PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 2: MECHANICS

WORK, ENERGY AND POWER

SCORE	PERCENTAGE
/399	%

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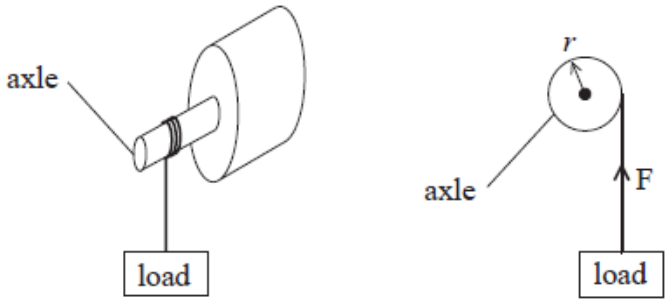
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Q1.

Motors usually have a rotating component which can do work *W*.

(a) A motor lifts a load in a time *t*. The axle of the motor has a radius *r* and exerts a force *F*.



The power produced by a motor can be calculated by using the following word equation.

Power = moment of the force exerted by the rotating axle × angular velocity

Derive this equation, starting with power $P = \frac{W}{t}$.

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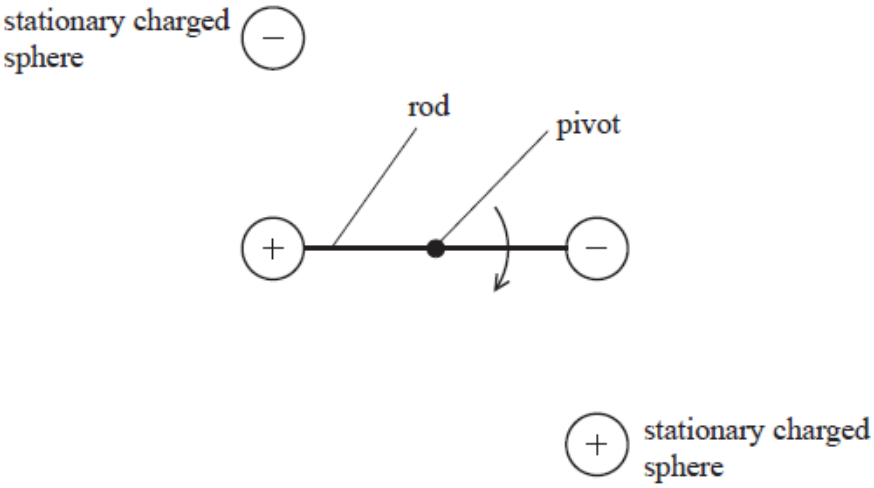
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(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

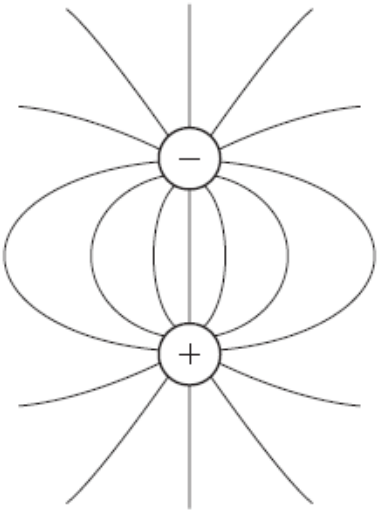


(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

(3)



(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

(2)

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

	Power / W	Angular velocity / rad s^{-1}
Electric car	2.0×10^4	300
Vacuum cleaner	1.4×10^3	1000
Small pond pump	0.5	200

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

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(Total for question = 13 marks)

Q2.

In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.



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A stone of mass 19.6 kg is accelerated uniformly for 1.25 s before being released by a curler. The stone then decelerates uniformly to rest, travelling 32.5 m in a time of 17.5 s.

Calculate the average useful power developed by the curler in accelerating the stone.

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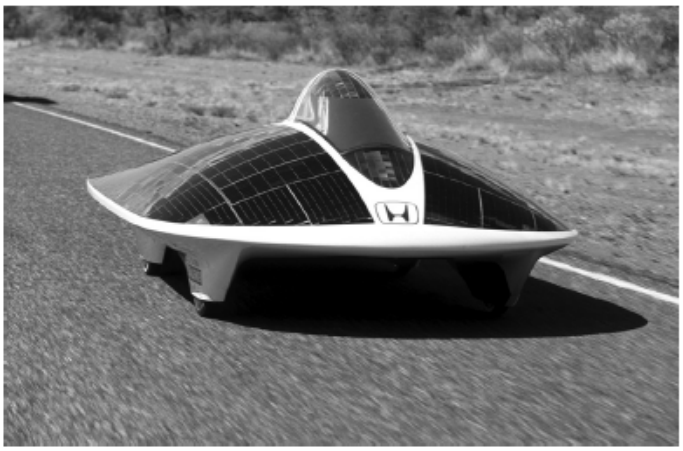
Average power = ...

(Total for question = 4 marks)

Q3.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

The vehicle can reach a maximum speed of 34 m s^{-1} on flat ground. The electric motor used to move the vehicle has a power of 4.5 kW.

(i) Calculate the initial acceleration of the vehicle as it starts from rest.

mass of vehicle and driver = 420 kg

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Initial acceleration = ...

(ii) State one assumption made in this calculation.

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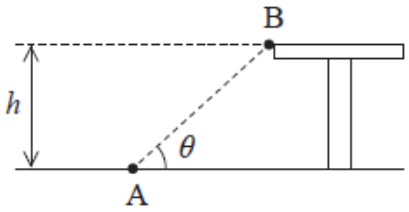
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(Total for question = 4 marks)

Q4.

An object of mass *m* is moved from point A on the ground, to point B on a bench of height *h* as

shown in the diagram.



Which of the following is a correct expression for the work done on the object?

(1)

☒ **A** $\frac{mgh}{\sin\theta}$

☒ **B** $\frac{mgh}{\cos\theta}$

☒ **C** mgh

☒ **D** $mgh\sin\theta$

(Total for question = 1 mark)

Q5.

Scientists have been studying a type of jumping spider that can jump up to six times its body length.

The scientists photographed a spider at 0.02 s intervals, during a jump. The picture is taken from the photograph and is shown actual size.



(i) Deduce whether the images show that the motion in the *x*-direction is independent of the motion in the *y*-direction. You should take measurements using the cross marking the centre of gravity of the spider.

(4)

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(ii) Show that the initial velocity of the spider at the start of the jump is about $1\,m\,s^{-1}$. You should take measurements using the cross marking the centre of gravity of the spider.

(5)

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(iii) The spider achieves this jump by extending its two back legs by 3.0 mm.

Calculate the average force the spider exerts in each leg to achieve the jump.

mass of spider = 150 mg

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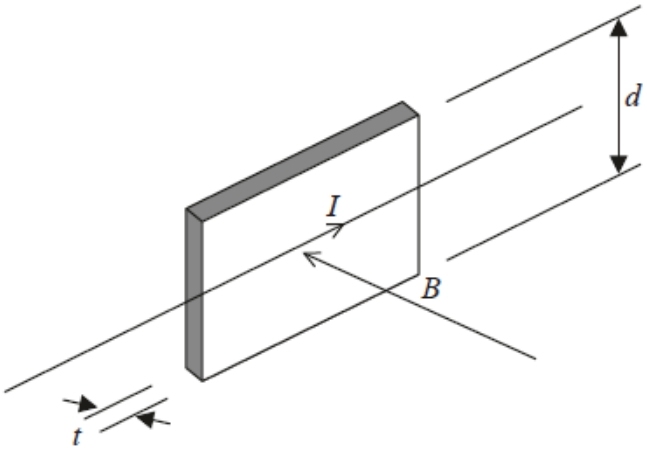
Average force = ...

(Total for question = 12 marks)

Q6.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Show that the units are the same on each side of the equation

$$V_{HALL} = \frac{BI}{nte}$$

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(Total for question = 3 marks)

Q7.

A student drives a go-kart up a slope.

The slope is at an angle of 5.7° to the horizontal. The go-kart moves with a constant velocity of 2.8 m s^{-1}.

Calculate the power of the go-kart.

mass of go-kart and driver = 60 kg

resistive force on the go-kart = 18 N

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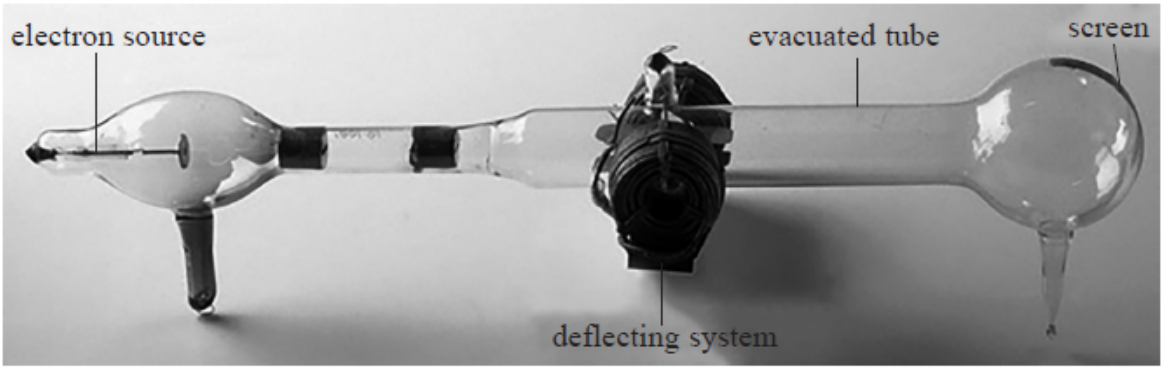
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Power = ...

(Total for question = 4 marks)

Q8.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

Explain how electrons from the source become a beam of high-energy electrons.

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(Total for question = 2 marks)

Q9.

The photograph shows an example of a Foucault pendulum.



This is a pendulum that consists of a massive sphere, suspended by a long wire from a high ceiling. Over time the vertical plane through which the pendulum swings appears to rotate because of the rotation of the Earth.

mass of sphere = 28.0 kg

To show the rotation of the Earth, the pendulum needs to oscillate for several hours.

Explain how using a heavy sphere is better than using a light sphere of the same diameter.

(3)

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(Total for question = 3 marks)

Q10.

A planet moves around the Sun in a circular orbit of circumference $2\pi r$. The work done in one orbit on the planet by the gravitational force F is

☒ **A** 0

☒ **B** $\pi Fr/2$

☒ **C** πFr

☒ **D** $2\pi Fr$

(Total for question = 1 mark)

Q1.

The photograph shows a vase made of uranium glass. Uranium glass is radioactive.



Uranium glass usually contains a maximum of 2% uranium. Uranium glass made in the early part of the 20th century can contain up to 25% uranium.

A uranium nucleus decays to thorium by emission of an alpha particle.

It can be assumed that all the energy of the decay is transferred to kinetic energy of the alpha particle.

Calculate the speed of the emitted alpha particle.

mass of uranium nucleus = 238.0003 u
mass of thorium nucleus = 233.9942 u
mass of alpha particle = 4.0015 u

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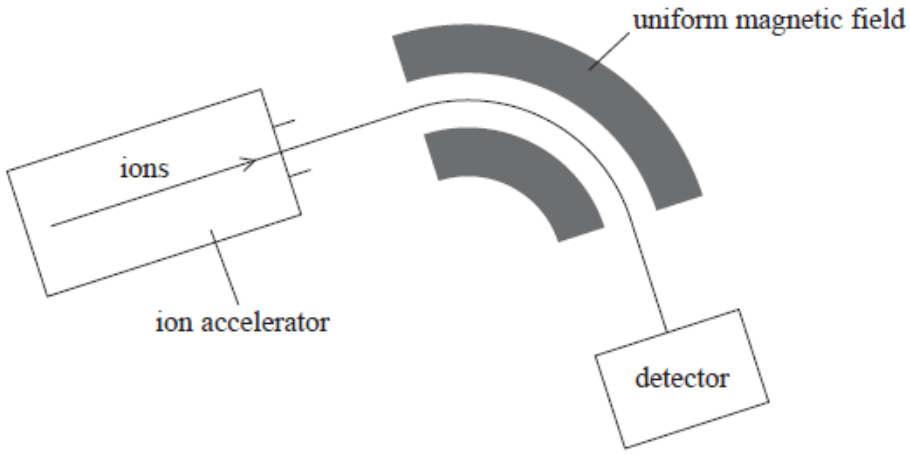
Speed of alpha particle = ...

(Total for question = 5 marks)

Q2.

Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam. This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

In a mass spectrometer, chlorine-35 ions are accelerated through a potential difference of 8.50 kV to produce an ion beam.

Show that the speed of singly ionised chlorine-35 atoms is about 2.2×10^5 m s^{-1}.

mass of an ion of chlorine-35 = 34.97 u

(4)

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(Total for question = 4 marks)

Q3.

In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.



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A stone of mass 19.6 kg is accelerated uniformly for 1.25 s before being released by a curler. The stone then decelerates uniformly to rest, travelling 32.5 m in a time of 17.5 s.

Calculate the average useful power developed by the curler in accelerating the stone.

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Average power = ...

(Total for question = 4 marks)

Q4.

In 1990, the Hubble Space Telescope (HST) was launched into a low Earth orbit above the Earth's

atmosphere.

HST orbits the Earth in a circular orbit with a speed of 7.59 km s^{-1}.

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

(i) Show that the height of HST above the surface of the Earth is about 6×10^{5} m.

(3)

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(ii) Calculate the increase in the gravitational potential energy as HST is raised, from its initial position at the Earth's surface, to its orbital height.

mass of HST = 11 600 kg

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Increase in gravitational potential energy = ...

(iii) A student suggests that giving HST more energy than that required in (ii) would result in the satellite orbiting at a greater height and with a greater speed.

Assess the validity of the student's suggestion.

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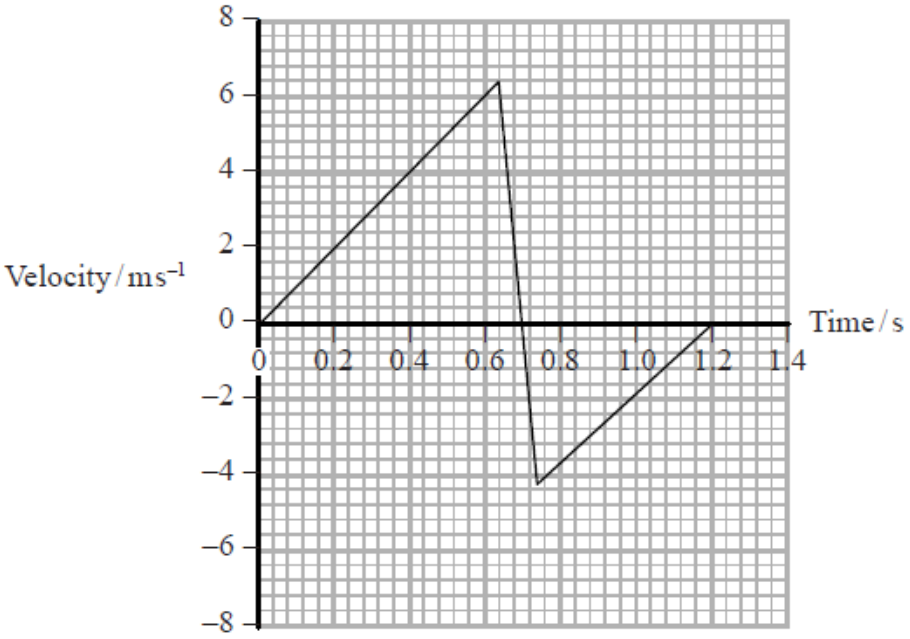
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(Total for question = 9 marks)

Q5.

A stationary ball is released from a height of 2.0 m onto a hard surface.

The simplified velocity-time graph shows the motion of the ball as it falls and bounces back to its maximum height.



(a) Calculate the maximum height reached by the ball after bouncing.

(2)

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Maximum height = ...

(b) Calculate the decrease in kinetic energy of the ball as it bounces.

mass of ball = 60 g

(2)

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Decrease in kinetic energy = ...

(c) Calculate the resultant force on the ball when it is in contact with the ground.

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Resultant force = ...

(d) The ball is replaced with one that is softer. It is released from a height of 2.0 m onto the same surface as before. A velocity-time graph is drawn to show the motion of the new ball.

Describe the similarities and differences between the two graphs.

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(Total for question = 10 marks)

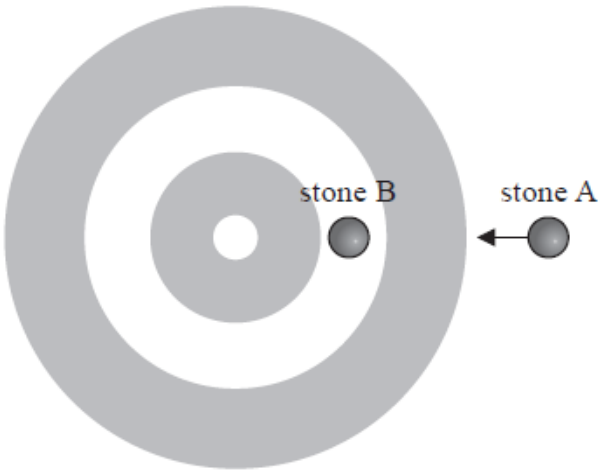
Q6.

In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.



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* Stone B is stationary. Stone A travels towards the target and makes a direct hit on stone B as shown. Both stones have mass *m*.



The collision is elastic. Just before the collision stone A has a velocity *v*. After the collision stone B moves off with velocity *v*.

Discuss how the relevant conservation laws apply to this collision.

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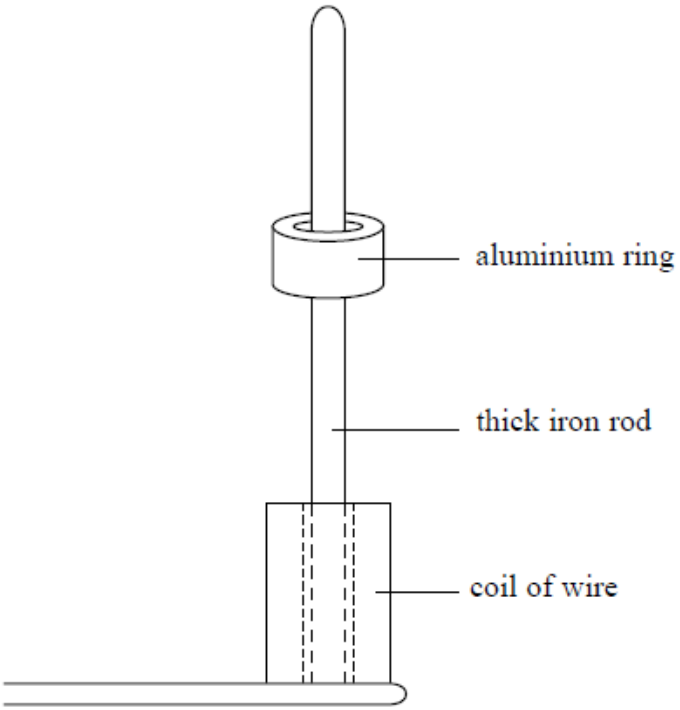
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(Total for question = 6 marks)

Q7.

A coil of wire is placed around the lower end of an iron rod. The coil is supplied with an alternating current.

A thick aluminium ring is placed around the iron rod above the coil. The coil remains in the position shown.



The current is switched off and the aluminium ring comes to rest on top of the coil.
The supply to the coil is changed and a direct current (dc) is switched on. An upwards force *F* acts on the ring for 0.05 s accelerating it to a final speed, *v*. The ring then moves freely through a height of 30 cm.

Mean diameter of ring = 4.8 cm
Mass of ring = 0.019 kg
Magnetic field strength = 0.032 T

(i) Use conservation of energy to calculate the speed *v* of the ring after 0.05 s.

(2)

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v = ...

(ii) Use the idea of impulse to calculate the magnitude of the mean force *F* acting on the ring and hence the mean current *I* in the ring.

(6)

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F = ...

I = ...

(Total for question = 8 marks)

Q8.

(a) State what is meant by the de Broglie wavelength.

(2)

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(b) An electron is accelerated from rest, in a vacuum, through a potential difference of 500 V.

(i) Show that the final momentum of the electron is about 1×10^{-23} N s.

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(ii) Calculate the de Broglie wavelength for this electron.

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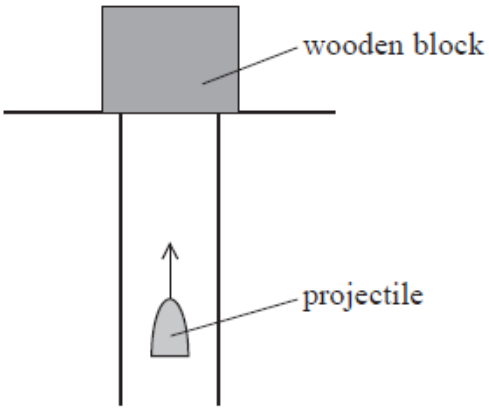
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de Broglie wavelength = ...

(Total for question = 7 marks)

Q9.

A projectile of mass 65 g is fired vertically upwards into a stationary wooden block of mass 2.400 kg, as shown.



The projectile becomes embedded in the block. They both move vertically upwards through a vertical displacement of 55 cm before momentarily coming to rest.

Calculate the energy dissipated as the projectile hits the block.

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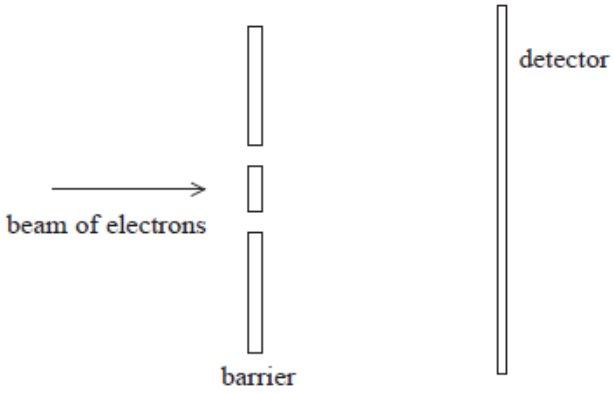
Energy dissipated = ...

(Total for question = 6 marks)

Q10.

In 1965, Richard Feynman proposed a double slit experiment to investigate the wave properties of electrons.

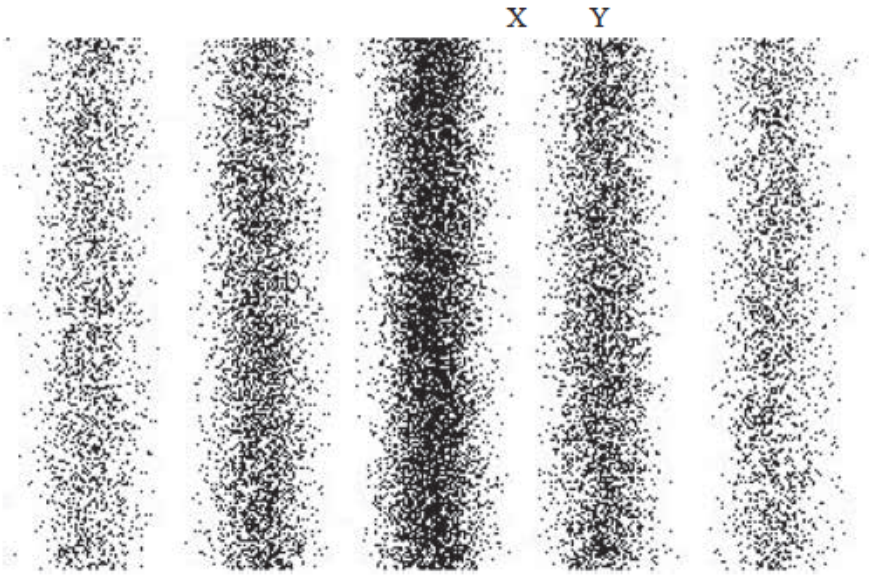
The experiment was later carried out using the arrangement shown.



A beam of electrons was directed at a barrier with two slits.

The detector recorded the positions where electrons arrived after passing through the slits.

The following pattern was obtained. Black dots represent points where electrons were detected. A band where electrons were not detected has been labelled X and a band where electrons were detected has been labelled Y.



The path difference for electrons arriving at band X from the separate slits was 2.5×10^{-1} m. For electrons arriving at band Y the path difference was 5.0×10^{-1} m.

Explain why this pattern is observed when the electron energy is 9.6×10^{-1} J.

The electrons are travelling at non-relativistic speeds.

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(Total for question = 6 marks)

Q11.

It was suggested on an online forum that it would be possible to cook a chicken by repeatedly slapping the chicken with one hand.

It was claimed that the energy transferred to a chicken in 8000 slaps would be sufficient to raise the temperature of the chicken from 23 °C to 165 °C.

In an investigation to test the claim, the effective mass of the hand was taken as 1.75 kg and the speed of the hand just before impact with the chicken as 6.25 m s^{-1}.

Deduce whether the data confirms that 8000 slaps would be sufficient.

Assume that no energy is transferred from the chicken to the surroundings.

mass of chicken = 0.875 kg

specific heat capacity of chicken = 1770 J kg^{-1} K^{-1}

efficiency of energy transfer from the hand = 65%

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(Total for question = 5 marks)

Q12.

Scientists have been studying a type of jumping spider that can jump up to six times its body length.

The scientists photographed a spider at 0.02 s intervals, during a jump. The picture is taken from the photograph and is shown actual size.



(i) Deduce whether the images show that the motion in the *x*-direction is independent of the motion in the *y*-direction. You should take measurements using the cross marking the centre of gravity of the spider.

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(ii) Show that the initial velocity of the spider at the start of the jump is about $1\ m\ s^{-1}$. You should take measurements using the cross marking the centre of gravity of the spider.

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(iii) The spider achieves this jump by extending its two back legs by 3.0 mm.

Calculate the average force the spider exerts in each leg to achieve the jump.

mass of spider = 150 mg

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Average force = ...

(Total for question = 12 marks)

Q13.

Astronomers observing stars at the centre of our galaxy have suggested that many of them are orbiting a supermassive black hole. The mass of this black hole is 9.2×10^{36} kg.

The star S0-2 is in a highly elliptical orbit around the position of the black hole.

At its point of closest approach, S0-2 is at a distance of 1.8×10^{13} m from the centre of the black hole.

At the most distant point of its orbit, S0-2 is 2.7×10^{14} m from the black hole.

(i) Show that the change in gravitational potential between the closest and most distant points in this orbit is about 3×10^{13} J kg^{-1}.

(2)

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(ii) At its point of closest approach, the star is travelling at a speed of 8.1×10^{6} m s^{-1}.

Calculate the speed of S0-2 at the furthest point in its orbit using the change in gravitational potential.

mass of S0-2 = 2.4×10^{31} kg

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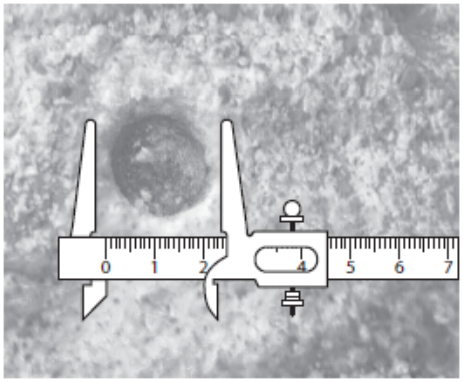
Speed = ...

(Total for question = 5 marks)

Q14.

Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

In one test, the spheres were dropped from the same height.

Determine the factor by which the kinetic energy of the sphere just before impact increases when the sphere diameter is increased from 2.0 cm to 4.0 cm.

(3)

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Factor = ...

(Total for question = 3 marks)

Q15.

Seat belts are being tested by a car manufacturer. In the test, a car moving at a steady speed of 28 m s^{-1} collides with a wall and stops.

A crash-test dummy in the driving seat is wearing a seat belt made from polyester webbing. The seat belt has a cross-sectional area of 0.85 cm^2 and a total length of 2.0 m. A student suggests that in the collision the seat belt absorbs all the kinetic energy of the dummy.

Show that the energy per unit volume that would have to be absorbed by the seat belt is about 2 × 10^8 J m^{-3}.

mass of dummy = 75 kg

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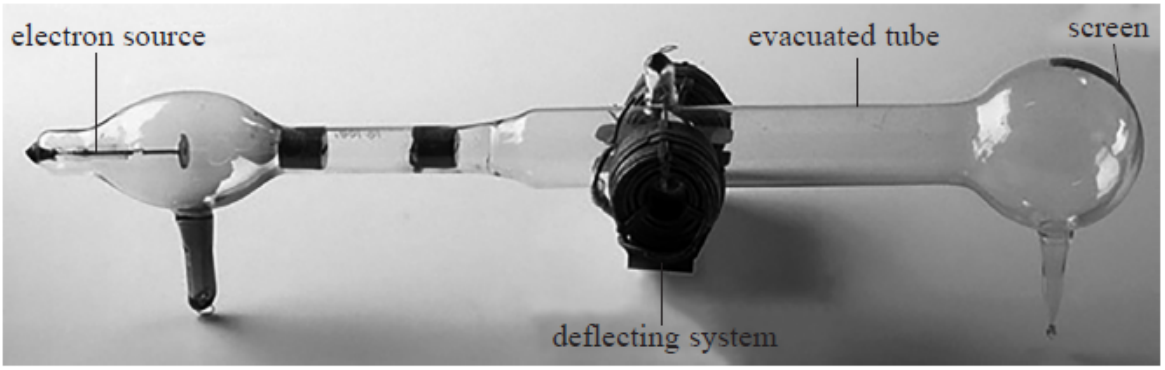
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(Total for question = 3 marks)

Q16.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



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Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In a modern version of Thompson's experiment, a uniform electric field of electric field strength E is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where B is the magnetic flux density of the magnetic field.

(2)

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V.

The electric field strength is 1.4×10^4 V m^{-1}. The magnetic flux density is 1.5×10^{-3} T.

Calculate the value of the specific charge e/m for the electron using this data.

(3)

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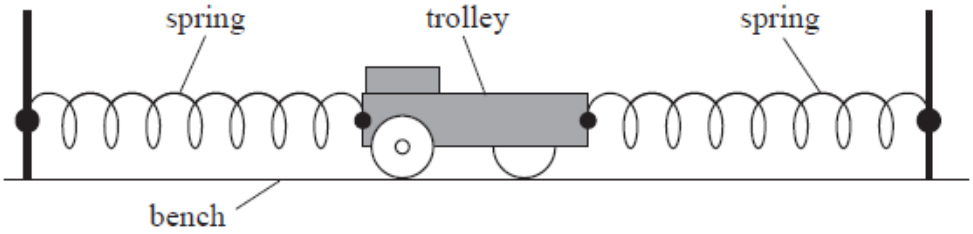
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e/m = ...

(Total for question = 5 marks)

Q17.

A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



The student displaces the trolley a greater distance from the equilibrium position, so the amplitude of oscillation is doubled. The trolley still moves with simple harmonic motion.

Explain how the maximum kinetic energy of the trolley will change.

(3)

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(Total for question = 3 marks)

Q18.

Astronauts on the 1971 Apollo 14 mission to the Moon brought back many rock samples. It is now believed that one of these contains a piece of rock that originated on Earth about 4 billion years (4×10^9 years) ago.

The piece of rock is believed to have been launched into space when an asteroid struck the Earth.

The gravitational potential between the Earth and the Moon due to the combined effect of their gravitational fields increases to a maximum value of $-1.28\,\text{MJ}\,\text{kg}^{-1}$ at a point between them.

Calculate the minimum speed at which a rock would have to leave the Earth in order to reach the Moon.

In your calculation, you may assume the rock has zero kinetic energy when it has maximum potential energy.

mass of Earth = $5.97 \times 10^{24}\,\text{kg}$
radius of Earth = $6370\,\text{km}$

(4)

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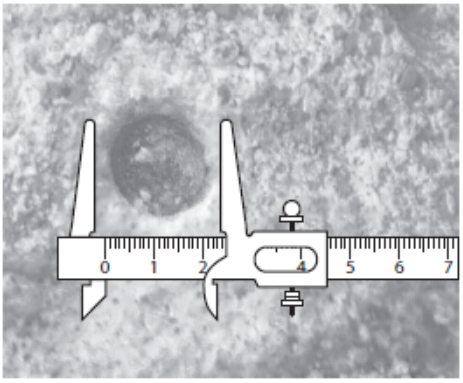
Minimum speed = ...

(Total for question = 4 marks)

Q19.

Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

* The student also dropped the spheres from different heights. His results are shown in the table.

Drop height / m	Sphere diameter / cm	Crater diameter / cm
0.30	2.0	3.6
	4.0	7.0
	6.0	6.8
0.60	2.0	4.8
	4.0	7.5
	6.0	7.3
0.90	2.0	5.6
	4.0	8.0
	6.0	8.3

The student wrote the following conclusion:

"The greater the drop height, the greater the diameter of the crater formed when a sphere hits the sand. This is because the impact velocity increases as the drop height is increased. As the speed of the sphere increases the diameter of the crater formed also increases. Also, the bigger the sphere the bigger the crater."

Assess the validity of the student's conclusion.

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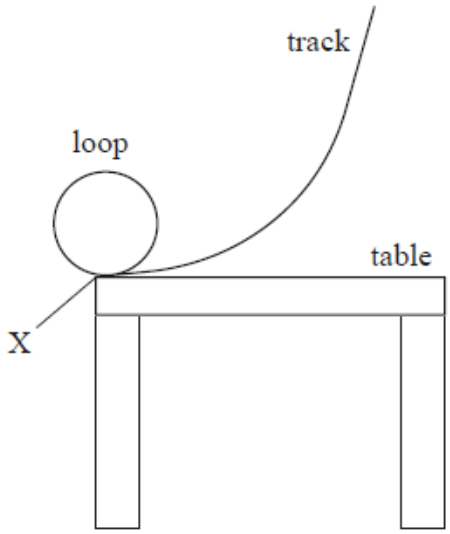
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(Total for question = 6 marks)

Q20.

A track for toy cars can be built with a circular loop as shown.



A toy car is placed on the track at various heights. It travels around the loop before leaving the track horizontally at X.

The toy car just completes the loop without losing contact with the track.

Show that the speed of the toy car at the bottom of the loop is about 3 m s^{-1}.

r = 0.15 m

(3)

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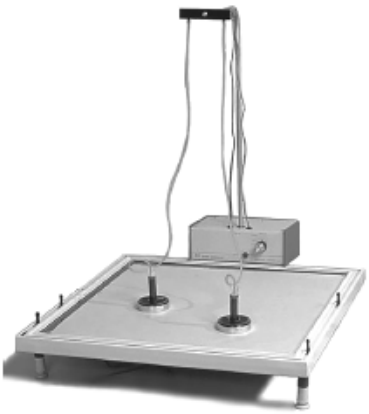
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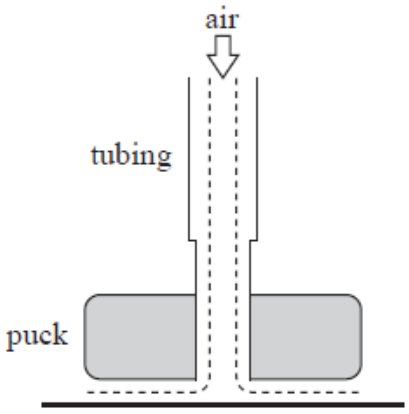
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(Total for question = 3 marks)

Q21.

A teacher is demonstrating the principle of conservation of momentum using a flat glass surface and air pucks. Lightweight tubing supplies compressed air to the pucks which is forced out from the bottom of the pucks. This means that the pucks move with very little friction across the glass surface.





(a) Explain, using ideas about molecular movement, how the puck is able to hover a small distance above the glass surface.

(4)

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*(b) Applying Newton's 2nd and 3rd laws of motion to the collision between two pucks leads to the conclusion that momentum is conserved.

Justify this statement.

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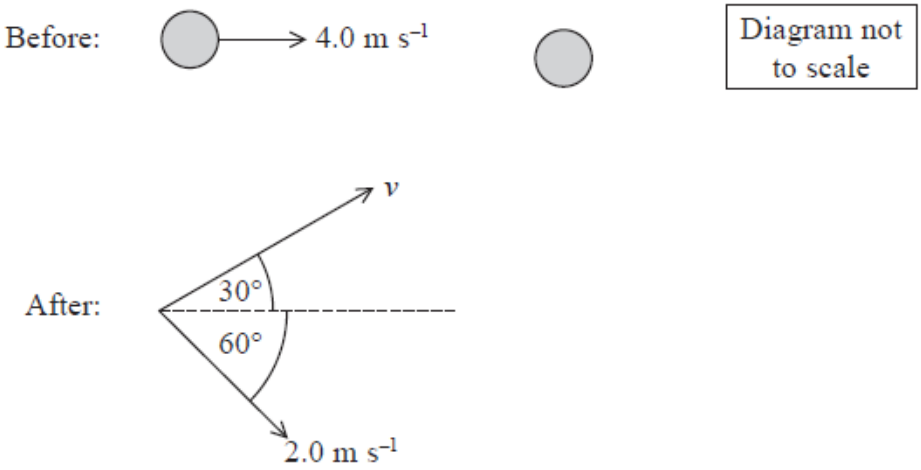
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(c) The teacher uses two identical pucks to investigate collisions. In one collision, one puck moves with a velocity of 4.0 m s^{-1} and collides with a second puck that is stationary.
After the collision, the first puck has a velocity *v* at an angle of 30° to its original direction, and the second puck moves off with a velocity of 2.0 m s^{-1} at an angle of 60° to the original direction.



(i) Show that the magnitude of the velocity v of the first puck after the collision is about 3.5 m s^{-1}.

(3)

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(ii) Use the data to determine if the collision is elastic or inelastic.

(3)

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(Total for question = 16 marks)

Q22.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer

with a cross ☒.

The velocity v of a non-relativistic particle can be expressed in terms of combinations of the following quantities: kinetic energy E_k, momentum p and mass m.

Which of the following expressions is correct?

☒ **A** $v = \frac{p^2}{m}$

☒ **B** $v = \sqrt{\frac{2E_k}{m}}$

☒ **C** $v = \frac{E_k}{2p}$

☒ **D** $v = \frac{2E_k}{pm}$

(Total for question = 1 mark)

Q23.

An electron gun uses a potential difference V to accelerate electrons of mass m and charge e from rest to a speed v.
The potential difference V can be expressed as

☒ **A** $\frac{mv^2}{2e}$

☒ **B** $\frac{2ev^2}{m}$

☒ **C** $\sqrt{\frac{2ev}{m}}$

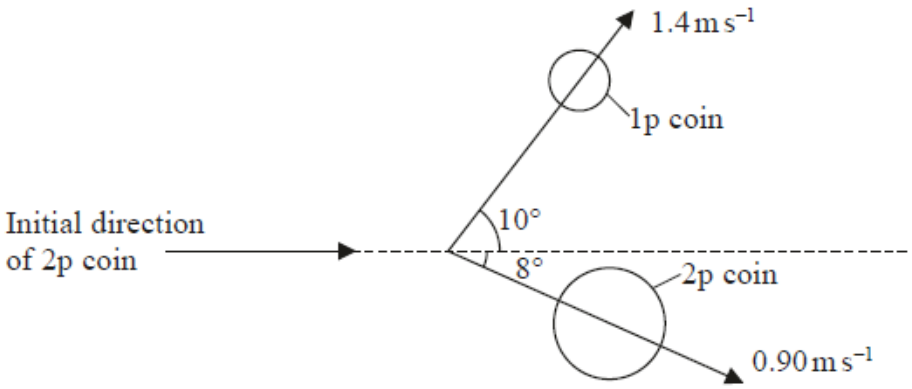
☒ **D** $\sqrt{\frac{mv}{2e}}$

(Total for question = 1 mark)

Q24.

A student carried out an experiment with coins.

She arranged a collision between a 2p coin and a stationary 1p coin. She noted the directions in which the coins moved after the collision and determined their velocities.



(i) Show that the velocity of the 2p coin just before the collision was about 2 m s^{-1}.

mass of 2p coin = 7.1 g

mass of 1p coin = 3.6 g

(4)

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(ii) Show that the collision was inelastic.

(2)

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(Total for question = 6 marks)

Q25.

In 2015 the Messenger spacecraft crashed into the surface of the planet Mercury after four years in orbit observing the surface of Mercury.

Messenger's orbit was highly elliptical, varying between 200 km and 15 000 km above the surface of Mercury. Messenger completed one full orbit every 12 hours.

mass of Messenger spacecraft = 565 kg
mass of planet Mercury = 3.30×10^{23} kg
radius of planet Mercury = 2430 km

Calculate the velocity an object would have as it reached the surface of Mercury if it was released from Messenger's maximum orbital height.
Assume the object is released from rest and that Mercury has no atmosphere.

(4)

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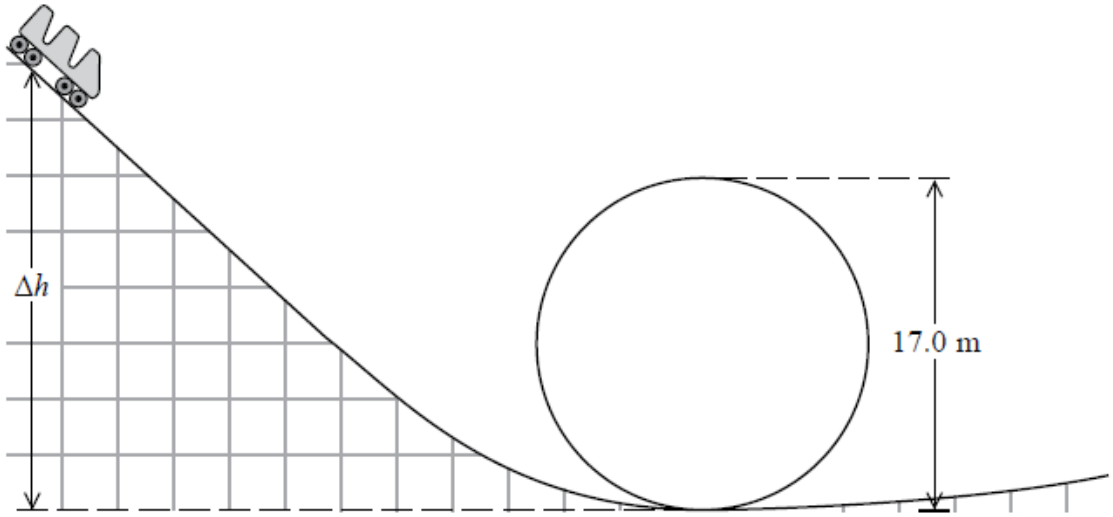
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Velocity = ...

(Total for question = 4 marks)

Q1.

The diagram shows the carriage of a rollercoaster about to enter a vertical loop of diameter 17.0 m. The carriage is initially at rest at a height Δh above the bottom of the loop.



(i) So that a passenger remains in contact with their seat at the top of the ride, show that the minimum speed of the car at the top of the loop is 9.1 m s^{-1}.

(3)

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(ii) Calculate the minimum value of Δh that will enable the passenger to remain in contact with their seat at the top of the loop.

(3)

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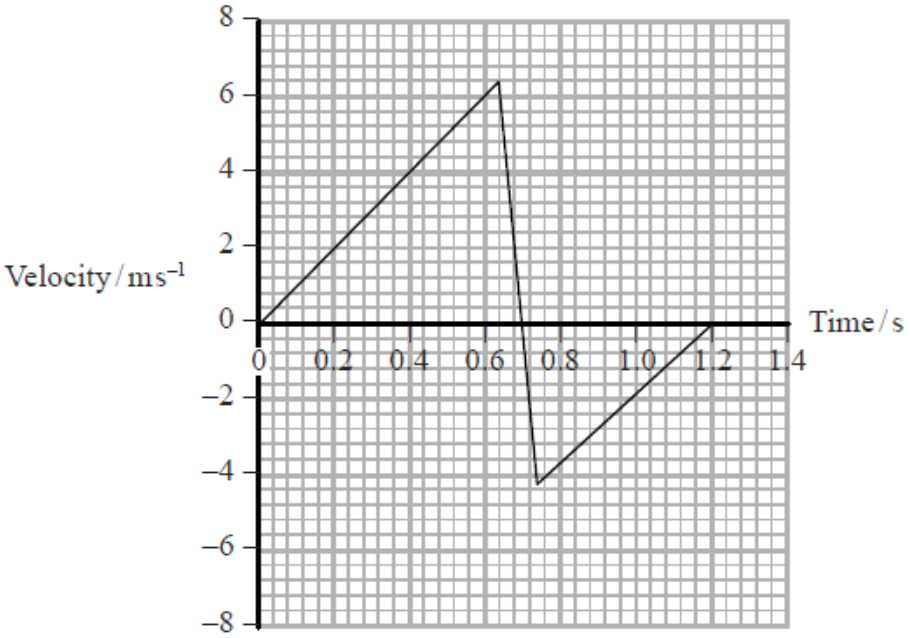
Δh = ...

(Total for question = 4 marks)

Q2.

A stationary ball is released from a height of 2.0 m onto a hard surface.

The simplified velocity-time graph shows the motion of the ball as it falls and bounces back to its maximum height.



(a) Calculate the maximum height reached by the ball after bouncing.

(2)

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Maximum height = ...

(b) Calculate the decrease in kinetic energy of the ball as it bounces.

mass of ball = 60 g

(2)

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Decrease in kinetic energy = ...

(c) Calculate the resultant force on the ball when it is in contact with the ground.

(3)

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Resultant force = ...

(d) The ball is replaced with one that is softer. It is released from a height of 2.0 m onto the same surface as before. A velocity-time graph is drawn to show the motion of the new ball.

Describe the similarities and differences between the two graphs.

(3)

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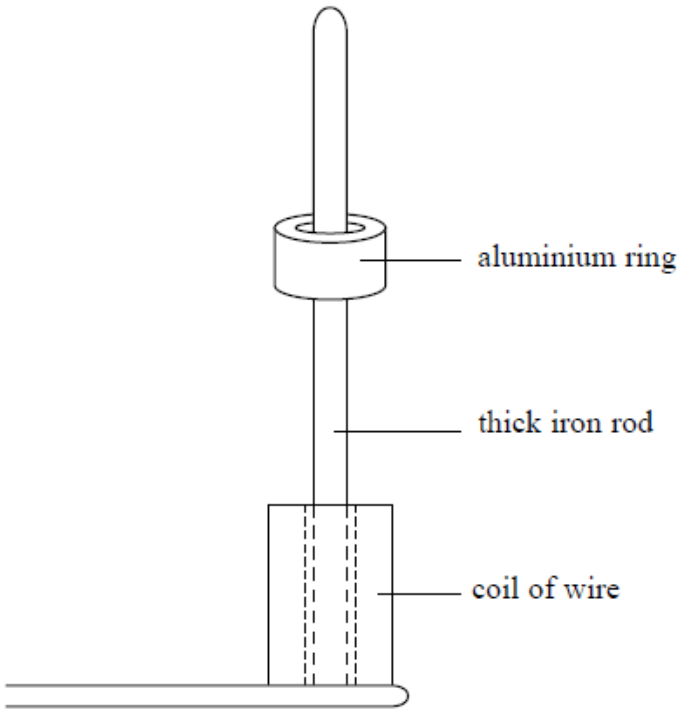
(Total for question = 10 marks)

Q3.

A coil of wire is placed around the lower end of an iron rod. The coil is supplied with an alternating current.

A thick aluminium ring is placed around the iron rod above the coil. The coil remains in the

position shown.



The current is switched off and the aluminium ring comes to rest on top of the coil.
The supply to the coil is changed and a direct current (dc) is switched on. An upwards force *F* acts on the ring for 0.05 s accelerating it to a final speed, *v*. The ring then moves freely through a height of 30 cm.

Mean diameter of ring = 4.8 cm
Mass of ring = 0.019 kg
Magnetic field strength = 0.032 T

(i) Use conservation of energy to calculate the speed *v* of the ring after 0.05 s.

(2)

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v = ...

(ii) Use the idea of impulse to calculate the magnitude of the mean force *F* acting on the ring and hence the mean current *I* in the ring.

(6)

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F = ...

I = ...

(Total for question = 8 marks)

Q4.

The diagram shows a battery-powered clock on a wall. It has a minute hand and an hour hand.



(a) Calculate the average angular velocity of the minute hand.

(2)

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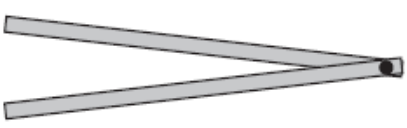
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Angular velocity = ...

(b) The diagram shows the position of the minute hand when the time is 1 : 44 and when the time is 1 : 46.



The diagram is not to scale.

Show that the work done against the force of gravity to move the minute hand from 1 : 44 to 1 : 46 is about 1 mJ.

mass of minute hand = 14 g

length of minute hand = 8.0 cm

(5)

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(c) The clock uses a 1.5 V cell and draws a maximum current of 8.0 μA.

After a time, the maximum power of the cell has reduced to 65% of its initial value making the clock run slowly.

Calculate the time taken for the minute hand to move from the 1 : 44 position to the 1 : 46 position.

(3)

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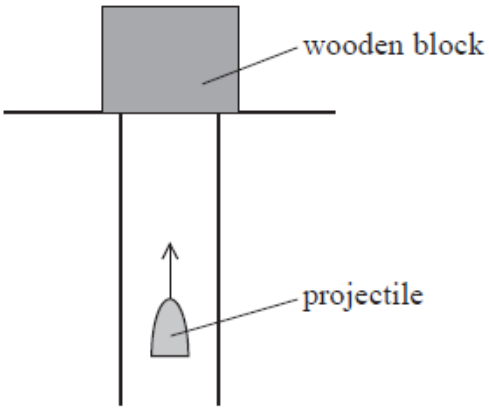
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Time taken = ...

(Total for question = 10 marks)

Q5.

A projectile of mass 65 g is fired vertically upwards into a stationary wooden block of mass 2.400 kg, as shown.



The projectile becomes embedded in the block. They both move vertically upwards through a vertical displacement of 55 cm before momentarily coming to rest.

Calculate the energy dissipated as the projectile hits the block.

(6)

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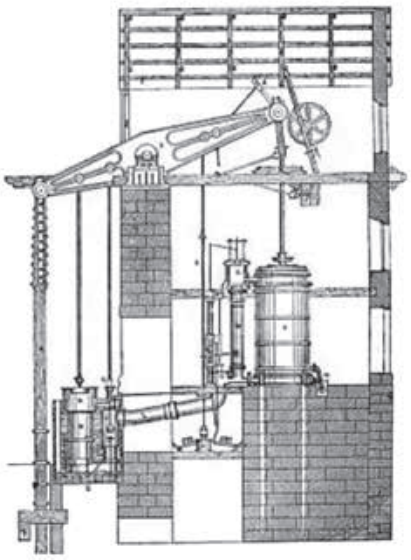
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Energy dissipated = ...

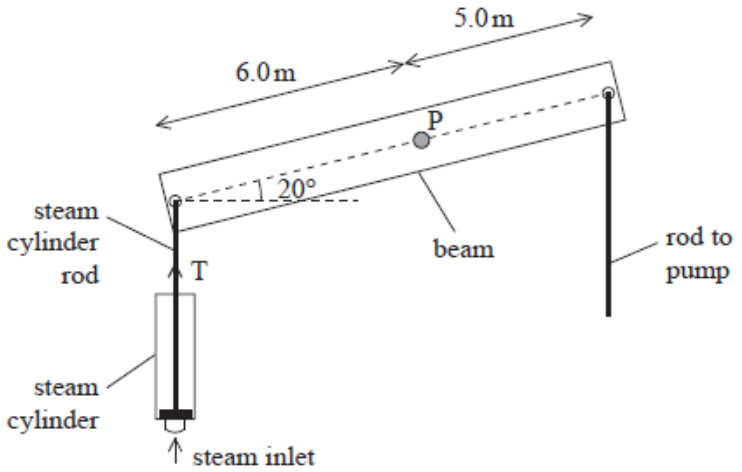
(Total for question = 6 marks)

Q6.

Beam engines contributed to powering the Industrial Revolution in Britain in the 18th century. A beam engine consisted of a beam which could rock to and fro around a well-oiled pivot. Attached to the beam there are two rods, one connected to a piston in a steam cylinder and the other connected to a pump.



The diagram below shows a simplified arrangement of a beam engine.



The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10 %.

Deduce whether this claim for efficiency was correct.

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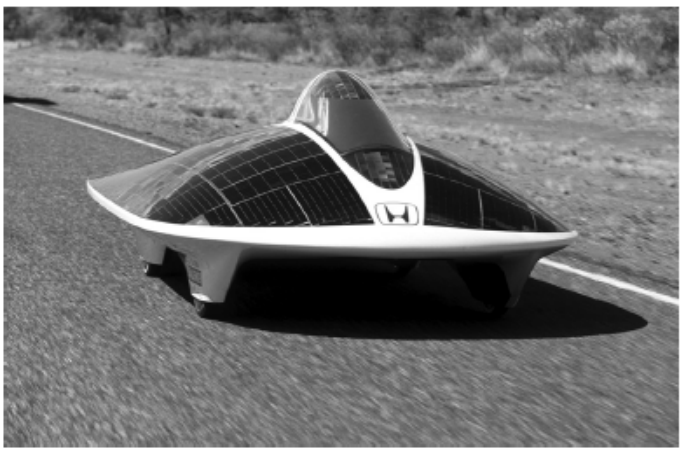
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(Total for question = 5 marks)

Q7.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

Solar power alone would not be suitable for a family car because it is not sunny all the time.

Give two further reasons why solar power alone would not be suitable.

(2)

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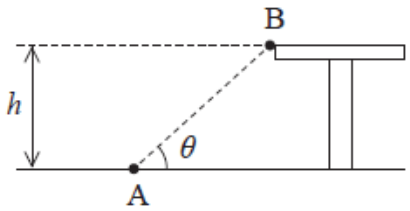
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(Total for question = 2 marks)

Q8.

An object of mass m is moved from point A on the ground, to point B on a bench of height h as shown in the diagram.



Which of the following is a correct expression for the work done on the object?

(1)

☒ **A** $\frac{mgh}{\sin\theta}$

☒ **B** $\frac{mgh}{\cos\theta}$

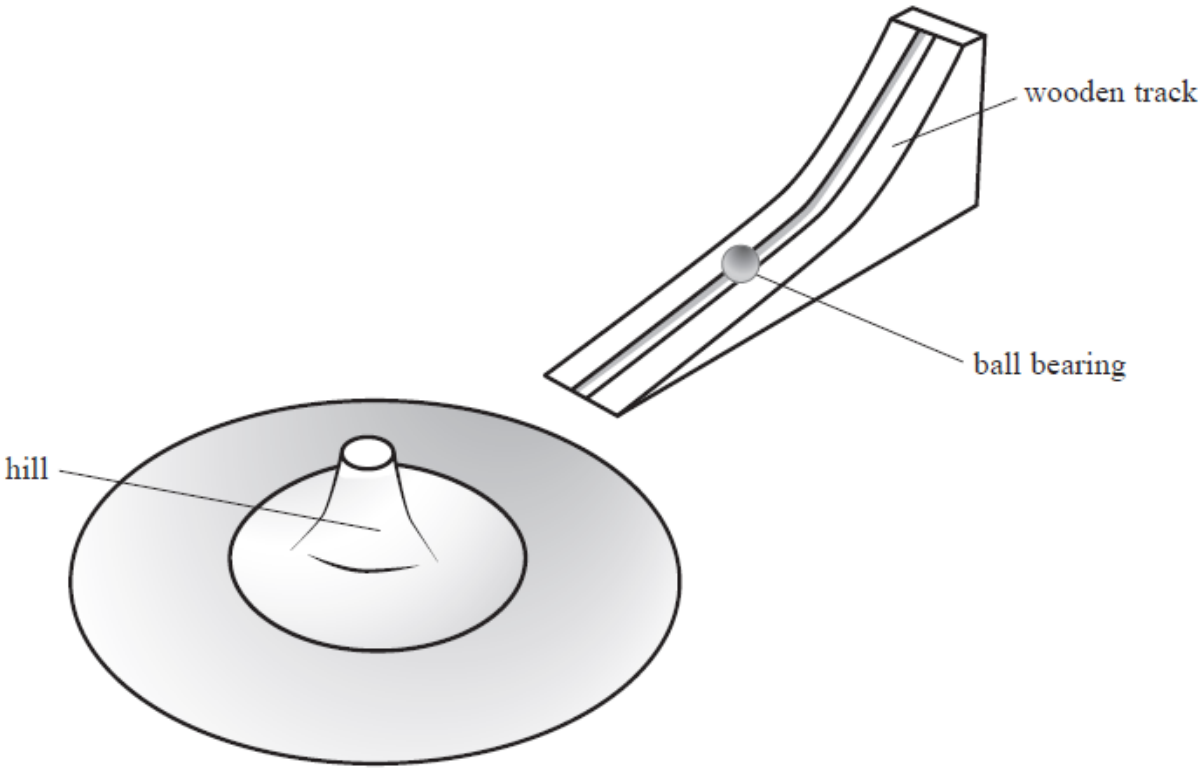
☒ **C** mgh

☒ **D** $mgh\sin\theta$

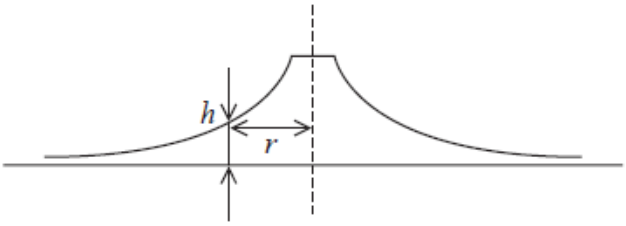
(Total for question = 1 mark)

Q9.

The diagram shows a model used to demonstrate alpha particle scattering. A ball bearing is set rolling on a wooden track. The track is positioned so that the ball bearing rolls onto a metal sheet with a curved surface known as a 'hill'.



The diagram shows a vertical cross-section through the hill. The surface is curved so that the height of a point *h* on the curved surface is inversely proportional to the distance *r* from the centre of the hill.



Explain why the hill is suitable as a model for the electric field surrounding the nucleus of an atom.

(3)

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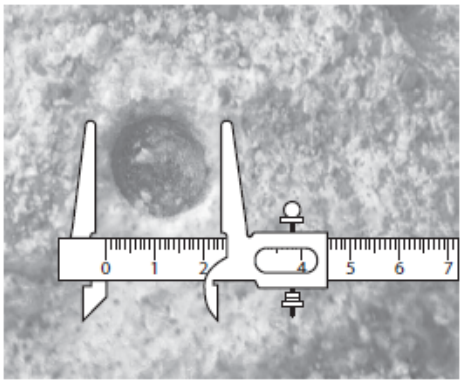
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(Total for question = 3 marks)

Q10.

Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

* The student also dropped the spheres from different heights. His results are shown in the table.

Drop height / m	Sphere diameter / cm	Crater diameter / cm
0.30	2.0	3.6
	4.0	7.0
	6.0	6.8
0.60	2.0	4.8
	4.0	7.5
	6.0	7.3
0.90	2.0	5.6
	4.0	8.0
	6.0	8.3

The student wrote the following conclusion:

"The greater the drop height, the greater the diameter of the crater formed when a sphere hits the sand. This is because the impact velocity increases as the drop height is increased. As the speed of the sphere increases the diameter of the crater formed also increases. Also, the bigger the sphere the bigger the crater."

Assess the validity of the student's conclusion.

(6)

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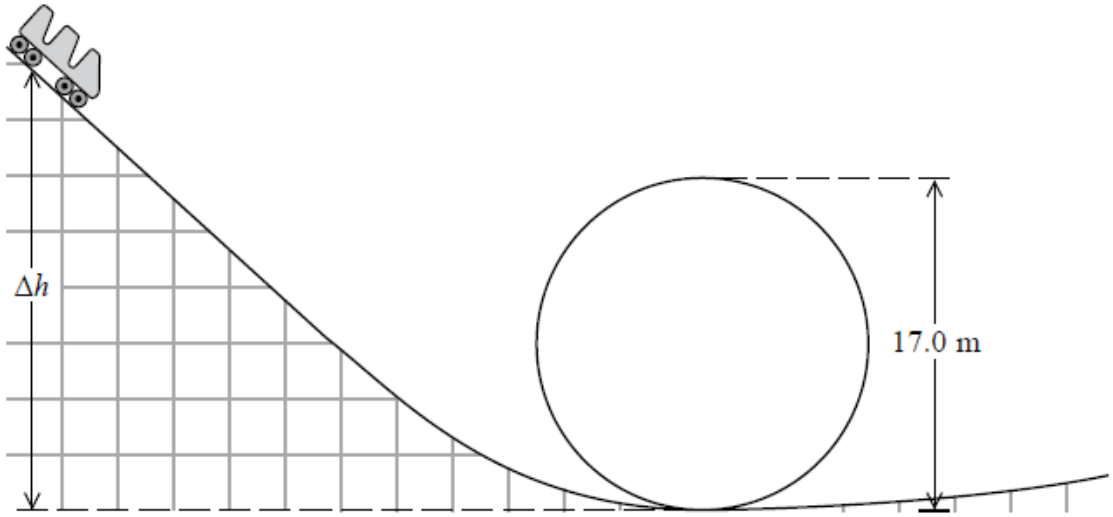
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(Total for question = 6 marks)

Q1.

The diagram shows the carriage of a rollercoaster about to enter a vertical loop of diameter 17.0 m. The carriage is initially at rest at a height Δh above the bottom of the loop.



(i) So that a passenger remains in contact with their seat at the top of the ride, show that the minimum speed of the car at the top of the loop is 9.1 m s^{-1}.

(3)

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(ii) Calculate the minimum value of Δh that will enable the passenger to remain in contact with their seat at the top of the loop.

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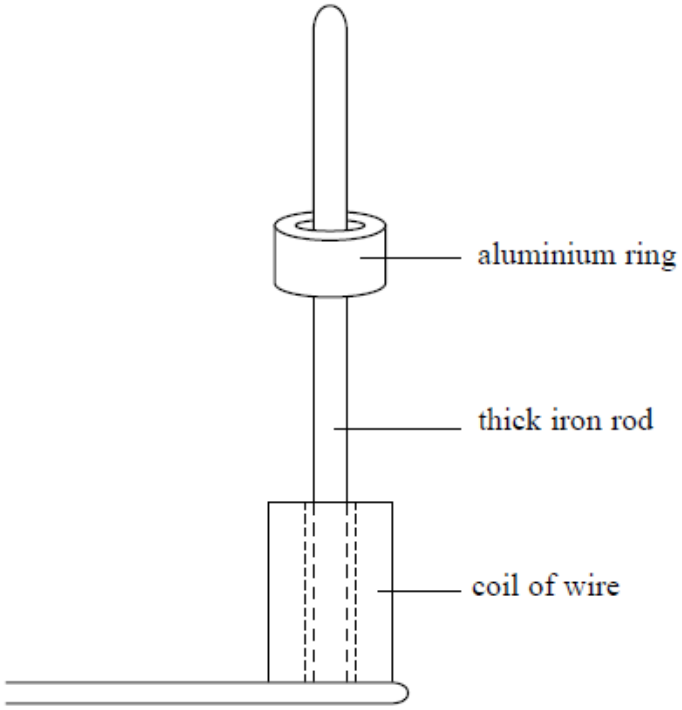
Δh = ...

(Total for question = 4 marks)

Q2.

A coil of wire is placed around the lower end of an iron rod. The coil is supplied with an alternating current.

A thick aluminium ring is placed around the iron rod above the coil. The coil remains in the position shown.



The current is switched off and the aluminium ring comes to rest on top of the coil.
The supply to the coil is changed and a direct current (dc) is switched on. An upwards force *F* acts on the ring for 0.05 s accelerating it to a final speed, *v*. The ring then moves freely through a height of 30 cm.

Mean diameter of ring = 4.8 cm
Mass of ring = 0.019 kg
Magnetic field strength = 0.032 T

(i) Use conservation of energy to calculate the speed *v* of the ring after 0.05 s.

(2)

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v = ...

(ii) Use the idea of impulse to calculate the magnitude of the mean force *F* acting on the ring and hence the mean current *I* in the ring.

(6)

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F = ...

I = ...

(Total for question = 8 marks)

Q3.

It was suggested on an online forum that it would be possible to cook a chicken by repeatedly slapping the chicken with one hand.

It was claimed that the energy transferred to a chicken in 8000 slaps would be sufficient to raise the temperature of the chicken from 23 °C to 165 °C.

In an investigation to test the claim, the effective mass of the hand was taken as 1.75 kg and the speed of the hand just before impact with the chicken as 6.25 m s^{-1}.

Deduce whether the data confirms that 8000 slaps would be sufficient.

Assume that no energy is transferred from the chicken to the surroundings.

mass of chicken = 0.875 kg

specific heat capacity of chicken = 1770 J kg^{-1} K^{-1}

efficiency of energy transfer from the hand = 65%

Explain whether the assumption made is realistic.

(2)

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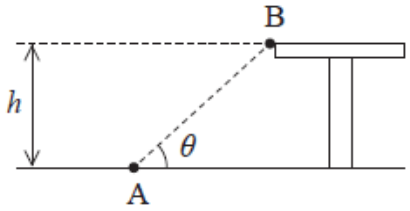
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(Total for question = 2 marks)

Q4.

An object of mass m is moved from point A on the ground, to point B on a bench of height h as shown in the diagram.



Which of the following is a correct expression for the work done on the object?

(1)

☒ **A** $\frac{mgh}{\sin\theta}$

☒ **B** $\frac{mgh}{\cos\theta}$

☒ **C** mgh

☒ **D** $mgh\sin\theta$

(Total for question = 1 mark)

Q5.

The International Space Station (ISS) is in a low Earth orbit. Astronauts in ISS have an apparent weight of zero. In order to determine their mass, the astronauts must secure themselves to a platform which is set into oscillation and moves with simple harmonic motion.





Describe how, using a stopwatch and a ruler, the following quantities could be determined for the oscillating platform:

(i) the frequency of oscillation

(2)

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(ii) the maximum speed of the platform.

(2)

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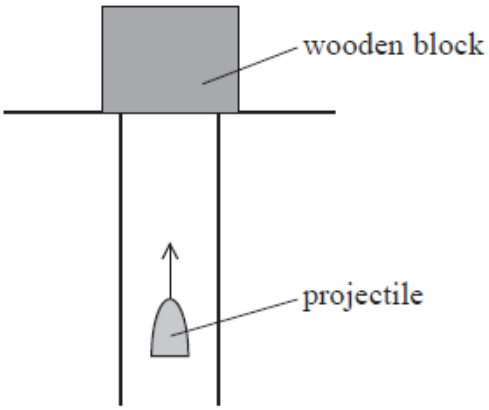
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(Total for question = 4 marks)

Q6.

A projectile of mass 65 g is fired vertically upwards into a stationary wooden block of mass 2.400 kg, as shown.



The projectile becomes embedded in the block. They both move vertically upwards through a vertical displacement of 55 cm before momentarily coming to rest.

Explain how the principle of conservation of energy applies to this collision.

(2)

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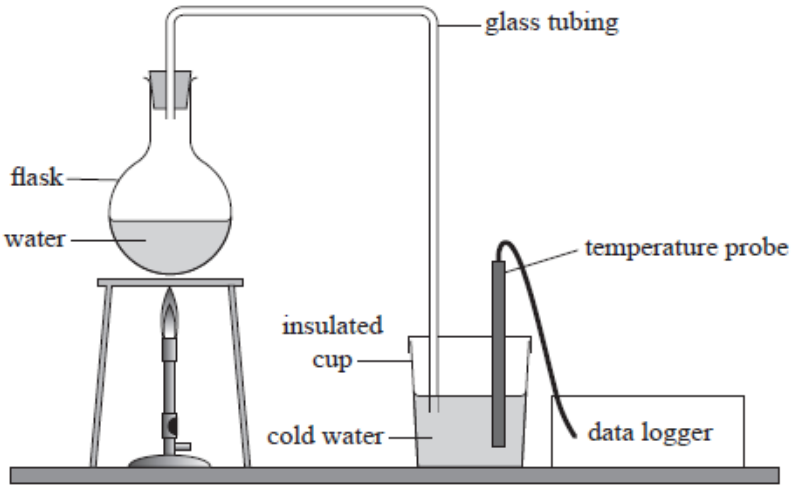
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(Total for question = 2 marks)

Q7.

A student carried out an experiment to determine the specific latent heat of vaporisation of water using the apparatus shown.



The water in the flask was heated and steam was forced out of the flask and through the glass tubing into the cold water in the insulated cup. The steam condensed as it passed into the cold water.

(i) Explain why the water was heated to boiling point and left boiling for a few minutes before the insulated cup of cold water was put in place.

(2)

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(ii) Identify a significant source of error in this experiment and the steps that should be taken to minimise its effect on the calculated value of the specific latent heat of vaporisation of water.

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(Total for question = 4 marks)

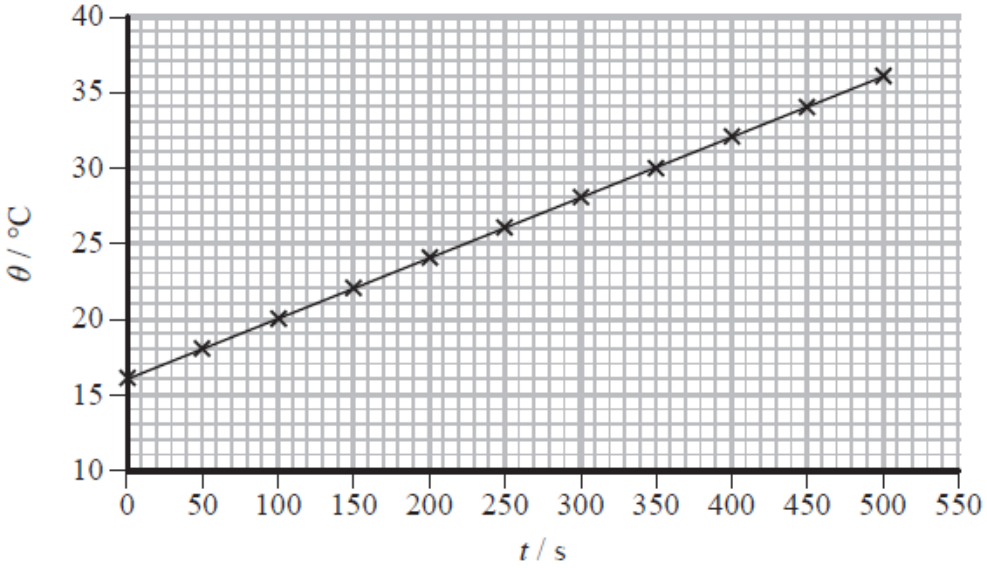
Q8.

A student determined the specific heat capacity of aluminium.

She used an electrical heater to heat an aluminium block and measured the temperature of the block with a digital thermometer.

The student monitored the temperature θ of the aluminium block over the time t for which the heater was switched on.

Her results are plotted on the graph.



(i) Determine the specific heat capacity of aluminium.

power of heater = 37.5 W
mass of aluminium block = 0.986 kg

(3)

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Specific heat capacity of aluminium = ...

(ii) The student looked up the accepted value for the specific heat capacity of aluminium. Using this value, the student predicted that it should have taken 240 s for the temperature of the aluminium block to increase by 10 °C.

Explain the difference between the predicted time and the student's actual observations.

(2)

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(Total for question = 5 marks)

Q9.

The photograph shows an example of a Foucault pendulum.



This is a pendulum that consists of a massive sphere, suspended by a long wire from a high ceiling. Over time the vertical plane through which the pendulum swings appears to rotate because of the rotation of the Earth.

mass of sphere = 28.0 kg

To show the rotation of the Earth, the pendulum needs to oscillate for several hours.

Explain how using a heavy sphere is better than using a light sphere of the same diameter.

(3)

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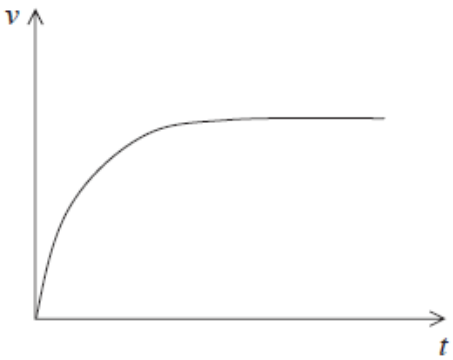
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(Total for question = 3 marks)

Q10.

A sports class is studying cycling. They produce a video of a cyclist on a horizontal lawn.
The cyclist starts from rest.
They produce a sketch graph of the velocity v of the cyclist against time t.





A student makes the following statement.

The work done by the cyclist is converted into the kinetic energy of the cyclist and bicycle.

Criticise this statement.

(3)

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(Total for question = 3 marks)

Q1.

Aluminium is one of the most widely recycled metals. Aluminium cans are heated from room temperature until all the aluminium has melted. The molten aluminium is then used to make new cans. This process uses only 5% of the energy needed to extract aluminium from raw materials.

On a website it is claimed that recycling one aluminium can of mass 14 g saves enough energy to listen to music on a mobile phone continuously for 7 days.

Assess the validity of this claim.

melting point of aluminium = 660 K
specific heat capacity of aluminium = 902 J kg^{-1} K^{-1}
specific latent heat of aluminium = 396 kJ kg^{-1}
room temperature = 293 K
mobile phone p.d. = 3.7 V
mobile phone current = 120 mA

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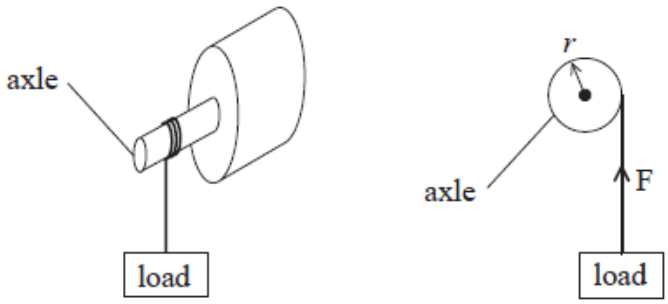
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(Total for question = 6 marks)

Q2.

Motors usually have a rotating component which can do work *W*.

(a) A motor lifts a load in a time *t*. The axle of the motor has a radius *r* and exerts a force *F*.



The power produced by a motor can be calculated by using the following word equation.

Power = moment of the force exerted by the rotating axle × angular velocity

Derive this equation, starting with power $P = \frac{W}{t}$.

(4)

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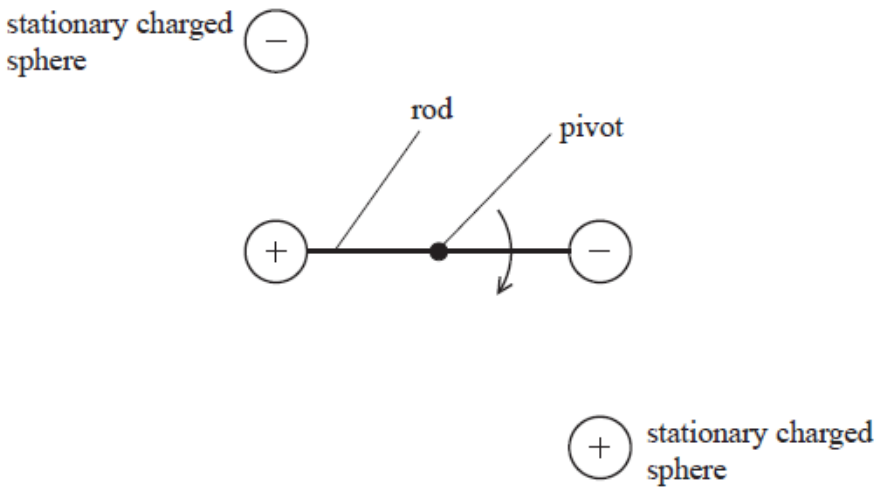
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(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

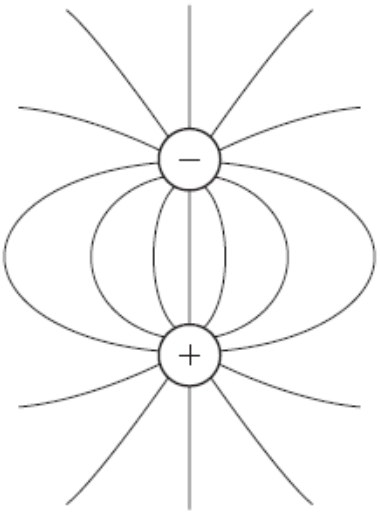


(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

(3)



(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

(2)

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

	Power / W	Angular velocity / rad s^{-1}
Electric car	2.0×10^4	300
Vacuum cleaner	1.4×10^3	1000
Small pond pump	0.5	200

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the

electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

(4)

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(Total for question = 13 marks)

Q3.

In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.



commons.wikimedia.org

A stone of mass 19.6 kg is accelerated uniformly for 1.25 s before being released by a curler. The stone then decelerates uniformly to rest, travelling 32.5 m in a time of 17.5 s.

Calculate the average useful power developed by the curler in accelerating the stone.

(4)

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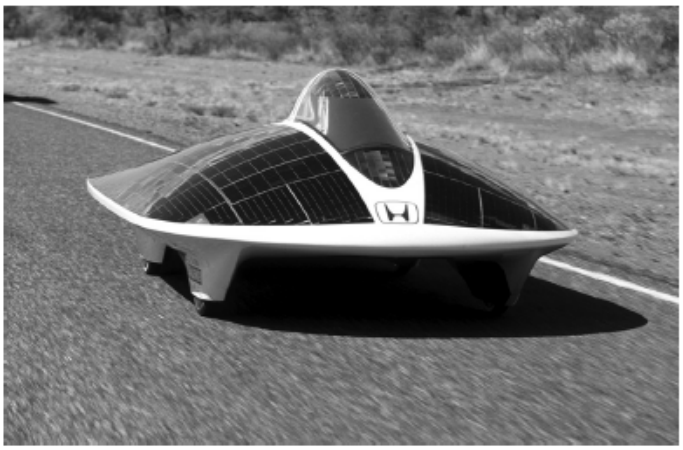
Average power = ...

(Total for question = 4 marks)

Q4.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

The vehicle can reach a maximum speed of 34 m s^{-1} on flat ground. The electric motor used to move the vehicle has a power of 4.5 kW.

(i) Calculate the initial acceleration of the vehicle as it starts from rest.

mass of vehicle and driver = 420 kg

(3)

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Initial acceleration = ...

(ii) State one assumption made in this calculation.

(1)

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(Total for question = 4 marks)

Q5.

The diagram shows a battery-powered clock on a wall. It has a minute hand and an hour hand.



(a) Calculate the average angular velocity of the minute hand.

(2)

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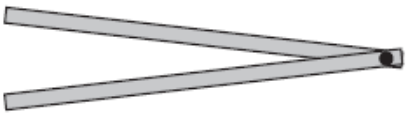
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Angular velocity = ...

(b) The diagram shows the position of the minute hand when the time is 1 : 44 and when the time is 1 : 46.



The diagram is not to scale.

Show that the work done against the force of gravity to move the minute hand from 1 : 44 to 1 : 46 is about 1 mJ.

mass of minute hand = 14 g

length of minute hand = 8.0 cm

(5)

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(c) The clock uses a 1.5 V cell and draws a maximum current of 8.0 μA.

After a time, the maximum power of the cell has reduced to 65% of its initial value making the clock run slowly.

Calculate the time taken for the minute hand to move from the 1 : 44 position to the 1 : 46 position.

(3)

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Time taken = ...

(Total for question = 10 marks)

Q6.

An electric kettle is used to heat water from room temperature to boiling point.

(a) (i) Calculate the electrical power used by the kettle.

potential difference = 230 V

current = 12.5 A

(2)

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Electrical power = ...

(ii) The kettle is switched on for 140 s.

Calculate the total energy supplied to the kettle.

(2)

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Total energy supplied = ...

(iii) The amount of thermal energy transferred to the water is calculated to be 351 000 J.

Calculate the efficiency of the kettle at heating the water.

(2)

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Efficiency = ...

(b) A student suggests that the useful energy required is thermal and the kettle only produces thermal energy, so it should be 100 % efficient.

Discuss this suggestion.

(2)

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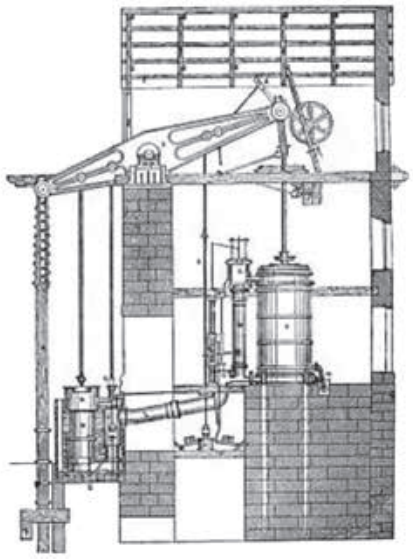
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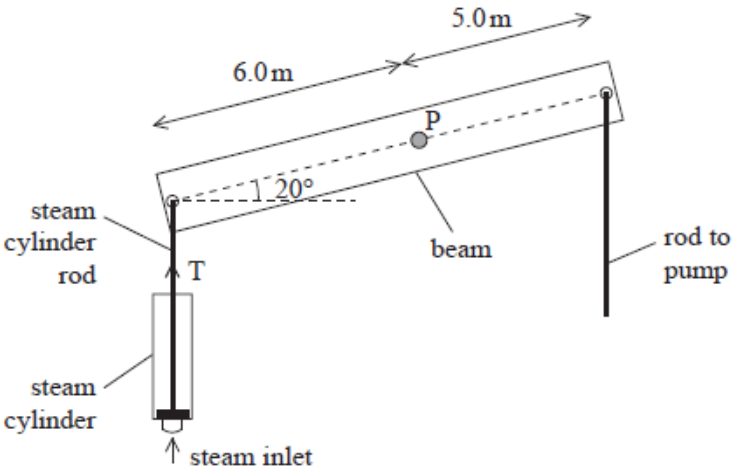
(Total for question = 8 marks)

Q7.

Beam engines contributed to powering the Industrial Revolution in Britain in the 18th century. A beam engine consisted of a beam which could rock to and fro around a well-oiled pivot. Attached to the beam there are two rods, one connected to a piston in a steam cylinder and the other connected to a pump.



The diagram below shows a simplified arrangement of a beam engine.



The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10 %.

Deduce whether this claim for efficiency was correct.

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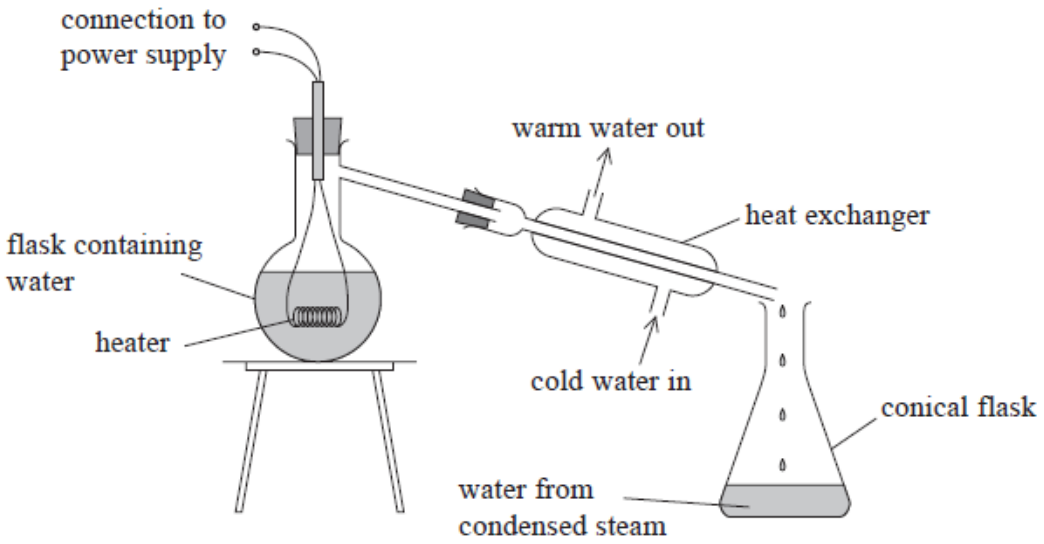
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(Total for question = 5 marks)

Q8.

The apparatus shown can be used to determine a value for the specific latent heat of vaporisation of water.



(a) In one experiment the current in the heater was 8.20 A, and the potential difference across the heater was 230 V.

(i) Show that the power of the heater was about 2 kW.

(2)

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(ii) There was 0.655 kg of water in the flask at an initial temperature of 22.5 °C.
The heater was switched on, and the water in the flask was heated to boiling point.

Calculate the minimum time taken for the water to be heated to 100.0 °C.

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

(3)

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Minimum time taken for water to be heated = ...

(b) The heater was left on and water continued to boil in the flask. The water was allowed to boil for a few minutes. The conical flask was then placed under the heat exchanger and water was

collected in it.

(i) Give a reason why the water was left boiling for a few minutes before the conical flask was put in place.

(1)

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(ii) Water with a mass of 95.0 g was collected in a time of 125 s.

Calculate the rate of energy transfer in the heat exchanger.

specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}

(3)

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Rate of energy transfer in the heat exchanger = ...

(iii) Discuss your answers to (a)(i) and (b)(ii).

(3)

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(Total for question = 12 marks)

Q9.

A cyclist travels up a slope through a vertical height h in a time t. The mass of the cyclist and his bike is m.

The average power of the cyclist is

- ☒ **A** $\frac{mg}{t}$
- ☒ **B** $\frac{t}{mg}$
- ☒ **C** $\frac{mgh}{t}$
- ☒ **D** $\frac{t}{mgh}$

(Total for question = 1 mark)

Q10.

The photograph shows a 'quiet boil' electric kettle. The makers of the kettle claim that it boils water with much less noise than a standard kettle.



A laboratory technician takes some measurements to compare a 'quiet boil' electric kettle with a standard electric kettle.

The table shows the results recorded by the technician.

	Quiet boil kettle	Standard kettle
Mass of water / kg	1.20	1.20
Initial temperature of water / °C	10	10
Final temperature of water / °C	100	100
Potential difference / V	243	247
Current / A	11.9	11.8
Time taken to heat water to boiling point / s	168	172
Average sound intensity / mW m^{-2}	3.72	10.5

A student uses the values in the table to calculate the efficiency of each kettle at heating the water to boiling point. He calculates the efficiency of the 'quiet boil' kettle to be 0.93

Calculate the efficiency of the standard kettle.

specific heat capacity of water = 4180 J kg^{-1} K^{-1}

(4)

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Efficiency = ...

(b) The intensity of the sound produced by each kettle was measured with a sound meter which was 30.0 cm from the centre of the kettle.

Calculate the energy transferred by sound while the water in the standard kettle is brought to the boil. You may treat the kettle as a point source.

(4)

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Energy transferred = ...

(c) The label on the original packaging of the quiet boil electric kettle states, 'This kettle is much more efficient than a standard kettle because it produces less sound.'

Explain the extent to which this statement is supported by your calculations.

(2)

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(Total for question = 10 marks)

Q1.

Aluminium is one of the most widely recycled metals. Aluminium cans are heated from room temperature until all the aluminium has melted. The molten aluminium is then used to make new cans. This process uses only 5% of the energy needed to extract aluminium from raw materials.

On a website it is claimed that recycling one aluminium can of mass 14 g saves enough energy to listen to music on a mobile phone continuously for 7 days.

Assess the validity of this claim.

melting point of aluminium = 660 K
specific heat capacity of aluminium = 902 J kg^{-1} K^{-1}
specific latent heat of aluminium = 396 kJ kg^{-1}
room temperature = 293 K
mobile phone p.d. = 3.7 V
mobile phone current = 120 mA

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(Total for question = 6 marks)

Q2.

It was suggested on an online forum that it would be possible to cook a chicken by repeatedly slapping the chicken with one hand.

It was claimed that the energy transferred to a chicken in 8000 slaps would be sufficient to raise the temperature of the chicken from 23 °C to 165 °C.

In an investigation to test the claim, the effective mass of the hand was taken as 1.75 kg and the speed of the hand just before impact with the chicken as 6.25 m s^{-1}.

Deduce whether the data confirms that 8000 slaps would be sufficient.

Assume that no energy is transferred from the chicken to the surroundings.

mass of chicken = 0.875 kg

specific heat capacity of chicken = 1770 J kg^{-1} K^{-1}

efficiency of energy transfer from the hand = 65%

(5)

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(Total for question = 5 marks)

Q3.

An electric kettle is used to heat water from room temperature to boiling point.

(a) (i) Calculate the electrical power used by the kettle.

potential difference = 230 V

current = 12.5 A

(2)

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Electrical power = ...

(ii) The kettle is switched on for 140 s.

Calculate the total energy supplied to the kettle.

(2)

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Total energy supplied = ...

(iii) The amount of thermal energy transferred to the water is calculated to be 351 000 J.

Calculate the efficiency of the kettle at heating the water.

(2)

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Efficiency = ...

(b) A student suggests that the useful energy required is thermal and the kettle only produces thermal energy, so it should be 100 % efficient.

Discuss this suggestion.

(2)

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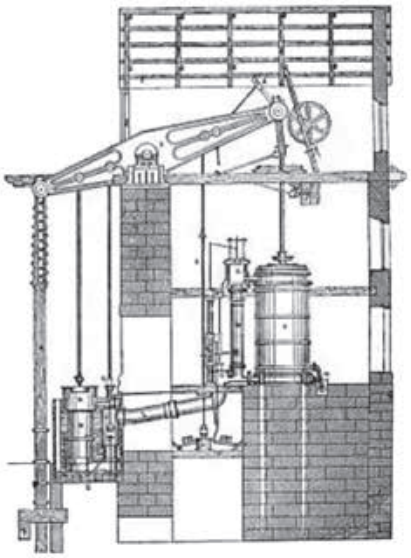
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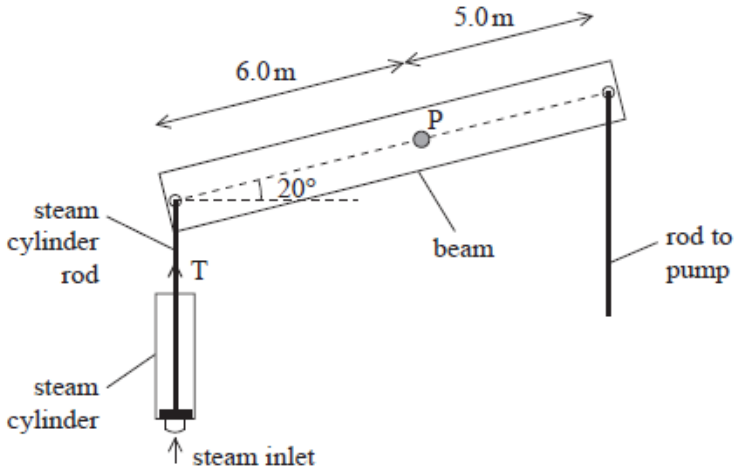
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Q4.

Beam engines contributed to powering the Industrial Revolution in Britain in the 18th century. A beam engine consisted of a beam which could rock to and fro around a well-oiled pivot. Attached to the beam there are two rods, one connected to a piston in a steam cylinder and the other connected to a pump.



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The beam engine was said to have an efficiency of 10 %.

Deduce whether this claim for efficiency was correct.

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(Total for question = 5 marks)

Q5.

The photograph shows a 'quiet boil' electric kettle. The makers of the kettle claim that it boils water with much less noise than a standard kettle.



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(4)

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(4)

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Energy transferred = ...

(c) The label on the original packaging of the quiet boil electric kettle states, 'This kettle is much more efficient than a standard kettle because it produces less sound.'

Explain the extent to which this statement is supported by your calculations.

(2)

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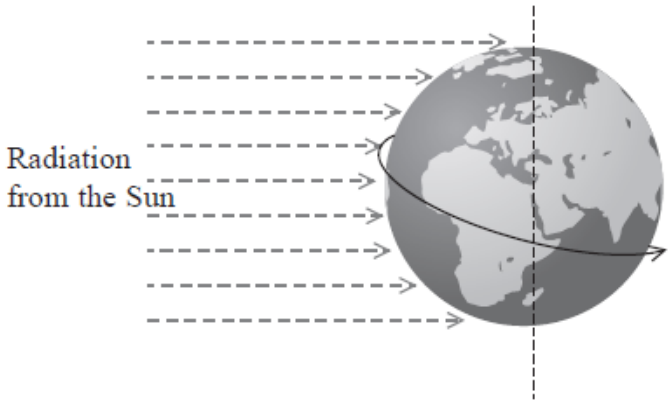
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(Total for question = 10 marks)

Q6.

Solar panels consisting of combinations of photovoltaic cells use energy in the radiation received from the Sun to generate electricity.

The average intensity of radiation from the Sun incident at the Earth's surface over a 24-hour period has been determined to be 164 $W\,m^{-2}$.



(i) The average intensity of radiation from the Sun at the Earth's surface is much less than the intensity incident at the top of the Earth's atmosphere.

Explain why.

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(ii) It is claimed that the area of solar panels needed to generate 100 GW of power is about 0.5% of the surface area of the Earth.

Assess the validity of this claim.

radius of Earth = 6.4×10^6 m

typical efficiency of solar panels = 25%

(4)

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(Total for question = 8 marks)