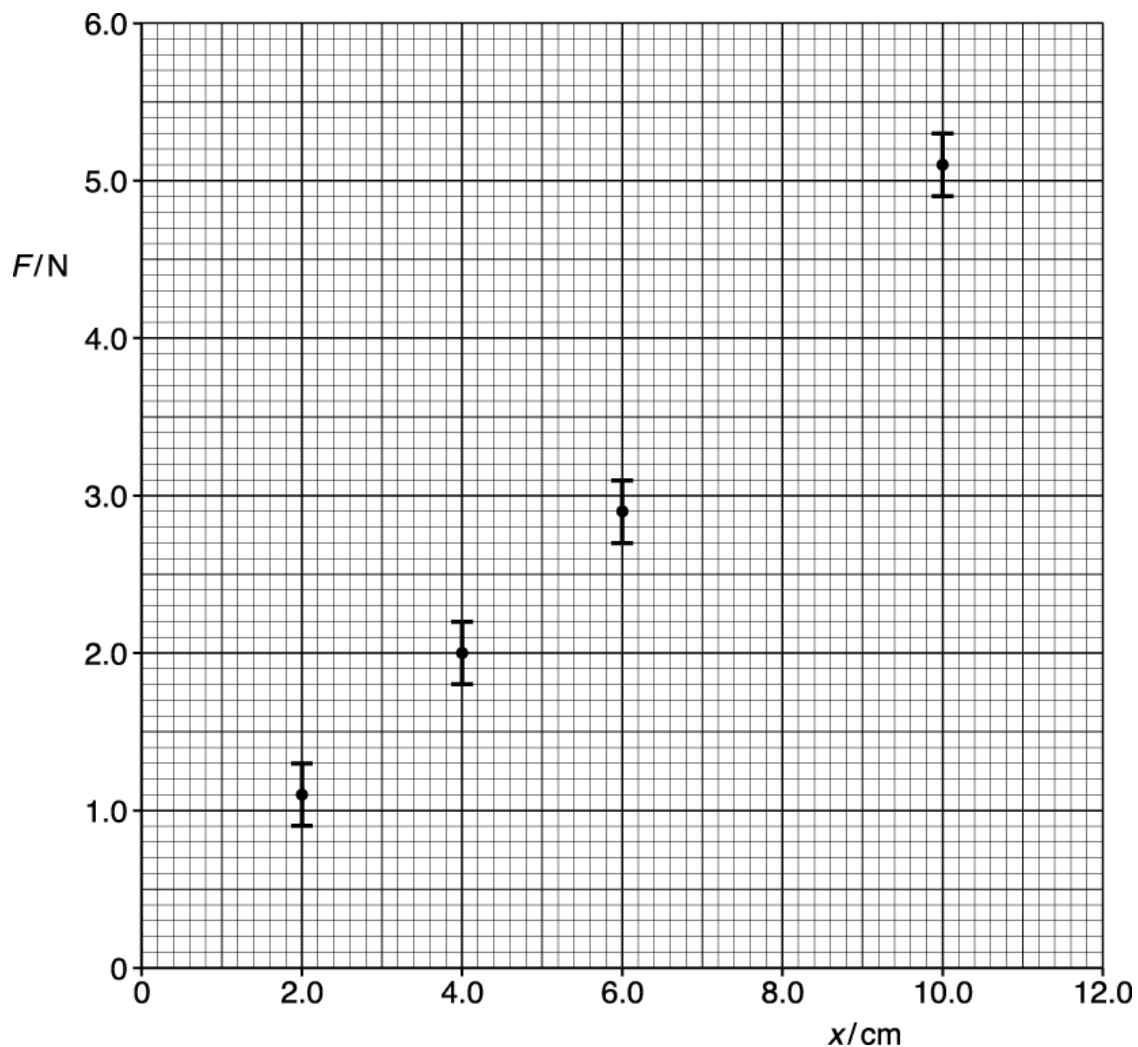


Fig. 17.2

- (i) Plot the missing data point and the error bar on Fig. 17.2.

[1]

- (ii) Describe how the data shown in the table may have been obtained in the laboratory.

[2]

- (iii) Draw the best fit and the worst fit straight lines on Fig. 17.2.

Use the graph to determine the force constant k for a **single** spring and the absolute uncertainty in this value.

$$k = \text{-----} \pm \text{-----} \text{ N m}^{-1} \text{ [4]}$$

(iv) State the feature of the graph that shows Hooke's law is obeyed by the springs.

----- [1]

(v) The mass of the ball is 0.39 kg.

Use your answer from (iii) to calculate the launch speed v of the ball when the plastic plate shown in Fig. 17.1 is pulled back 12.0 cm.

$$v = \text{-----} \text{ m s}^{-1} \text{ [3]}$$

(b) A new arrangement for the ball-release mechanism using three identical springs is shown in Fig. 17.3.

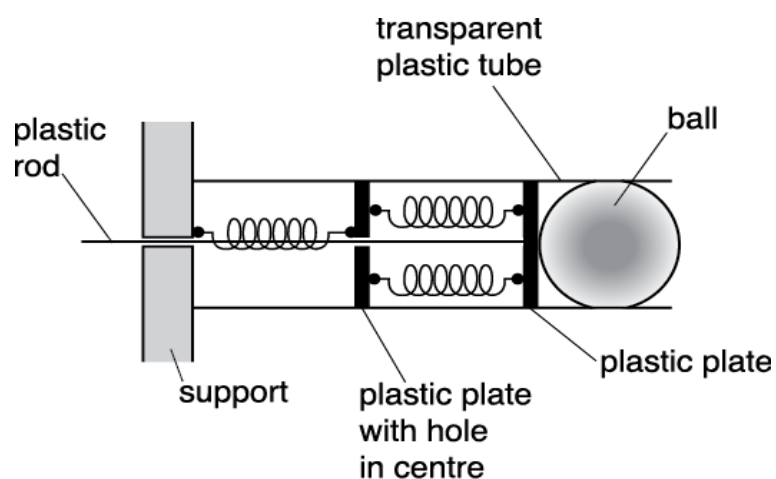


Fig. 17.3

The force constant of each spring is k .

The same ball of mass 0.39 kg is used. The plastic rod is pulled to the left by a distance of x .

Show that initial acceleration a of this ball is given by the equation

$$a = 1.7\, kx.$$

[2]

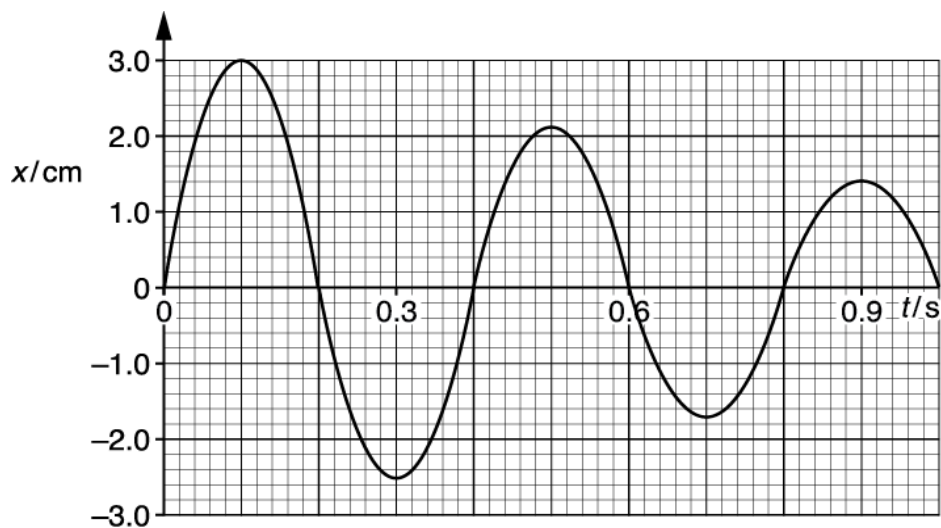


Fig. 21.2

- (i) According to a student, the amplitude of the oscillator decays by the same fraction every half oscillation. Analyse Fig. 21.2 to assess whether or not the student is correct.

----- [2]

- (ii) State and explain at which time the oscillator dissipates **maximum** energy.

----- [2]

16 This question is about helium in the atmosphere of the Earth.

Experiment shows that most of the Earth's atmosphere is contained within a very thin shell around the surface of the Earth. Less than 0.0001% of this is helium.

The height of the atmosphere is negligible compared with the radius R of the Earth.

- (i) Show that the minimum speed v_E required for an atom or molecule to escape from the top of the Earth's atmosphere is given by the expression

$$v_E = \sqrt{2gR}.$$

[3]

- (ii) The radius R of the Earth is 6.4×10^6 m. Calculate this escape speed v_E .

$v_E =$ _____ m s⁻¹ [1]

- (iii) Calculate the temperature T in kelvin required at the top of the Earth's atmosphere for the root mean square speed $c_{r.m.s.}$ of the helium atoms there to equal this escape speed.

Molar mass of helium = $0.004 \text{ kg mol}^{-1}$

$T = \dots\dots\dots$ K [3]

(iv) Fig. 1 shows the distribution of the speeds of the atoms of an ideal gas.

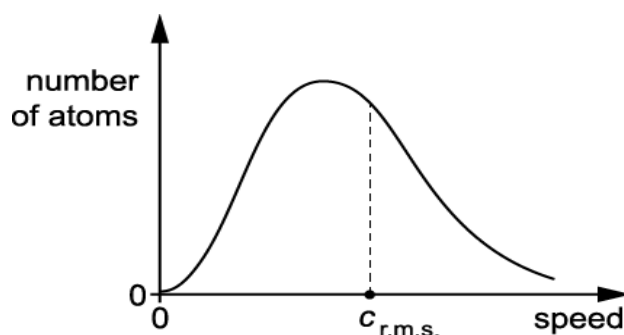


Fig. 1

Use your knowledge of the kinetic theory of gases to describe the shape of this distribution and explain why some helium is able escape from the Earth.

[4]

(v) Over a very long period of time all of the helium should have escaped from the Earth. Suggest why there is still a small amount of helium, about 0.0001%, in the Earth's atmosphere.

[2]

17(a)

Electromagnetic radiation is incident on a negatively charged zinc plate. Electrons are emitted from the surface of the plate when a weak intensity ultraviolet source is used. Electrons are not emitted at all when an intense visible light from a lamp is used.

Explain these observations.

[4]

- (b) The **maximum** wavelength of the electromagnetic radiation incident on the surface of a metal which causes electrons to be emitted is 2.9×10^{-7} m.

Calculate the maximum kinetic energy of electrons emitted from the surface of the metal when each incident photon has energy of 5.1 eV.

maximum kinetic energy = ... J [3]

- (c) Electromagnetic radiation of constant wavelength is incident on a metal plate. Photoelectrons are emitted from the metal plate. Fig. 19.1 shows an arrangement used to determine the maximum kinetic energy of electrons emitted from a metal plate.

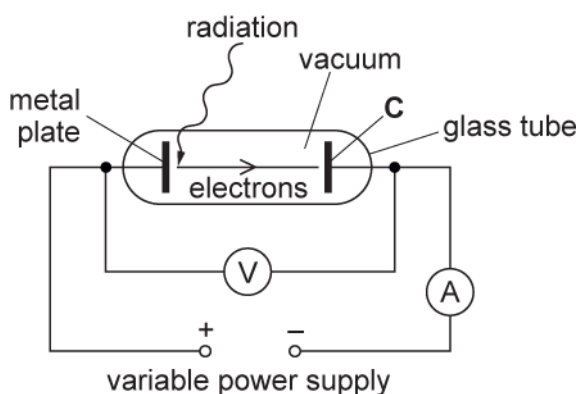


Fig. 19.1

The metal plate and the electrode C are both in a vacuum. The electrode C is connected to the negative terminal of the variable power supply.

Fig. 19.2 shows the variation of current I in the circuit as the potential difference V between the metal plate and C is increased from 0 V to 3.0 V.

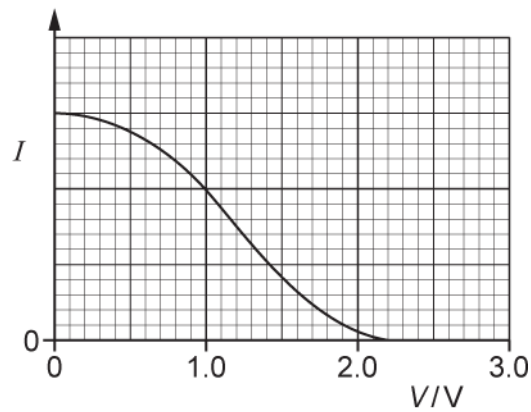


Fig. 19.2

Explain why the current decreases as V increases and describe how you can determine the maximum kinetic energy of the emitted electrons.

[3]

- 18 A plastic kettle is filled with 0.60 kg of water at a temperature of 20°C.
A 2.2 kW electric heater is used to heat the water for a time of 4.0 minutes.

Calculate the total energy supplied by the heater during the time of 4.0 minutes.

energy = ... J [2]

19(a) Fig. 16 shows a hydraulic jack used to lift a car which has a mass of 1200 kg. A mechanic exerts a downwards force of 400 N on the handle of the jack, moving it 80.0 cm downwards. As he moves the handle, the car rises 2.0 cm.

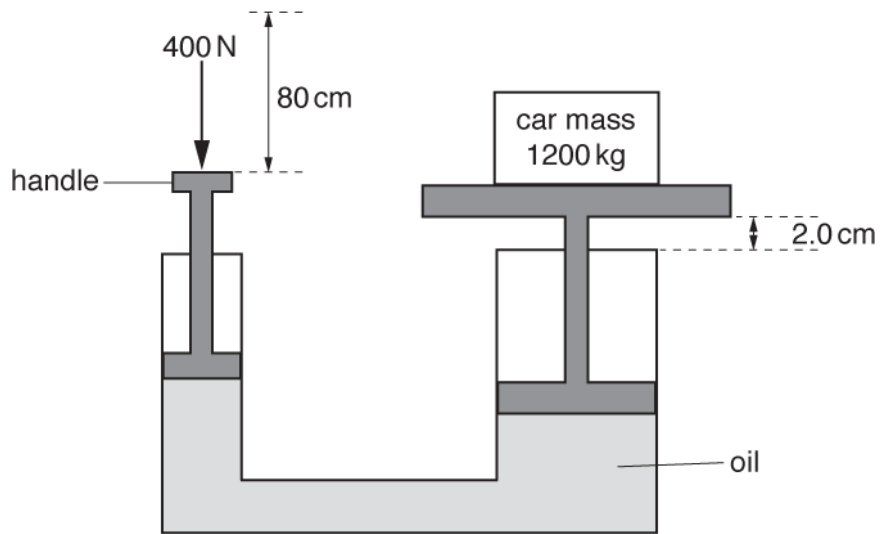


Fig. 16

Calculate the work done by the 400 N force exerted by the mechanic.

work done = ... J [2]

(b) Calculate the ratio

$$\frac{\text{speed of handle moving down}}{\text{speed of car moving up}}.$$

ratio = _____ [2]

(c) Calculate the useful work done on the car and hence the percentage efficiency of the jack.

efficiency = _____ % [2]

20(a)

A tennis ball is struck with a racket.

The initial velocity v of the ball leaving the racket is 30.0 m s^{-1} and it makes an angle of 70° to the horizontal as shown in Fig. 16.

Air resistance is negligible

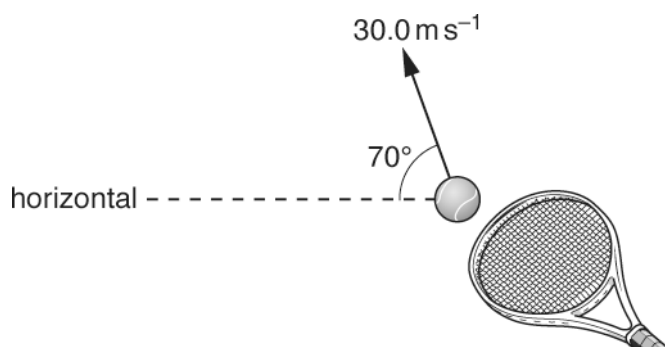


Fig. 16

(i) Calculate the vertical component of the initial velocity of the ball.

vertical component = ----- m s^{-1} [1]

(ii) Use your answer in (i) to show that the ball reaches a maximum height h of about 40 m.

$h =$ ----- m [2]

(iii) Explain why the kinetic energy of the ball is not zero at maximum height.

----- [1]

(iv) The mass m of the ball is 57.0 g.

Calculate the kinetic energy E_k of the ball when it is at its maximum height.

$E_k =$ ----- J [2]

(b)



A metal ball is rolled off the edge of a horizontal laboratory bench. The initial horizontal velocity of the ball is v . The ball travels a horizontal distance x before it hits the level floor.

Use your knowledge of projectile motion to suggest the relationship between v and x . Describe how an experiment can be safely conducted to test this relationship and how the data can be analysed.

[6]

21(a) Wind turbines convert the kinetic energy of the wind into electrical energy.

Fig. 18 shows a wind turbine.

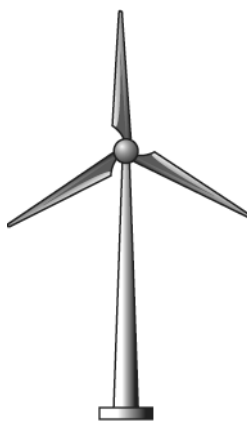


Fig. 18

When the wind speed is 8.0 m s^{-1} , the kinetic energy of the air incident at the turbine per second is 1.2 MJ s^{-1} .
Calculate the mass of the air incident at the turbine per second.

mass per second = _____ kg s^{-1} [2]

- (b) A group of engineers are investigating the design of wind turbines.
The maximum input power P from the wind is given by the equation

$$P = \frac{1}{2} \rho A v^3$$

where A is the area swept out by the rotating blades, ρ is the density of air and v is the speed of the wind.

- (i) Show that the equation is homogeneous with both sides of the equation having the same base units.

[3]

- (ii) The input power to the wind turbine is 1.2 MW when the wind speed is 8.0 m s^{-1} .
The density of air is 1.3 kg m^{-3} .

Calculate the length L of the turbine blades.

$L =$ _____ m [2]

- (iii) A wind farm is required to produce an output power of 50 MW when the average wind speed is 8.0 m s^{-1} .
The efficiency of each wind turbine is 42%.

Calculate the minimum number N of wind turbines required to meet this demand.

$N =$ _____ [2]

22(a)

Use the equations for momentum and kinetic energy to derive an expression for the kinetic energy E_k of a particle in terms of its momentum p and mass m .

[2]

(b) Fig. 20.1 shows an electric motor used to lift and lower a load.

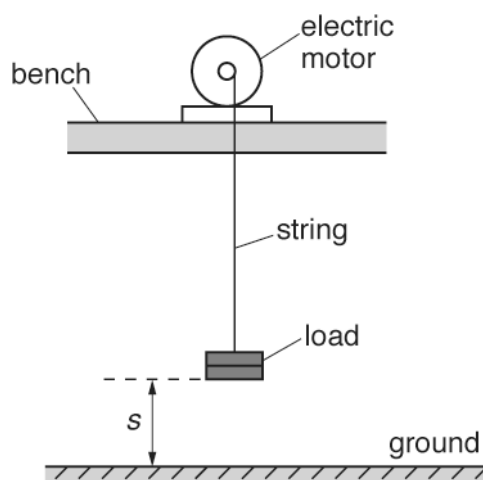


Fig. 20.1

At time $t = 0$ the load is on the ground with displacement $s = 0$.

Fig. 20.2 shows the variation of the displacement s of the load with time t .

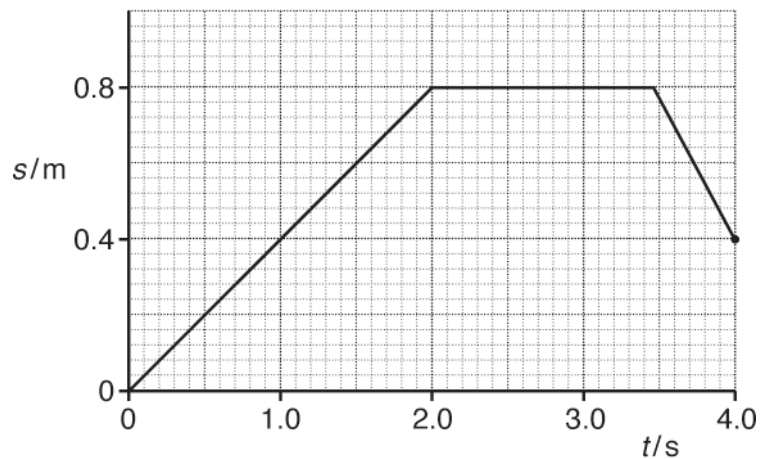


Fig. 20.2

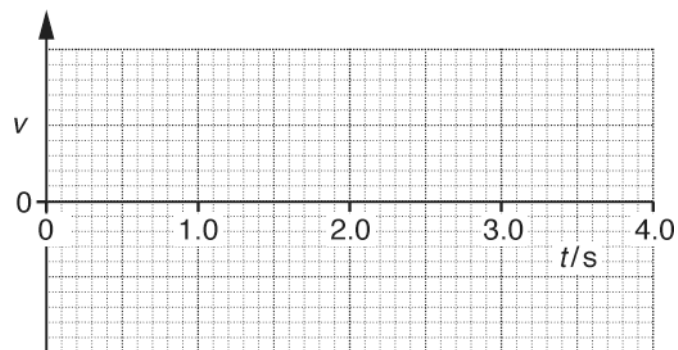


Fig. 20.3

- (i) On Fig. 20.3, sketch a graph to show the variation of the velocity v of the load with time t .
You do not need to insert a scale on the v axis.

[3]

- (ii) Describe how the kinetic energy and the gravitational potential energy of the load varies from $t = 0$ to $t = 2.0$ s.

[2]

(iii) During the **downward** journey of the load, the string breaks at $t = 4.0$ s. It then falls vertically towards the ground. The mass of the load is 120 g.

Air resistance is negligible.

- 1 Calculate the velocity V of the load just before it hits the ground.

$V = \text{-----ms}^{-1}$ [2]

- 2 The load hits the ground and comes to **rest** in a time interval of 25 ms.

Calculate the average force F exerted by the ground on the load.

$F = \text{----- N}$ [2]

23(a) Fig. 4.1 shows an arrangement used by a student to determine the acceleration of free fall.

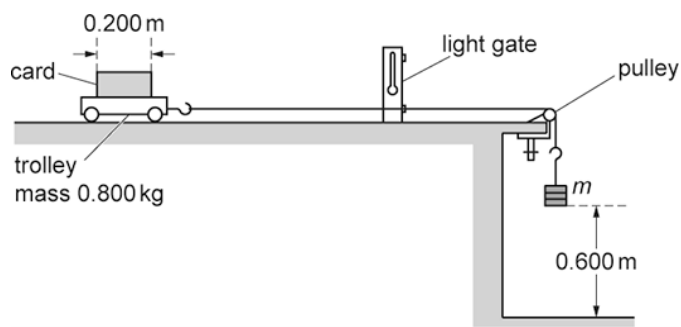


Fig. 4.1

A trolley is attached to a variable mass m by a string which passes over a pulley.

The mass m is released from rest and falls through a fixed height of 0.600 m accelerating the trolley of mass 0.800 kg. When the mass m hits the floor, the trolley then continues to move at a **constant** velocity v .

This constant velocity v is determined by measuring the time t for the card of length 0.200 m to pass fully through a light gate connected to a timer.

Frictional forces on the trolley and the falling mass m are negligible.

Show that the relationship between v and m is

$$v^2 = \frac{1.20mg}{(m + 0.800)}$$

where g is the acceleration of free fall.

[2]

(b) The student records the information from the experiment in a table. The column headings and just the last row for $m = 0.600$ kg from this table are shown below.

m/kg	$t/10^{-3}\text{s}$	$\frac{m}{(m + 0.800)}$	v/ms^{-1}	$v^2/\text{m}^2\text{s}^{-2}$
0.600	90 ± 2	0.429	2.22 ± 0.05	

(i) Complete the missing value of v^2 in the table including the absolute uncertainty. [2]

(ii) Fig. 4.2 shows some of the data points plotted by the student. Plot the missing data for $m = 0.600$ kg on Fig. 4.2 and draw the straight line of best fit. [2]

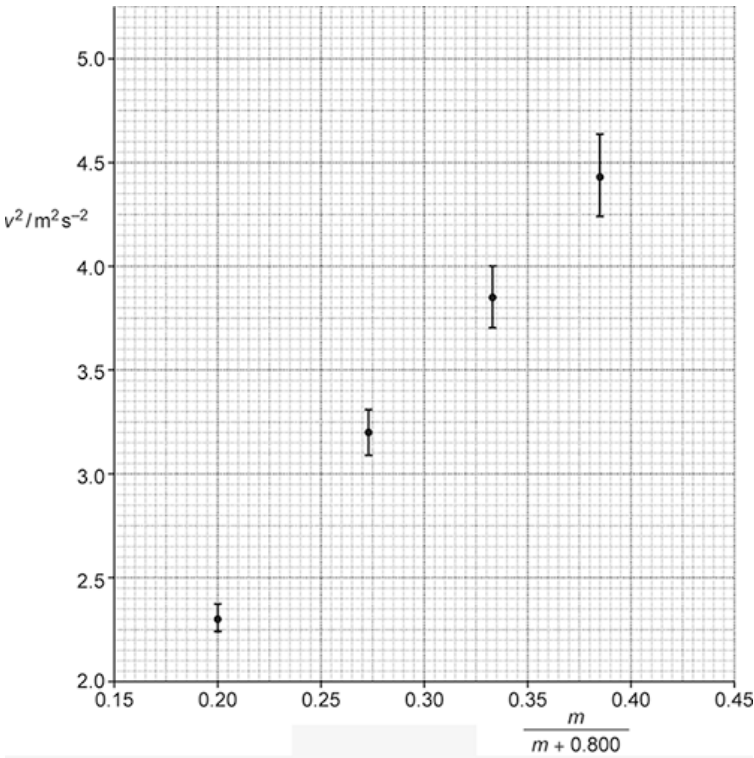


Fig. 4.2

(c)

- (i) Use the equation given in (a) to show that the gradient of the graph of v^2 against $\frac{m}{(m + 0.800)}$ is equal to $1.20 g$.

[1]

- (ii) Assume that the best-fit straight line through the data points gives 9.5 m s^{-2} for the experimental value of g . Draw a worst-fit line through the data points on Fig. 4.2 and determine the absolute uncertainty in the value for g .

absolute uncertainty = $\pm$ ----- ms^{-2} [4]

- (d) It is suspected that the card on the trolley did not pass at right angles through the light beam.

Discuss, without doing any calculations, the effect this may have on the experimental value for the acceleration of free fall g .

[4]

24(a) Fig. 3.1 shows the design of a ‘mechanical’ torch.

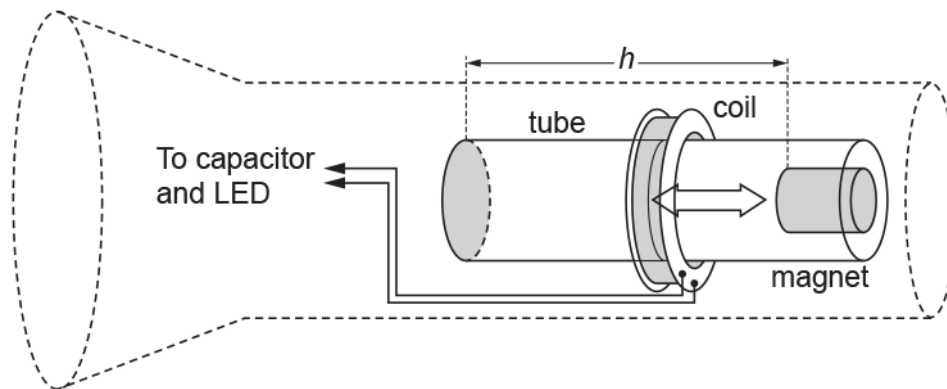


Fig. 3.1

There is no battery in the torch. Instead, when the torch is inverted, the magnet falls a short vertical distance h through the coil of wire, as shown in Fig. 3.2. This induces an electromotive force (e.m.f.) across the ends of the coil. The e.m.f. is used to store charge in a capacitor, which lights a light-emitting diode (LED) when it discharges.

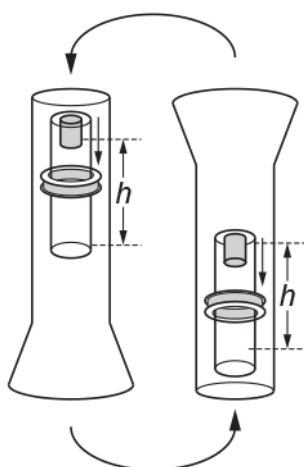


Fig. 3.2

Fig. 3.3 shows the variation with time of the e.m.f. generated as the magnet falls the distance h .

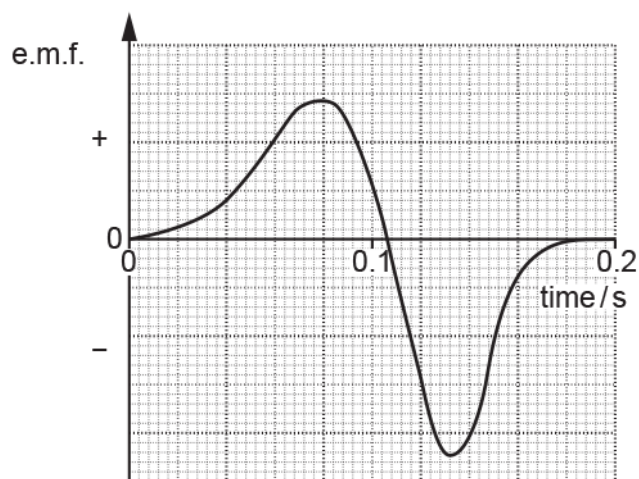


Fig. 3.3

When the torch is inverted, the pulses of e.m.f. shown in Fig. 3.3 cause a capacitor of capacitance 0.12 F to become charged.

Each positive **and** each negative pulse adds 9.0×10^{-3} C to the charge stored in the capacitor.

- (i) The torch is inverted 80 times.

Calculate the total energy stored in the capacitor.

total energy = ... J [3]

- (ii) When the torch is switched on, the energy stored in the capacitor lights a 50 mW LED.

Estimate the time for which the LED lights.

time = ... s [1]

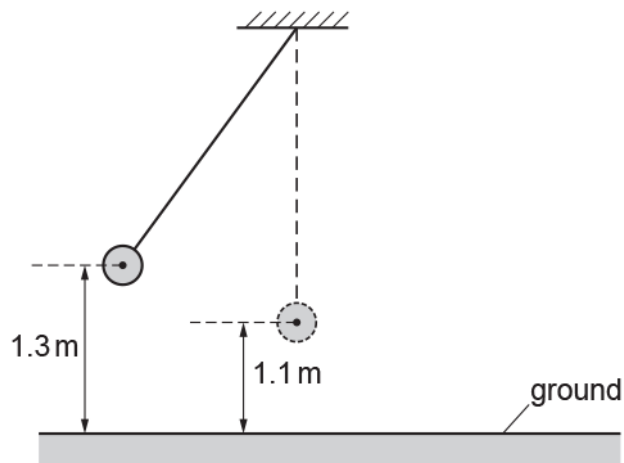
- (b) In the torch, the gravitational potential energy of the magnet is converted into electrical energy supplied to the 50 mW LED.

You are asked to investigate whether the efficiency of this energy conversion depends on the number of inversions of the torch.

- Describe how you will make accurate measurements to collect your data. Assume that both the torch and the tube can be opened.
- Explain how you will use the data to reach a conclusion.

Blank lined paper for writing.

- 25 A pendulum bob is oscillating in a vacuum.
The maximum height of the bob from the ground is 1.3 m and its minimum height is 1.1 m.



What is the maximum speed of the pendulum bob?

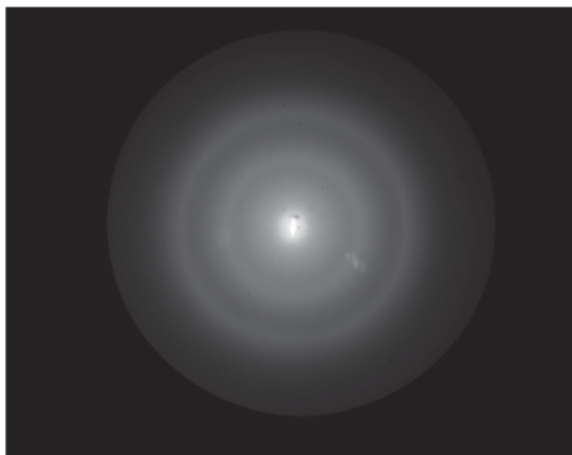
- A 2.0 m s^{-1}
- B 3.9 m s^{-1}
- C 5.1 m s^{-1}
- D 26 m s^{-1}

Your answer

[1]

26 * A student is investigating electron diffraction. A beam of electrons is directed towards a thin slice of graphite in an evacuated tube.

The electrons are accelerated by a potential difference of 2000 V. The diagram below shows the pattern formed on the fluorescent screen of the evacuated tube.



Describe and explain how the pattern changes as the potential difference is increased. Include how the de Broglie wavelength λ of the electron is related to the potential difference V .

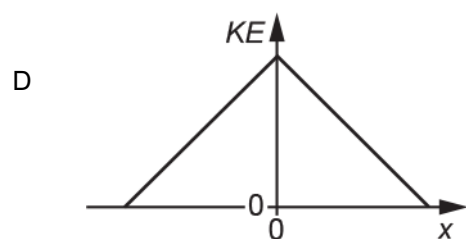
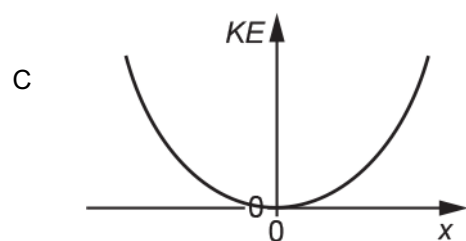
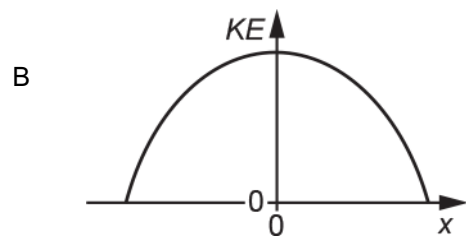
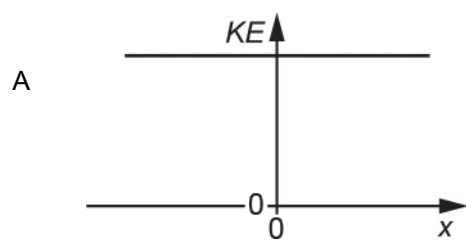
[6]

- | | |
|---|-----------|
| A | 12 J |
| B | 100 J |
| C | 900 J |
| D | 800 000 J |

[1]

28 An oscillator is executing simple harmonic motion.

Which graph of kinetic energy KE against displacement x is correct for this oscillator?

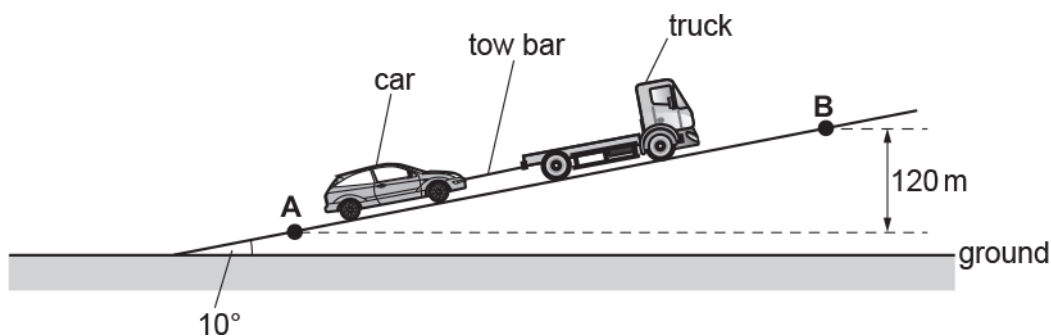


Your answer

[1]

29(a) A truck pulls a car up a slope at a **constant speed**.

The truck and the car are joined with a steel tow bar, as shown in the diagram.



The diagram is **not** drawn to scale.

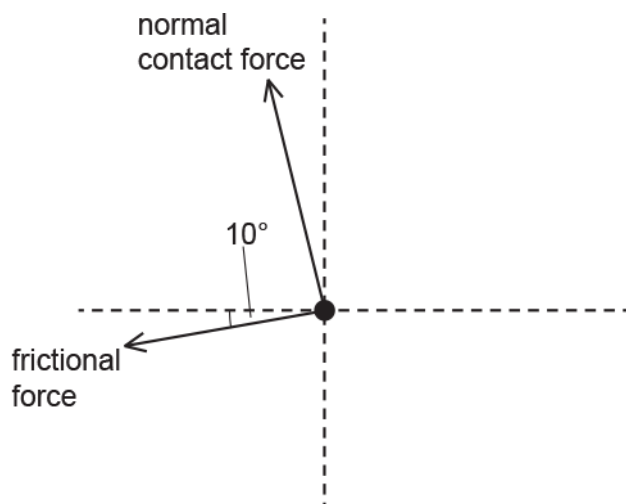
The slope is 10° to the horizontal ground.

The mass of the car is 1100 kg.

The car travels from A to B. The vertical distance between A and B is 120 m.

There are four forces acting on the **car** travelling up the slope.

Complete the free-body diagram below for the car and label the missing forces.



[2]

(b) Show that the component of the weight of the car W_s acting down the slope is about 1900 N.

[1]

(c) The total frictional force acting on the car as it travels up the slope is 300 N.

Calculate the force provided by the tow bar on the car.

force = ... N [1]

(d) Calculate the work done by the force provided by the tow bar as the car travels from A to B .

work done = ... J [3]

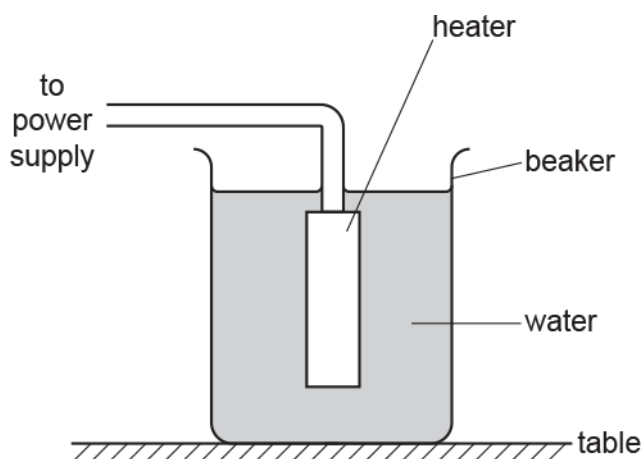
(e) The steel tow bar used to pull the car has length 0.50 m and diameter 1.2×10^{-2} m.

The Young modulus of steel is 2.0×10^{11} Pa.

The force on the tow bar is 2200 N.

Calculate the extension x of the tow bar as the car travels up the slope.

x = ... m [3]



- (i) Before switching on, the metal heater and the water are both at room temperature.
Describe the motion of the atoms of the metal heater and of the water molecules.

[3]

- (ii) The heater is now switched on.
The power of the heater is 200 W.
The mass of the water in the beaker is 500 g.
It takes 10.0 minutes to increase the temperature of the water in the beaker from 20 °C to 60 °C.

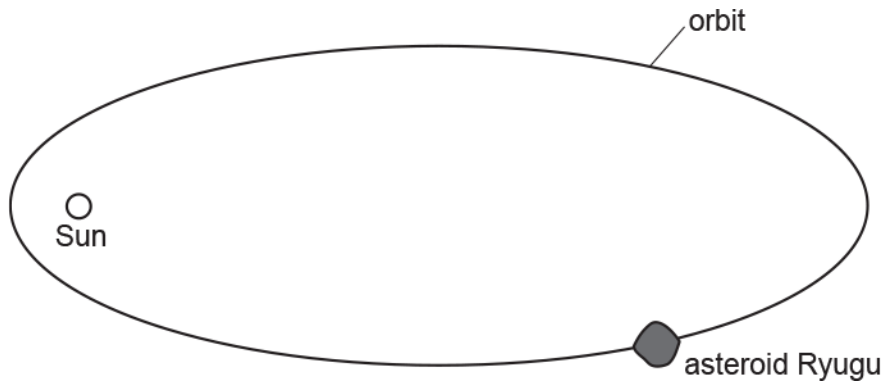
Calculate the energy transferred from the water to the **beaker and the surroundings** .

- specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

energy transferred = ... J [3]

31(a) In June 2018, the spacecraft Hayabusa2 arrived at an asteroid called Ryugu.

The asteroid orbits the Sun in an elliptical orbit as shown below.



The diagram is **not** drawn to scale.

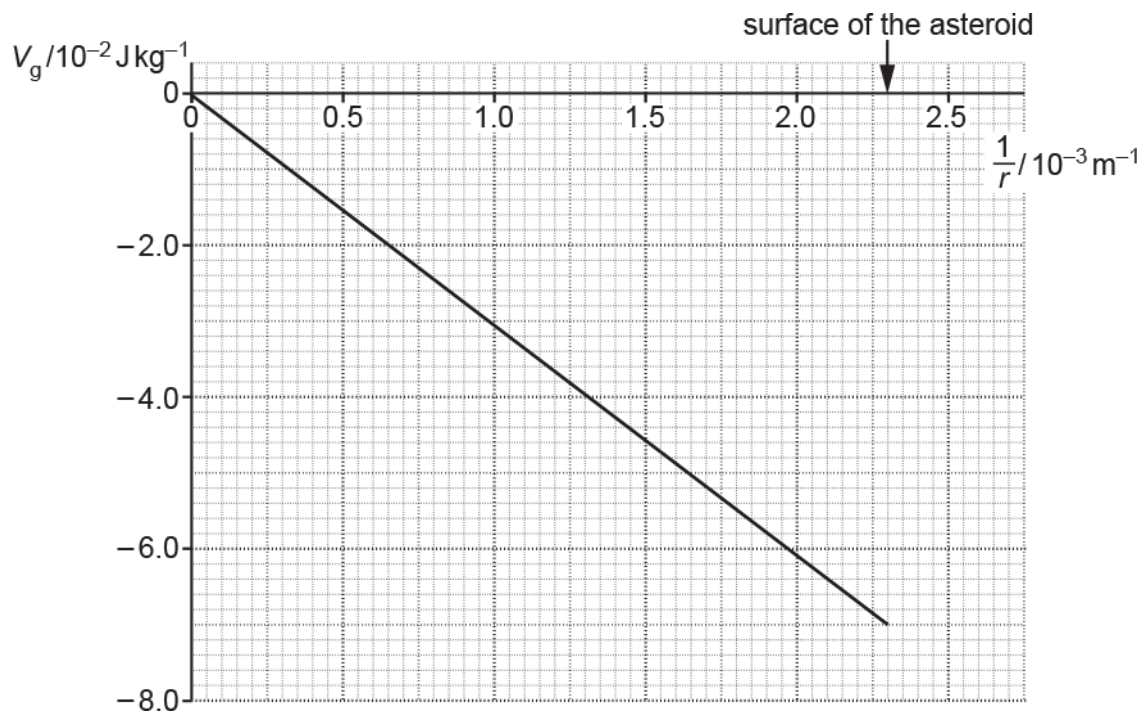
- (i) Indicate with a letter **X** on the orbit where the asteroid would be moving at maximum speed.

[1]

1 Use Kepler's **second law** to explain your answer to (a)(i) .

[2]

- (b) The gravitational potential at a distance r from the centre of the asteroid Ryugu is V_g . The graph of V_g against $\frac{1}{r}$ for the asteroid is shown below.



(i) Define gravitational potential .

[1]

(ii) Show that the magnitude of the gradient of the graph is equal to GM , where M is the mass of the asteroid and G is the gravitational constant.

[1]

(iii) Use the gradient of the graph to show that the mass M of the asteroid is about $4.6 \times 10^{11} \text{ kg}$.

$M = \dots\dots\dots \text{ kg}$ [2]

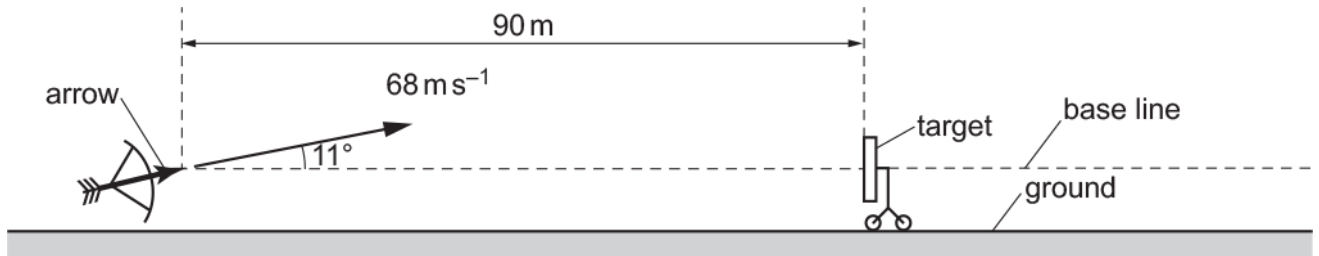
- (c) In October 2018, the probe Mobile Asteroid Surface Scout (MASCOT) was released from **rest** from the Hayabusa2 spacecraft from a distance of 600 m from the centre of the asteroid.

Assume that the spacecraft was stationary relative to the asteroid when MASCOT was dropped.

Use information from **(b)** to calculate the speed of the impact v when MASCOT landed on the surface of the asteroid.

$$v = \dots\dots\dots \text{ m s}^{-1} \text{ [3]}$$

32 An archer fires an arrow towards a target as shown below.



The diagram is **not** drawn to scale.

The centre of the target is at the same height as the initial position of the arrow.

The target is a distance of 90 m from the arrow.

The arrow has an initial velocity of 68 m s^{-1} and is fired at an angle of 11° to the horizontal.

Air resistance has negligible effect on the motion of the arrow.

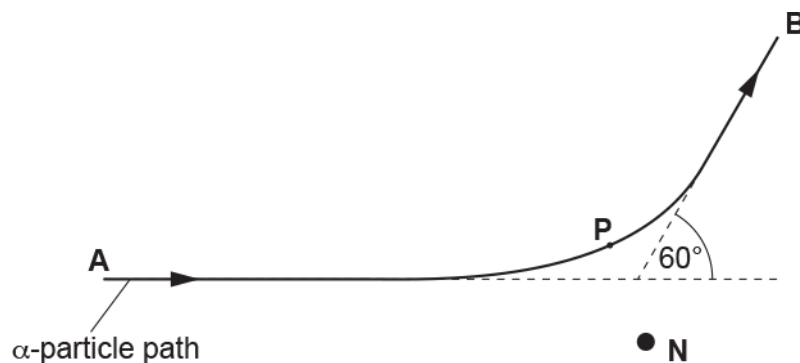
Describe how the kinetic energy of the arrow changes during its journey from when it is fired until it reaches its maximum height.

[2]

- 33 A beam of α -particles is incident on a thin gold foil. Most α -particles pass straight through the foil. A few are deflected by gold nuclei.

The diagram shows the path of one α -particle which passes close to a gold nucleus **N** in the foil. The α -particle is deflected through an angle of 60° as it travels from **A** to **B**.

P marks its position of closest approach to the gold nucleus.



The initial kinetic energy of each α -particle is 5.0 MeV.

Show that the magnitude of the initial momentum of each α -particle is about $10^{-19} \text{ kg m s}^{-1}$.

Take the mass of the α -particle to be $6.6 \times 10^{-27} \text{ kg}$.

[3]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		Graph correct shape and always positive and suitable scale on kinetic energy axis.	B1	
			Maxima occur at zero displacement times.	B1	
	b	i	Period from graph = $500/3.5 = 143 \text{ ms}$	C1	
		i	Acceleration = $\omega^2 A = (2\pi/0.143)^2 \times 0.006 = 12 \text{ (ms}^{-2}\text{)}$	A1	
		ii	KE = $0.5 \times 0.005 \times (2\pi / 0.143 \times 0.006)^2$	C1	
		ii	KE = $1.7 \times 10^{-4} \text{ (J)}$	A1	
			Total	6	
2			C	1	
			Total	1	
3	a		energy input = $mc\Delta\theta = 0.327 \times 4200 \times 80 = 110 \text{ kJ}$	C1 M1	Allow 0.3 kg in the calculation
			energy input = power $\times$ time	C1	
			time = 220 (s)	A0	
	b		Thermal losses to kettle and surroundings	B1	
			Lagging the kettle	B1	
			Cover to prevent evaporation	B1	
			Total	6	
4	a		work done = force $\times$ distance moved or displacement in the direction of the force	B1	
	b	i	tension = $850 \text{ kg} \times 9.81 = 8300 \text{ N}$	B1	
		ii	work done = $mgh = 850 \times 9.81 \times 12$	C1	
		ii	work done = 100 kJ	C1	
		ii	output power = $100 \times 10^3 / 40 (=2501 \text{ W})$	C1	
		ii	input power (= $2501 / 0.6 = 4200 \text{ (W)}$)	A1	
		iii	Suggestion to reduce heat losses through friction in moving parts e.g. oil, bearings	B1	
		iii	Use a stiffer / stronger cable to reduce energy loss through stretching	B1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	8	
5		i	$250 \times 60 = 15000 \text{ J}$	C1	
		i	energy = $\frac{15000}{0.65} = 2.3 \times 10^4 \text{ (J)}$	A1	
		ii	drag force = $0.4 \times 6.0^2 = 14.4 \text{ N}$	C1	
		ii	forward force = power / velocity = $250/6.0 = 41.7 \text{ N}$	C1	
		ii	acceleration = $\frac{41.7 - 14.4}{85} = 0.32 \text{ m s}^{-2}$	A1	
			Total	5	
6			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7		i	$E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{380 \times 10^{-9}} \quad \text{or} \quad \phi = 1.1 \times 1.6 \times 10^{-19}$	C1	This is substituting values into $\frac{hc}{\lambda} = \phi + \frac{1}{2}mv^2$
		i	$\frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{380 \times 10^{-9}} = 1.1 \times 1.6 \times 10^{-19} + \frac{1}{2} \times 9.11 \times 10^{-31} v^2$	C1	
		i	speed = $8.7 \times 10^5 \text{ (m s}^{-1}\text{)}$	A1	
		ii	The energy of a photon depends only on wavelength or frequency, so intensity does not change the maximum speed of the photoelectrons.	B1	
			Total	4	
8		i	Parallel and equidistant field lines.	B1	Note: Field lines must be right angle to the plates.
		i	Field direction is correct (from left to right).	B1	
		ii	work done = $1500 \times 1.6 \times 10^{-19} \times 1.2 \times 10^{-2} = 2.88 \times 10^{-18} \text{ (J)}$	C1	Correct use of: final KE = initial KE – work done.
		ii	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = \frac{1}{2} \times 9.11 \times 10^{-31} \times (5.0 \times 10^6)^2 - 2.88 \times 10^{-18}$	C1	
		ii	speed = $4.3 \times 10^6 \text{ (m s}^{-1}\text{)}$	A1	
			Total	5	
9			The force is towards the centre of the circle.	B1	
			The force is perpendicular to the motion or no component of force in direction of motion; hence no work is done on the particle.	B1	
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	a		power or P : $\text{kg m}^2 \text{s}^{-3}$	B1	power = force $\times$ distance / time = force $\times$ velocity
	b	i	1. <i>either</i> resultant force $F = ma - R$ or resultant force decreases as R increases	B1	allow for points 2 and 3 <i>when</i> $F = R$ appearing only once
		i	2. acceleration a decreases to zero when $F = R$	B1	
		i	3. velocity rises from zero to a terminal / maximum value when $F = R$	B1	
		ii	1 initial acceleration is $40/120 = 0.33 \text{ (m s}^{-2}\text{)}$	B1	or forward force = 40 N so $R = 40 \text{ N}$ for constant speed / zero acceleration
		ii	2 from the graph $Rv = 200 \text{ (W)}$ so $R = 40 \text{ N}$	C1	
		ii	and terminal velocity v is $5 \text{ (m s}^{-1}\text{)}$	A1	
	c		p.e. / second = $mgv \sin \theta = 120 \times 9.81 \times 5 \times \sin \theta$	C1	allow force downhill $F = mg \sin \theta$, extra power = Fv
			extra power = 200 (W)	C1	
			so $\sin \theta = 1/29.4$ giving $x = 29 \text{ m}$	A1	
			Total	10	
11			(Gravitational) potential energy is converted to kinetic energy which is then converted to thermal energy/heat	B1	Not 'GPE to KE and thermal'
			Statement that KE to thermal takes place on impact	B1	Examiner's Comments Many of the answers here lacked precision and it was common for marks to be lost by implying thermal energy was created as the pellets were falling rather than on impact at the end of the tube.
			Total	2	
12			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13			C	1	
			Total	1	
14	a	i	Missing data point and error bar plotted correctly.	B1	Allow ½ square tolerance.
		ii	Force measured by pulling back plate with a newton-meter.	B1	
		ii	Extension measured with a ruler (placed close to the transparent plastic tube).	B1	
		iii	Best fit line drawn correctly and gradient determined correctly.	B1	Ignore POT for this mark; gradient = 50 ± 4 (N m ⁻¹)
		iii	Worst fit line drawn correctly and its gradient determined correctly.	B1	Note: The line must have a greater/smaller gradient than the best fit line and must pass through all the error bars. Ignore POT for this mark.
		iii	$2k = 50$ (N m ⁻¹), therefore $k = 25$ (N m ⁻¹)	B1	Possible ECF.
		iii	Absolute uncertainty determined correctly.	B1	Possible ECF within calculation.
		iv	$F \propto x$ / straight line passing through the origin.	B1	
		v	energy stored = $\frac{1}{2} \times 50 \times 0.12^2$	C1	Possible ECF from (iii)
		v	$\frac{1}{2} \times 50 \times 0.12^2 = \frac{1}{2} \times 0.39 \times v^2$	C1	
		v	$v = 1.4$ (m s ⁻¹)	A1	Allow 1 mark for $v = 0.96$ m s ⁻¹ ; used k for single spring
	b		force constant of spring arrangement) = $\frac{2k}{3}$ $\frac{2k}{3}x = ma$ $a = \frac{2}{3 \times 0.39}kx$ $a = 1.7 kx$	M1 M1 A0	
			Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15		i	Using the graph to determine at least two ratios of the amplitudes.	M1	For example: 2.5/3.0 and 2.1/2.5
		i	Correct statement matching the ratios.	A1	For example: 'The statement is correct because $2.5/3.0 \approx 2.1/2.5 \approx \text{constant}$.'
		ii	At time $t = 0$	M1	
		ii	Oscillator has maximum speed and hence the greatest friction. (AW)	A1	
			Total	4	
16		i	$-mV_g = \frac{1}{2}mv^2$ or $\frac{1}{2}mv^2 + mV_g = 0$	B1	
		i	$V_g = -GM/R = -gR$	B1	
		i	$v = \sqrt{2gR}$	B1	Working must be shown
		ii	$v = \sqrt{(2 \times 9.81 \times 6.4 \times 10^6)} = 11 \times 10^3 \text{ m s}^{-1}$	B1	allow 11(.2) km s^{-1}
		iii	$\frac{1}{2}mc^2 = 3/2 \text{ kT}$ where $m = (M/N_A) = 6.6 \times 10^{-27} \text{ kg}$	B1	ecf (ii); allow $m = 4u$ or $4 \times 1.67 \times 10^{-27}$
		iii	$T = 6.6 \times 10^{-27} \times 121 \times 10^6 / 3 \times 1.38 \times 10^{-23}$	C1	
		iii	$T = 1.9 \times 10^4 \text{ (K)}$	A1	allow 2 or 2.0
		iv	1 random motion and elastic collisions of particles	B1	max 4 out of 5 marking points where answer is a logical progression
		iv	2 lead to distribution of kinetic energies/velocities among particles	B1 B1	
		iv	3 a very few will have very high velocities at top end of distribution 4 a long way from mean /r.m.s. velocity at 300 K 5 hence some able to escape	B1	
		v	helium nucleus is an α -particle	B1	max 2 out of 3 marking points
		v	so helium is generated by radioactive decay helium is found in (natural gas) deposits underground	B1	
			Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17	a		Photon(s) mentioned	B1	
			One-to-one interaction between photons and electrons	B1	Allow 'photon absorbed by an electron' Allow: collide etc. for interaction
			Energy of photon is independent of intensity / intensity is to do with rate (of photons / photoelectric emission) / photon energy depends on frequency / energy of photon depends on wavelength / photon energy $\propto$ frequency / photon energy $\propto 1/\lambda$	B1	Allow $E = hf$ or $E = hc/\lambda$
			energy of uv photon(s) > work function (of zinc) / frequency of uv > threshold frequency	B1	Allow energy of light photon(s) < work function (of zinc) / frequency of light > threshold frequency Allow $\geq$ instead of > here Not $f > f_0$ Examiner's Comment Many candidates wrote enthusiastically about photoelectric effect and understood the significance of work function energy (or threshold frequency) and the one-to-one interaction between photon and an electron. Some candidates did not mention 'photons' and this limited the marks they could acquire. The role of intensity was less understood. Many candidates thought it was linked to 'the <i>number of photons</i> ' or 'the <i>amount of electrons emitted</i> '. The important term rate of the missing ingredient. Top-end candidates gave eloquent answers, typified by the response: ' <i>intensity of visible light only affects the rate of photons incident on the plate but not the energy of each photon</i> '. Two common misconceptions were: • Photons were emitted from the negative plate. • Confusing threshold frequency and work function energy.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		$\phi = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{2.9 \times 10^{-7}} \text{ or } 6.86 \times 10^{-19} \text{ (J)}$ $E = 5.1 \times 1.60 \times 10^{-19} \text{ or } 8.16 \times 10^{-19} \text{ (J)}$ $\text{max kinetic energy} = (8.16 - 6.86) \times 10^{-19}$ $\text{max kinetic energy} = 1.3 \times 10^{-19} \text{ (J)}$	C1 C1 A 1	Note: Using 5.1 and not 8.16×10^{-19} cannot score this mark or the next mark Allow 2 marks for 0.81 eV Examiner's Comment This was a notable success for most of the candidates. Examiners were pleased to see a range of techniques being used to get the correct answer of 1.3×10^{-19} J. Many answers showed excellent structure, effortless conversion of energy from electronvolt to joule and excellent use of the calculator when dealing with powers of ten. Most candidates scored three marks. A small number of candidates left the final answer as 0.81 eV; the only thing missing was the conversion to J.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		Any <u>three</u> from: The electrons are repelled by C / electrons travel against the electric field (AW) The electrons are emitted with a 'range' of speed / velocity / kinetic energy (AW) As V increases the slow(er) electrons do not reach C and hence I decreases maximum KE in the range 2.1 eV to 2.2 eV or $3.36 \times 10^{-19} \text{ J}$ to $3.52 \times 10^{-19} \text{ J}$	B1×3	Note 'range' can be implied by 'highest' or 'lowest' Allow 'find p.d. when current is (just) zero, and then $\text{KE} = e \times V$ Examiner's Comment The electrons emitted from the metal plate have a range of kinetic energy. The emitted electrons are repelled by the negative electrode C. Fewer electrons reach C as the p.d. is increased. When the p.d. is about 2.2 V, and the current zero, the most energetic electron are stopped from reaching C. This makes the maximum kinetic energy of the electrons equal to 2.2 eV or $3.4 \times 10^{-19} \text{ J}$. The question baffled most candidates. Some top-end candidates commented on '<i>the electrons repelled by C</i>' and the maximum kinetic energy of the emitted electrons being 2.2 eV. Such answers were rare. Too many candidates made guesses with answers such as '<i>the current drops because resistance increases</i>' and '<i>temperature increases and hence the current decreases</i>'.
			Total	10	
18			power $\times$ time = $2200 \times 4.0 \times 60$ energy = $5.3 \times 10^5 \text{ (J)}$	C1 A1	Note: Answer to 3 s.f. is $5.28 \times 10^5 \text{ (J)}$ Examiner's Comments Virtually all candidates correctly found the total energy supplied, remembering to convert the time from minutes into seconds.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a		work done = 400×0.80 work done = 320 (J)	C1 A1	Examiner's Comments This was answered correctly by most candidates; a tiny number did not convert from cm to m correctly.
	b		ratio of speeds = ratio of distances (since same time) or ratio = $80 / 2$ ratio = 40	C1 A1	Allow 40:1 Allow 2 marks for ratio 29.4 (assuming p same) Not 1:40 for A1 Examiner's Comments Unsuccessful candidates tried to employ 'suvat' equations, although many candidates realised that the required ratio was also the ratio of the distances travelled in the same time period. Some credit was given for those candidates that assumed constant pressure and 100% efficiency.
	c		work done = $1200 \times 9.81 \times 0.02$ (= 235.4) efficiency = $235.4 / 320 \times 100$ efficiency = 74 %	C1 A1	Note: Using $g = 10 \text{ N kg}^{-1}$ gives 75%: allow 1 mark max Possible ECF from (a) Note: 0.74 scores 1 mark Allow 2 marks for using $235/320 \times 100 = 73\%$ Allow use of 9.8 N kg^{-1} gives 73.5% for 2 marks Allow 1 mark for 71%, force = $(1200g - 400) \text{ N}$ used Allow 1 mark for 76%, force = $(1200g + 400) \text{ N}$ used Examiner's Comments The majority of candidates successfully calculated the work done on the car and hence the efficiency of the system.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20	a	i	vertical component = $30.0 \sin(70^\circ)$ or $30.0 \cos(20^\circ)$ vertical component = $28.2 \text{ (m s}^{-1}\text{)}$	A1	Allow 2 SF answer of 28
		ii	Evidence of $v^2 = u^2 + 2as$ and $v = 0$ or $gh = \frac{1}{2} u^2$ $h = \frac{28.2^2}{2 \times 9.81}$ (Any subject) $h = 40.5 \text{ (m)}$	C1 M1 A0	Allow v and u interchanged; a and g interchanged Allow use of candidate's answer for (a)(i) at this point Ignore sign Allow $h = \frac{28^2}{2 \times 9.81}$ or $(30 \sin(70)) / (2 \times 9.81)$ No ECF from (a)(i) for the second mark
		iii	The ball has horizontal motion / velocity (AW)	B1	Allow idea of horizontal e.g. sideways, forwards Not: 'moving' unqualified
		iv	(horizontal velocity =) $30.0 \cos 70^\circ$ or $10.2 \dots \text{ (m s}^{-1}\text{)}$ or $30.0 \sin 20^\circ$. $E_k = \frac{1}{2} \times 0.057 \times 10.26^2$ $E_k = 3.0 \text{ (J)}$	C1 A1	Allow 1 SF answer Not 22 (J), $v = 28$ used Not 23 (J), $v = 28.2$ used Not 140 (J), $v = 70$ used <u>Examiner's Comments</u> Part (i) was particularly well answered by 95% of all candidates. Nine out of ten candidates scored full marks in part (a)(ii), as they remembered that the question asks to <i>show</i> that the maximum height is around 40m. Working for this type of question is essential. In part (a)(iii), three quarters of all candidates correctly talked about the ball still having a horizontal velocity (which wasn't zero) and therefore still possessing some KE. The key to this part (a)(iv), remembered by most candidates, was to use the horizontal component of velocity to find the KE at the maximum height. Some used the initial speed and others used the initial vertical velocity component found in part (a)(i).

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	Level 3 (5–6 marks) Clear description and analysis. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description and some analysis. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description and limited analysis or limited description or limited analysis <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response (NR) or no response worthy of credit (0).	B1 x 6	Indicative scientific points may include: Description • Ruler used to determine x • Average readings to determine x • x recorded for various v • Suitable method for consistent v or varying v e.g. • Released from same point on a track • Ejected from a spring device with different compressions • Suitable method of determining point of impact e.g. • trial run to get eye in approximate correct position • carbon paper so that ball makes a mark on paper • scale in frame of video recording • tray of sand to catch ball • Suitable instrument used to determine v (light-gate / motion sensor / video techniques) or suitable description of inference of v from other measurements such as energy released from spring of known k and x • Ensuring the initial velocity of ball is horizontal Analysis • Horizontal velocity is constant • Time of fall is independent of v /horizontal velocity • Suggested relationship: e.g. $x \propto v$, x d.p. to V^2, etc • Plot a graph of x against v or graph consistent with candidate's suggested relationship • If relationship is correct, then a straight line through the origin. • Suggested relationship supported by correct physics or algebra. • Correct relationship supported by physics.

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			Note: L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded. <u>Examiner's Comments</u> Many candidates had plenty to say that was sensible. There was plenty of evidence that candidates had seen this experiment or had performed a similar one themselves. A few confused the question, instead describing how to find the time of flight or that the ball was falling vertically. Others described what they thought would happen to the vertical component of velocity when they changed the vertical distance that the ball dropped. Exemplar 2 Use your knowledge of projectile motion to suggest the relationship between v and x. Describe how an experiment can be safely conducted to test this relationship and how the data can be analysed. As m a projectile the horizontal component of velocity is constant given air resistance is negligible then an equation of $x = \frac{1}{2}(uv)t$ could become $x = vt$ where x is distance traveled v is velocity of ball and t is time of flight. Therefore for a constant time of flight it can be said $x \propto v$. To test this it is very hard to keep time of flight constant as this is due to its time of freefall. To test this a ball would be rolled off a table at varying speeds. To calculate this speed a light gate can be used passing through the center of the metal ball. As distance travelled is equal to the diameter of the ball, measured by a ruler, speed can be calculated using distance/time from light gate. For safety the ball should land in sand as not to shatter or land on someone's foot. This also makes measuring x much easier as x is equal to the horizontal distance from the edge of the table to the center in the sand measured using a ruler. If the time taken to fall is kept constant measured by using a stop watch and controlled by raising or lowering the launch point then v is plotted against x on a graph it can be expected to be linear and pass through the origin.

Mark Scheme

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					In the first paragraph, the candidate has made clear that the time of flight is constant and goes on to explain why towards the end of the response. This supports the prediction that $v \propto x$. In addition, the candidate takes time to explain how to obtain data for both the horizontal velocity and horizontal distance. It was pleasing to see light gates and motion sensors being employed, with the best answers explaining how to use the data provided by the sensors to calculate the velocity of projection. The exemplar response also includes the correct analysis. There is a graph of v against x and the resulting best fit straight line through the origin supports the idea that these two variables are directly proportional. Too many candidates did not mention the crucial statement about the line going through the origin, limiting their response to a high L1 or low L2.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21	a		$1.2 \times 10^6 = \frac{1}{2} \times (\text{mass per second}) \times 8.0^2$ mass per s = $3.8 \times 10^4 \text{ (kg s}^{-1}\text{)}$	C1 A1	Answer is $3.75 \times 10^4 \text{ (kg s}^{-1}\text{)}$ to 3sf Note: $3.8 \times 10^4 \text{ (kg s}^{-1}\text{)}$ scores 1 for PoT error. <u>Examiner's Comments</u> A large majority of candidates got this right. Those that did not usually forgot to square the velocity.
	b	i	$A \rightarrow \text{m}^2$ <u>and</u> $\rho \rightarrow \text{kg m}^{-3}$ $P \rightarrow \text{kg m}^2 \text{ s}^{-3}$ Clear working to show units are equivalent on either side of equation	M1 M1 A1	Note: No mark for $v \rightarrow \text{m s}^{-1}$ since units are in (a) Allow $P \rightarrow \text{kg m s}^{-2} \text{ m s}^{-1}$ (from $P = Fv$ or $P = \text{Work done/t}$) Note: clear working includes $\text{m}^3 \text{s}^{-3}$ seen. <u>Examiner's Comments</u> Exemplar 5 $\begin{aligned} [\frac{1}{2} \rho A v^3] &= (\text{kg m}^{-3})(\text{m}^2)(\text{ms}^{-1})^3 \\ &= \text{kg m}^{-3} \text{m}^2 \text{m}^3 \text{s}^{-3} \\ &= \text{kg m}^2 \text{s}^{-3} \end{aligned}$ $\begin{aligned} [P] &= \text{J s}^{-1} \\ &= \text{N ms}^{-1} \\ &= \text{kg ms}^{-2} \text{ms}^{-1} \\ &= \text{kg m}^2 \text{s}^{-3} \end{aligned}$ $\therefore [\frac{1}{2} \rho A v^3] = [P]$ $\therefore$ The equation is homogenous Candidates generally made an excellent attempt at this question, although for many the working was difficult to follow. In the exemplar, the candidate has made it very clear that they are considering the two sides of the equation separately and have reduced each unit to its S.I. base units as required by the question. The use of square brackets to distinguish between a quantity rather than a base unit was helpful.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$1.2 \times 10^6 = \frac{1}{2} \times 1.3 \times A \times 8.03$ or $A = 3600$ (m ²) seen $L = 34$ (m)	C1 A1	Allow volume s⁻¹ = 28846 (m³) using 3.75×10^4 (kg s⁻¹) or 29231 (m³) using 3.8×10^4 (kg s⁻¹) Allow ECF from (a) Note: 3.4×10^n (m) scores 1 for PoT error. <u>Examiner's Comments</u> About two thirds of candidates got full marks on this item. By substituting the values into the formula, the area required is approximately 3600 m². Some candidates did not read the question and instead of thinking about area swept out being a circle, they took it to be square, giving the length of the blade to be $\sqrt{3600} = 60$ m.
		iii	(output power =) $0.42 \times 1.2 / 0.504$ (MW) $(N = 50/0.504 = 99.2)$ $N = 100$	C1 A1	Allow: $50 \times 10^6 / 0.42 = 119$ MW and then $119 / 1.2$ Not 99 Note: answer of 99.2 scores 1 mark max <u>Examiner's Comments</u> Rather more candidates got this item right. Some candidates mis-converted the unit and got values that could not be right i.e. 1 or 10^6 yet the majority arrived at 99.2 and correctly stated that the minimum number of required turbines must be 100 and not 99.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22	a		$E_k = \frac{1}{2}mv^2$ <u>and</u> $p = mv$	M1	Allow: any subject
			(Correct manipulation leading to) $E_k = \frac{1}{2} \frac{p^2}{m}$	A1	Allow: $E_k = p^2/(2m)$
	b	i	From $t = 0$ to $t = 2.0$ s: a non-zero horizontal line	B1	Judgement by eye
			From $t = 2.0$ to $t = 3.5$ s: line showing $v = 0$	B1	
			From $t = 3.5$ to $t = 4.0$ s: non-zero horizontal line showing v is <u>opposite</u> in direction <u>and</u> magnitude larger than that of line drawn at $t = 0$ to $t = 2.0$.	B1	
		ii	KE is constant.	B1	
			GPE increases linearly / proportional to t	B1	

Allow: 'at constant rate' for 'linear' Not: unqualified 'constantly'

Examiner's Comments

Nearly four fifths of candidates completed 20a well, especially if they clearly stated the equations for momentum and kinetic energy. Those that did not generally forgot that the question required an expression with 'p' and 'm' in it. $\frac{1}{2}pv$ was a common wrong answer.

20bi was answered well, with some candidates either slightly misreading the graph when the velocity became negative or not spotting that the line was steeper for the last section of the movement than it was in the first.

Most candidates spotted that the KE was constant because the velocity was constant. Rather fewer candidates explained that the GPE increased *at a constant rate*.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$V^2 = 0.80^2 + 2 \times 9.81 \times 0.40$ $V = 2.9 \text{ (m s}^{-1}\text{)}$	C1 A1	Allow 1 mark for $(2 \times 9.81 \times 0.40)^{1/2} = 2.8 \text{ (m s}^{-1}\text{)}$ <u>Examiner's Comments</u> Many candidates selected the correct equation, although did not realise that the load was not at rest when it was released. The initial velocity was found from the graph on page 22 of the paper and was 0.80 ms^{-1}.
		iv	$F = 0.12 \times 2.9/0.025$ $F = 14 \text{ (N)}$	C1 A1	Possible ECF from (iii)1 Note: use of 2.8 m s^{-1} gives $F = 13(.44 \text{ N})$ Note: $1.4 \times 10^n \text{ (N)}$ scores 1 mark <u>Examiner's Comments</u> Nearly three quarters of the candidates used the correct method for finding the average force acting on the load by considering the rate of change of momentum.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23	a		(change in) KE = (change in) GPE /AW $\frac{1}{2}(m + 0.8)v^2 = 0.6 mg$ (and hence equation as shown on QP)	M1 A1	allow $mgh = \frac{1}{2}Mv^2$ as long as it is clear that m and M are different, i.e. NOT $mgh = \frac{1}{2}mv^2$ allow linear motion equation $v^2 = u^2 + 2as$ and $F = Ma$ (W =) $mg = (m + 0.8)a$; $u = 0$ and $s = 0.6$ Examiner's Comments The challenge to candidates in answering this <i>show that</i> question was to produce a convincing proof. More chose to use constant acceleration equations and $F = ma$ rather than loss of potential energy equates to gain in kinetic energy. The difficulty in the former method was justifying the statement $F = mg = (m + 0.800) a$. Most just quoted that $a = mg / (m + 0.800)$ which immediately gave the relationship shown in the question. The difficulty with the second method was that most candidates wrote $mgh = \pm \frac{1}{2}mv^2$ as the first line of their answer. In the next line one m became $(m + 0.800)$ without explanation to give the required relationship. Only candidates who gave more explanation were credited the marks. The candidate who wrote this perfect answer (exemplar 7) solved the problem in the first method of solution by introducing the tension in the string (labelled T on Fig. 4.1). Exemplar 7 (a). Show that the relationship between v and m is $v^2 = \frac{1.20mg}{(m + 0.800)}$ where g is the acceleration of free fall. $T = 0.800 a$ $mg - T = ma$ $mg = a(0.800 + m)$ $s = 0.600$ $v = ?$ $a = ?$ $t = ?$ $v^2 = u^2 + 2as$ $v^2 = 2(0.600)a$ $v^2 = \frac{1.20mg}{(0.800 + m)}$
	b	i	$(v^2 =) 4.93$ $(\pm) 0.22$	B1 B1	allow 4.9 $(\pm) 0.2$ (same number of decimal places)

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Point (and error bar) plotted correctly Line of best-fit drawn through all points shown (use protractor tool at 49°)	B1 B1	tolerance $\pm \frac{1}{2}$ small square; possible ecf from (b)(i) allow ecf from point plotted incorrectly or point omitted <u>Examiner's Comments</u> Most candidates calculated the value of v^2 to two decimal places successfully. Fewer were successful in giving the absolute uncertainty as ± 0.22. A popular distractor was ± 0.10. On the graph of Fig. 4.2 only the correct position of the point was required to gain the mark. The length of the uncertainty bar was ignored. A significant number of candidates forgot to draw the line of best fit on the graph.
	c	i	$v^2 = \frac{1.20mg}{(m + 0.800)}$ compared with $y = mx + c$	B1	allow minimum of gradient = $v^2/[m/(m + 0.8)] = 1.2 \text{ g}$ or expect $y = v^2$ <u>and</u> $x = m/(m + 0.800)$ so gradient = $1.20g$ <u>Examiner's Comments</u> The common successful method employed by the majority was to compare the given equation with standard form for a straight line $y = mx + c$. A simple rearrangement of the relationship without any explanation was not considered to be adequate.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	one acceptable worst-fit line drawn	B1	roughly between extremes of top and bottom error bars or by eye; consequential ecfs for rest of (ii) $\Delta x > 0.13$; expect steepest 12.5 ± 0.2 or shallowest 10.3 ± 0.2 if point from bii not plotted steepest line is 12.9 answer from ± 0.8 to $1.1(\text{m s}^{-2})$; allow ecf from gradient value <u>Examiner's Comments</u> To avoid the problem of various lengths of error bar, candidates were judged to have drawn an acceptable worst fit line if it passed through opposite ends of the top and bottom bars on their graphs. Almost all gained the mark for using a triangle to determine the gradient of the line which spanned more than 0.13 on the x – scale. Most candidates were able to gain credit for finding the gradient of their graph correctly. The determination of the absolute uncertainty to one decimal place then proved to be too difficult a challenge for the majority.
			large triangle used to determine gradient	B1	
			Gradient (used to determine 'worst' g)	B1	
			absolute uncertainty given to one decimal place	B1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		card appears shorter or time measured shorter calculated speed of trolley larger gradient of graph steeper or $v^2 \propto g / AW$ so calculated g is greater	B1 B1 B1 B1	N.B. each B mark is consequential on the previous statement; e.g. ecf max of 3 marks for correct consequences of stating card appears longer or time longer <u>Examiner's Comments</u> Candidates gave full and usually clear answers to this part. There were four consequential marking points in this answer. Each candidate was given credit for every point that followed logically from the previous one, even when that previous one was incorrect. In the example (exemplar 8) shown here the candidate stated that the card appeared longer, which is incorrect. There were still three marks available for stating that the speed would appear lower and deducing that g would appear smaller. By this method most candidates were credited with at least half of the available marks. Exemplar 8 The time taken to... is increased. ✗ SO constant velocity. V decreases. ✓ (Ecf) $V^2 = \frac{m}{m+300} \cdot 1.20g$ ✓ (Ecf) Gradient would be smaller, therefore, the experimental value of g would be smaller. ✓ (Ecf)
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24	a	i	$Q = 9.0 \times 10^{-3} \times 2 \times 80 = 1.44 \text{ (C)}$ $W = (Q^2/2C =) 1.44^2/2 \times 0.12$ $W = 8.6(4) \text{ (J)}$	C1 C1 A1	ECF for incorrect Q e.g. 2/3 for use of $Q = 0.72 \text{ (C)}$ giving $W = 2.2 \text{ (J)}$ Examiner's Comments The strongest answers were those where candidates set out their response in steps; first calculating the total charge and then using a correct formula to calculate the total energy stored. Many candidates performed the steps of their calculation randomly across the answer space, making it hard to determine their method.
		ii	$(W = Pt \text{ so } 8.6 = 0.050t)$ $t = 8.6/0.050 = 170 \text{ (s)}$	A1	ECF (b)(i) for incorrect W Examiner's Comments Almost all candidates gained the mark for 3(b)(ii), as any incorrect answer to 3(b)(i) was accepted with error carried forward (ECF).

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	Level 3 (5 - 6 marks) Clear determination of input energy, procedure and analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear, relevant and substantiated.</i> Level 2 (3 – 4 marks) Clear determination of input energy and procedure, but no analysis or Clear analysis but limited determination of input energy and/or limited procedure or Attempted determination of input energy, basic procedure, and an attempt at analysis <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) A limited selection from the scientific points worthy of credit. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. 0 marks</i> No response or no response worthy of credit	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2+ for 3 marks, etc. Candidates can gain full credit for investigating the efficiency of either: Method 1(M1): GPE ($nmgh$) to energy conversion in LED (Pt) or Method 2(M2): GPE ($nmgh$) to energy stored in capacitor ($\frac{1}{2}CV^2$ or $\frac{1}{2}Q^2/C$) <u>L1 maximum for any answers which do not use GPE as input energy</u> Indicative scientific points may include: Determination of input energy - record the number of inversions, n (use electronic / top pan balance to) measure mass of magnet m (use mm ruler to) measure tube length l_t and magnet length l_m - calculate $h = l_t - l_m$ - calculate (GPE =) $nmgh$ Procedure - invert torch n times (with torch switched off) - make sure that the magnet falls the full height h between inversions - M1 switch torch on and (use stopwatch to 0.1 s to) measure time t taken until LED goes out (use video with timer for greater accuracy) - M1 use a darkened room or view LED through tube - M2 (use voltmeter across capacitor to) measure final p.d. V_f - M2 (with coulombmeter) measure final charge Q_f stored by capacitor - repeat experiment for different n Analysis of efficiency - M1 calculate $W = Pt$ where $P = 50 \text{ mW}$ - M2 calculate $W = \frac{1}{2}CV_f^2$ or $\frac{1}{2}Q_f^2/C$ - calculate efficiency = $W/nmgh$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					• compare efficiency values for different n • plot suitable graph e.g. efficiency against n / W against $nmg h$ • plot t against n (M1) / V^2 or Q^2 against n (M2) with justification • discuss shape / gradient of graph Examiner's Comments In level of response questions like 3(c), candidates must remember to refer closely to the stem of the question when planning their extended answer to make sure that they are addressing the question asked. The challenge in this question was to design an experiment that would yield results leading to a valid conclusion. Candidates could gain full credit for investigating the efficiency of gravitational potential energy (GPE) to either: • energy conversion in the LED (power x time) or • energy stored in the capacitor ($\frac{1}{2}CV^2$ or $\frac{1}{2}Q^2/C$) Candidates were then expected to describe how the efficiency would be calculated, and how they could tell whether the efficiency depended on the number of times the torch is turned or inverted, n. Many candidates were able to describe a valid graphical method, usually plotting efficiency against n, or output energy against input energy. Some candidates plotted time against number of inversions, which was able to score maximum credit provided that they clearly explained that t and n were proportional to output and input energy respectively. The best responses were those where candidates had not just stated what to plot but had gone on to describe and explain the expected shape of the graph and what its gradient would show. Exemplar 4

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Determine the length l using a ruler at eye level to reduce parallax. Measure the mass of the magnet using a mass balance and use the formula $E = mgh$ to find the gravitational potential energy. Make a circuit across the capacitor with a resistor and data logger to find different intervals of number of turns, how long the LED is lit up for and use $Pt = W$ to find the work done by the LED. Find the efficiency of the torch using $\frac{\text{output}}{\text{input}} \times 100$ for each interval and plot a graph of efficiency against number of turns and draw a line of best fit. If it goes through the origin and is straight, then energy is proportional to number of turns. Exemplar 4 shows a typical Level 2 response. The candidate is correctly trying to find the efficiency of GPE converted to electrical energy in the torch, but their response lacks the clarity and detail needed for a Level 3 response. Also, their method will not yield correct results because they have - not realised that GPE increases with the number of turns, so they need to use the formula $GPE = nmgh$. - not specified that the length h is the distance that the magnet falls, rather than the length of the tube. - not made clear which is the input and which the output energy in the (correct) efficiency formula. - used incorrect graphical analysis for their graph of efficiency against n. We want to discover whether efficiency depends on n, not demonstrate that efficiency increases proportionally to n, which is impossible.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25			A	1	<u>Examiner's Comments</u> The key to this question is to consider the GPE lost and equate it to the KE gained. The GPE lost here = mass $\times$ 9.81 $\times$ 0.20 = $\frac{1}{2} \times$ mass $\times v^2$. The masses cancel (which is why the mass wasn't given). This makes $v^2 = 3.924$. The most common wrong answer was B, as candidates had forgotten to take the square root. The correct speed is 1.98 m s⁻¹ giving the correct answer, A.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
26	Level 3 (5–6 marks) Description and explanation of pattern changes and quantitatively explains link between de Broglie wavelength and potential difference. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Clear description of how pattern changes and explanation of pattern changes and qualitatively explains link between de Broglie wavelength and potential difference or limited description of how pattern changes and quantitatively explains link between de Broglie wavelength and potential difference. <i>There is a line of reasoning presented with some structure.</i> <i>The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description of how pattern changes and limited attempts to explain qualitatively the link between de Broglie wavelength and potential difference or qualitatively explains link between de Broglie wavelength and potential difference. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1 ×6	<i>Indicative scientific points may include:</i> Description of pattern changes • Rings become closer (not just smaller) • Rings become brighter Qualitative explanation of pattern changes in terms of de Broglie wavelength and potential difference • Electrons gain greater energy • Electrons have a greater speed • Electrons have a greater momentum • Implies smaller wavelength • Smaller wavelength means less diffraction • Shorter wavelength gives shorter path differences between areas of constructive and destructive interference Quantitative explanation of pattern changes in terms of de Broglie wavelength and potential difference • $eV = \frac{1}{2}mv^2$ • $p = mv$ • $v^2 \propto V$ or $p^2 \propto V$ • $\lambda = \frac{h}{p}$ or $\lambda \propto \frac{1}{v}$ • $\lambda = \frac{h}{\sqrt{2meV}}$ or $\lambda \propto \frac{1}{\sqrt{V}}$ Examiner's Comments This question tested an understanding of electron diffraction. Many candidates gave a good qualitative explanation of how the pattern would change. High achieving candidates clearly demonstrated how the de Broglie wavelength λ was related to the potential difference V by equating the energy eV to kinetic energy, then using the definition of momentum and the de Broglie wavelength. Some candidates confused speed v with potential difference V. Many candidates gave a good qualitative explanation. Many candidates did not state that the rings would become brighter.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					 AfL Candidates should be able to describe how to use light gates. In particular, candidates should be able to indicate the measurements that are needed to determine speed and acceleration. Candidates should state that the light gates should be connected to a timer or data-logger.
					 AfL When analysing experimental data, candidates should be able to determine appropriate graphs to plot which will give a straight line (if the given relationship is true). Candidates should also be able to describe how unknown quantities may be determined using the gradient and / or y-intercept.
					 Misconception There is some confusion between the equations to use for photoelectric effect and the equations to use when considering the de Broglie wavelength. For the de Broglie wavelength, a common misconception is to relate the energy to wavelength by the equation for the energy of a photon, $E = \frac{hc}{\lambda}$
			Total	6	
27			C	1	
			Total	1	
28			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a		Arrow vertical down <u>and</u> an arrow opposite to the frictional force.	M1	Allow weight / mg / W for the downward arrow <u>and</u> tension / T / 'force in rod' / 'force in tow bar' / 'driving force' for the 'upward' arrow
			Both arrows labelled correctly.	A1	
	b		$(W_s =) 1100 \times 9.81 \times \sin 10^\circ$ or $1100 \times 9.81 \times \cos 80^\circ$	C1	Allow g instead of value
			$(W_s = 1874 \text{ N or } 1900 \text{ N})$	A0	
	c		force = $1900 + 300$ force = 2200 (N)	A1	Allow $1870 + 300 = 2170 \text{ (N)}$
	d		(distance =) $120 / \sin 10^\circ$ or 691 (m)	C1	Allow ECF from (c) Allow ECF from an incorrect attempt at first mark.
			(work done =) 2200×691	C1	
			work done = $1.5 \times 10^6 \text{ (J)}$	A1	
	e		$(A =) \pi \times \quad$ or $1.1 \times 10^{-4} \text{ (m}^2\text{)}$ 0.006^2	C1	Allow ECF from (c) Allow $x (=FL/EA) = \frac{2174 \times 0.5}{2.0 \times 10^{11} \times 1.1 \times 10^{-4}}$ Allow 2 marks for 1.2×10^{-5} ; $1.2 \times 10^{-2} \text{ m}$ used as radius Allow answer between 4.7 and $5.1 \times 10^{-5} \text{ (m)}$
			(stress =) $\frac{2200}{\pi \times 0.006^2}$ <u>and</u> $2.0 \times 10^{11} = \frac{\text{stress}}{\text{strain}}$	C1	
			$x = 4.8 \times 10^{-5} \text{ (m)}$	A1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	10	
30		i	Any THREE from: Atoms of metal vibrate (about fixed points) Water molecules have translational KE The motion of the water molecules is random Metal atoms and water molecules have the same KE	B1×3	Allow particles for atoms / molecules throughout Allow idea that water particles move past each other Not idea that the water molecules have more KE than metal atoms
		ii	($E_{\text{heater}} =$) $200 \times 10 \times 60$ or 120000 (J) ($E_{\text{water}} =$) $0.5 \times 4200 \times 40$ or 84000 (J) (energy transferred = 120000 – 84000) energy transferred = 3.6×10^4 (J)	C1 C1 A1	
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31	a	i	X at closest point on orbit to the Sun	B1	Allow X on the orbit to the <u>left</u> of the Sun
		ii	(When the asteroid orbits the sun a) line segment joining the asteroid to the Sun sweeps out equal areas in equal time (intervals) Longer distance (in orbit for the same time)	B1 B1	Allow this mark on diagram (no labelling required) Allow 'equal area swept in same time'
	b	i	Work done per unit mass to move an object from infinity (to that point)	B1	Not 'work done on 1 kg'
		ii	Manipulation of $V_{(g)} = (-) GM/r$	B1	
		iii	gradient = $(-)30.4$ or equivalent working candidate's gradient or expression = $6.67 \times 10^{-11} \times M$ and M calculated correctly from that gradient $M = 4.6 \times 10^{11}$ (kg)	C1 C1 A0	Allow ± 2 Possible ECF from incorrect gradient Allow any subject
	c		Method 1: Evidence of 2.3×10^{-3} <u>and</u> 600^{-1} or $(2.3 \times 10^{-3})^{-1}$ and 600 $\frac{1}{2} v^2 = 6.67 \times 10^{-11} \times 4.6 \times 10^{11} \times (2.3 \times 10^{-3} - 600^{-1})$ $v = 0.20 \text{ (m s}^{-1}\text{)}$ Method 2: Evidence of 7.0×10^{-2} <u>and</u> 5.1×10^{-2} from graph $\frac{1}{2} v^2 (= \Delta V_{(g)}) = 7.0 \times 10^{-2} - 5.1 \times 10^{-2}$ $v = 0.19 \text{ (m s}^{-1}\text{)}$	C1 C1 A1 (C1) (C1) (A1)	Possible ECF from (b)(iii) for either value of GM or M Allow $\frac{1}{2} v^2 = 30 \times (2.3 \times 10^{-3} - 600^{-1})$ Note answer can be 0.19 or 0.20 or 0.2 m s ⁻¹ Note answer can be 0.19 or 0.20 or 0.2 m s ⁻¹ Allow correct use of one piece of data arriving at a value for v for 1 mark max
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32			(Kinetic energy) reduces (with height)	B1	Allow idea that KE is transferred to GPE / KE store reduces and GPE store increases Not references to KE being a vector / having components for second mark
			At maximum height, KE is minimum / non-zero	B1	
			Total	2	
33			(k.e. =) $E = 5.0 \times 10^6 \times 1.6 \times 10^{-19}$	C1	$E = 8(.0) \times 10^{-13} \text{ J}$ or ($E = p^2/2m$ so) $p = \sqrt{2mE}$ Note: A value of $v = 1.6 \times 10^7 \text{ (ms}^{-1}\text{)}$ automatically scores both C1 marks even if the calculation for E is not shown or $p (= \sqrt{2mE}) = \sqrt{(2 \times 6.6 \times 10^{-27} \times 8.0 \times 10^{-13})}$ giving $p = 1.0 \times 10^{-19} \text{ (kg m s}^{-1}\text{)}$ Full substitution of values must be shown and answer (if calculated) must be correct <u>Examiner's Comments</u> This question provided an excellent opportunity for candidates to produce immaculate responses: identify the physics involved, select and write down the correct formula, do the necessary conversion (MeV to J), rearrange the formula, substitute correctly and then write the final response in standard form to a correct number of significant figures. Some of the common errors were: • forgetting to convert 5.0 MeV into J • not showing a full substitution of values (which is necessary for a 'show that' question) • not calculating the response to more than 1 s.f. (which is necessary for a 'show that' question).
			$v = \sqrt{2E/m}$ or $= \sqrt{(2 \times 8.0 \times 10^{-13} / 6.6 \times 10^{-27})} = 1.6 \times 10^7 \text{ (ms}^{-1}\text{)}$	C1	
			$p (= mv) = 6.6 \times 10^{-27} \times 1.6 \times 10^7$ giving $p = 1.1 \times 10^{-19} \text{ (kg m s}^{-1}\text{)}$	A1	
			Total	3	