2020 HSC Physics Examination

NSW Education Standards Authority

Table of contents

Exam Overview

Year	2020
Total Marks	100
Section I	20 marks (Questions 1-20, Multiple Choice)
Section II	80 marks (Questions 21-34, Extended Response)

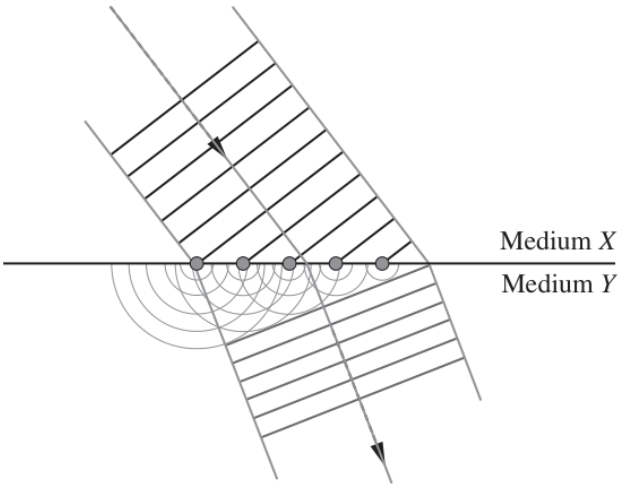
Section I: Multiple Choice

20 marks - Questions 1-20

Allow about 35 minutes for this section

Question 1

1 The diagram shows a model used to explain the refraction of light passing from medium *X* into medium *Y*.



Who proposed this model?

A. Malus

B. Planck

C. Newton

D. Huygens

Figure 1: Q1

Question 2

2 Which of the following is NOT required for the operation of AC induction motors?

A. Brushes

B. Stator winding

C. Magnetic fields

D. Current applied to the rotor

Figure 2: Q2

Question 3

3 What was the basis for Maxwell's prediction of the velocity of electromagnetic waves?

A. Experiments using magnetic fields to accelerate particles

B. Experiments using light and mirrors to establish the finite speed of light

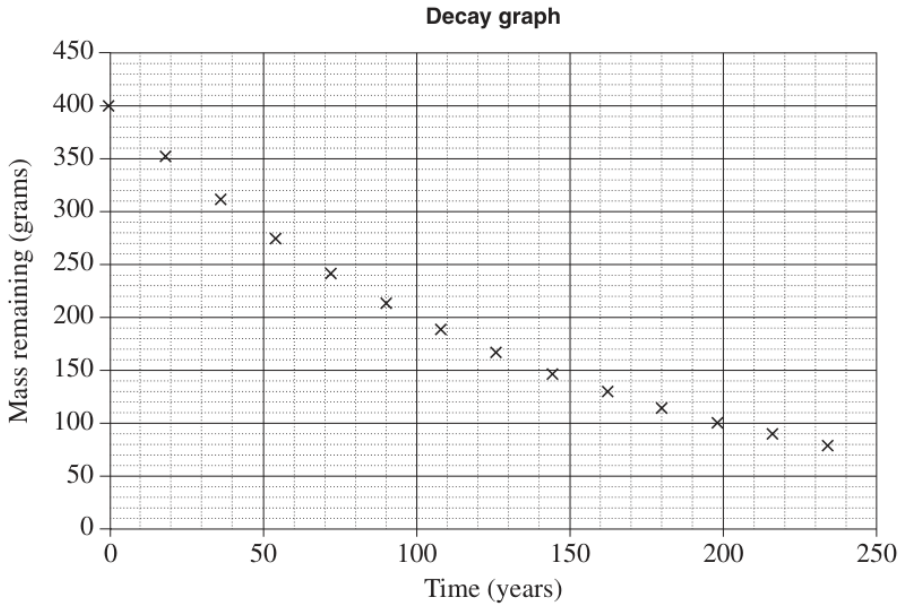
C. Equations showing how oscillating electric and magnetic fields propagate

D. Equations showing how electromagnetic waves are affected by gravitational fields

Figure 3: Q3

Question 4

4 The graph shows the mass of a radioactive isotope as a function of time.



What is the decay constant, in years^{-1}, for this isotope?

A. 0.0030

B. 0.0069

C. 2.0

D. 100

Figure 4: Q4

Question 5

5 A student throws a ball that follows a parabolic trajectory.

What change to the initial velocity would make the ball's time of flight shorter?

A. Increasing only the vertical component

B. Decreasing only the vertical component

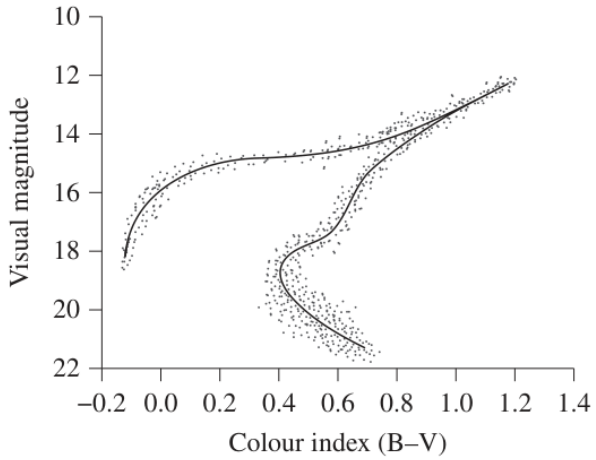
C. Increasing only the horizontal component

D. Decreasing only the horizontal component

Figure 5: Q5

Question 6

6 The Hertzsprung–Russell diagram shows characteristics of stars in a globular cluster 100 light years in diameter and 27 000 light years from Earth.



The stars plotted on this Hertzsprung–Russell diagram have approximately the same

A. age.

B. colour.

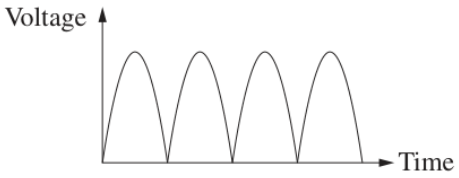
C. luminosity.

D. mass.

Figure 6: Q6

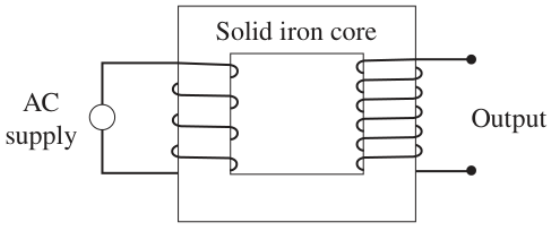
Question 7

7 The output of a device is shown.



Which diagram represents the device that has the output shown?

A.



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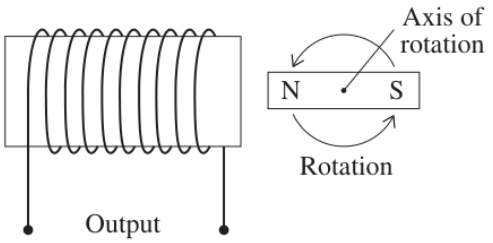

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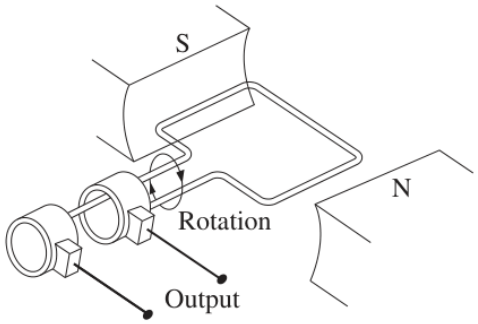

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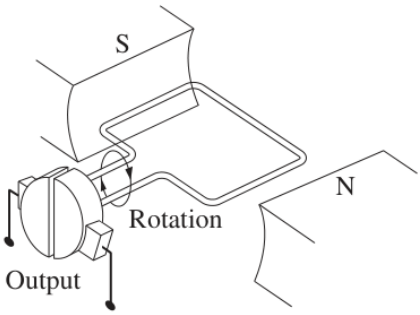
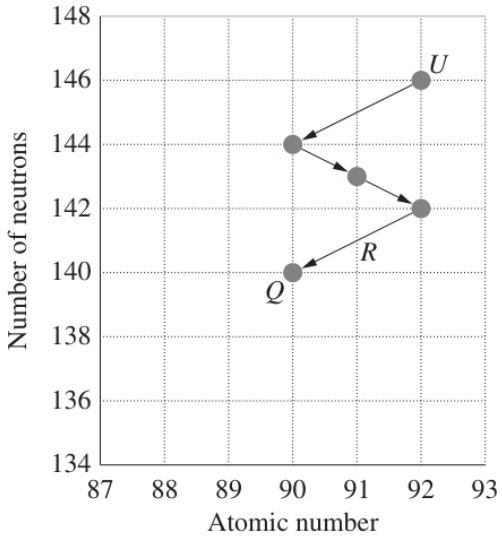


Figure 7: Q7

Question 8

8 A uranium isotope, U, undergoes four successive decays to produce Q.



Which row of the table correctly shows the decay process R and product Q?

	Process R	*Product Q*
A.	α	Pa-230
B.	β	Pa-234
C.	α	Th-230
D.	β	Th-234

Figure 8: Q8

Question 9

9 Bohr improved on Rutherford's model of the atom.

Which observation by Bohr provided evidence supporting the improvement?

A. Elements produced unique emission spectra consisting of discrete wavelengths.

B. The collision of an electron and a positron produced two photons that travelled in opposite directions.

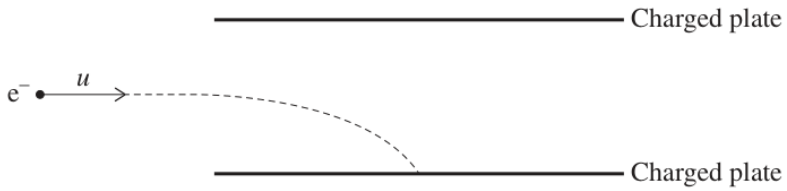
C. A small percentage of alpha particles fired at a gold foil target were deflected by angles of more than 90 degrees.

D. A beam of electrons reflected from a nickel crystal produced a pattern of intensity at different angles, consistent with their wave properties.

Figure 9: Q9

Question 10

10 An electron travelling in a straight line with an initial velocity, u, enters a region between two charged plates in which there is an electric field causing it to travel along the path as shown.



A magnetic field is then applied causing a second electron with the same initial velocity to pass through undeflected.

Which row of the table shows the directions of the electric and magnetic fields when the second electron enters the region between the plates?

	Electric field	*Magnetic field*
A.	Towards top of page	Into page
B.	Towards top of page	Out of page
C.	Towards bottom of page	Into page
D.	Towards bottom of page	Out of page

Figure 10: Q10

Question 11

11 Consider the following nuclear reaction.

$$^{6}_{3}\text{Li} + ^{1}_{0}\text{n} \longrightarrow ^{4}_{2}\text{He} + ^{3}_{1}\text{H}$$

The mass of the reactants is 7.023787704 u and the mass of the products is 7.018652532 u.

What type of reaction is this?

A. A fusion reaction in which energy is released

B. A fusion reaction that requires an input of energy

C. A transmutation reaction in which energy is released

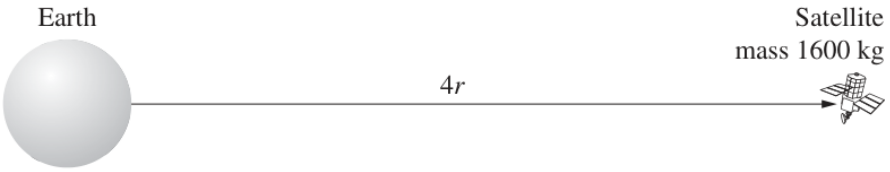
D. A transmutation reaction that requires an input of energy

Figure 11: Q11

Question 12

12 In which of the following would the satellite have the greatest escape velocity from Earth?

A.



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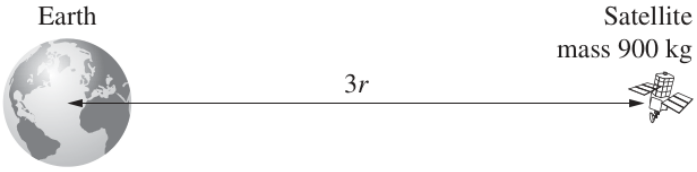

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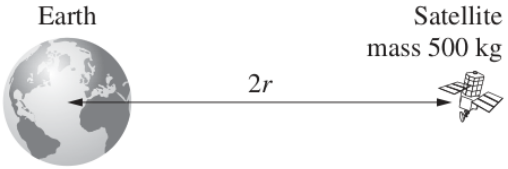


D.

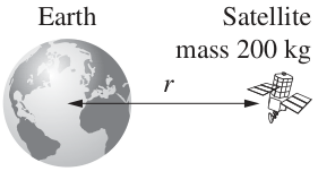
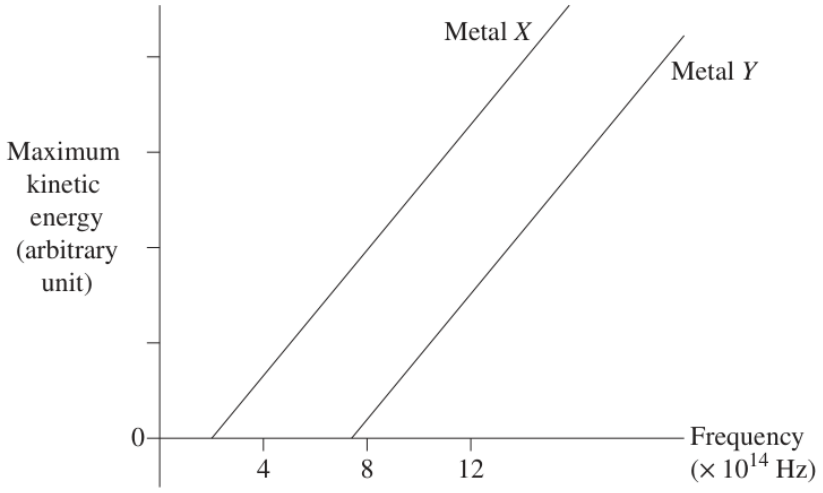


Figure 12: Q12

Question 13

13 The graph shows the relationship between the frequency of light used to irradiate two different metals, and the maximum kinetic energy of photoelectrons emitted.



Suppose that light having a frequency of 8×10^{14} Hz is used to irradiate both metals.

Compared to the photoelectrons emitted from metal *X*, photoelectrons emitted from metal *Y* will

A. have a lower maximum velocity.

B. have a higher maximum velocity.

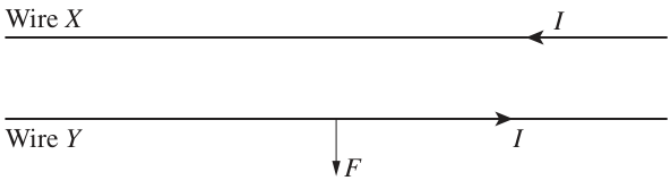
C. take a longer time to gain sufficient energy to be ejected.

D. take a shorter time to gain sufficient energy to be ejected.

Figure 13: Q13

Question 14

14 Two parallel wires, X and Y, each carry a current I.



The magnitude and direction of the force on wire Y are represented by the vector F.

The current in wire Y is then doubled and its direction is reversed. The current in wire X remains unchanged.

Which vector arrow represents the force on wire X after the change to the current in wire Y?

A.

B.

C.

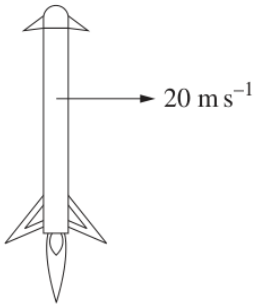
D.

Figure 14: Q14

Question 15

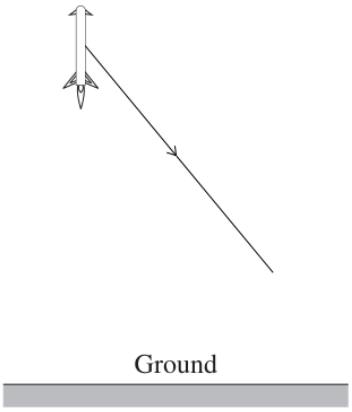
15 A rocket returns to Earth for reuse after launching satellites, using its engines to make a controlled landing.

The rocket having a mass of 7800 kg is on approach to the ground, travelling horizontally at 20 m s^{-1} as shown in the diagram, when the engine thrust is changed to 90 000 newtons.

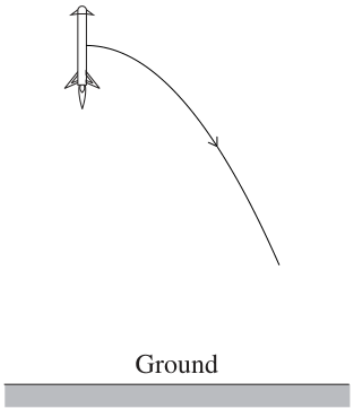


Which diagram shows the trajectory of the rocket following this change of thrust?

A.



B.



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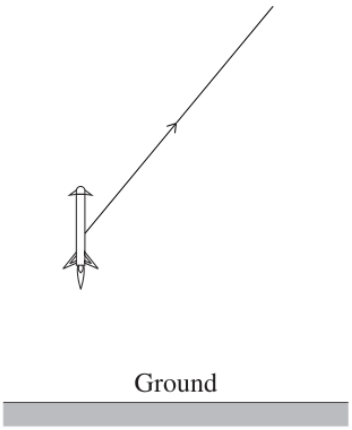


D.

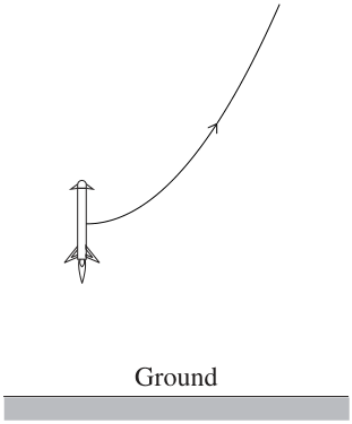
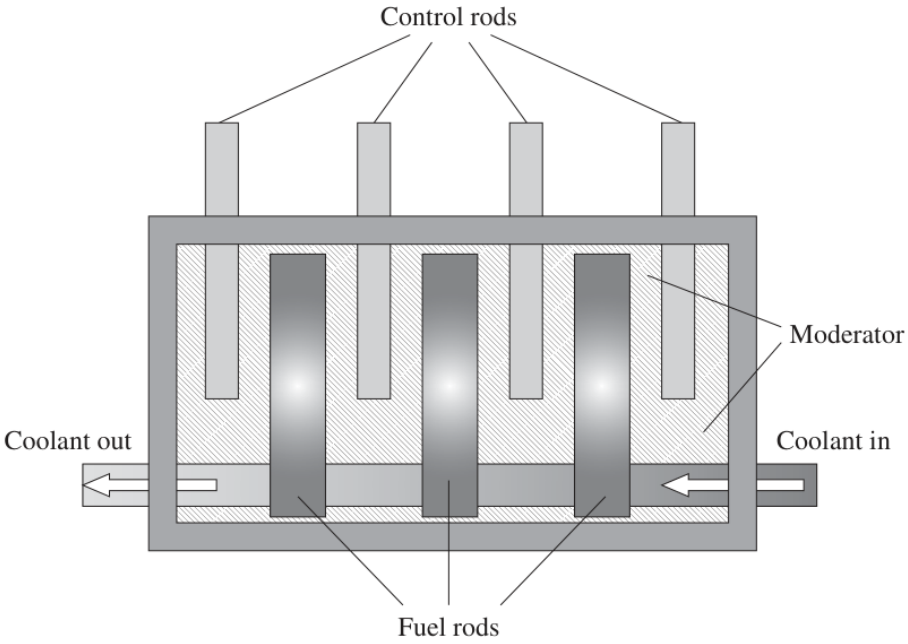


Figure 15: Q15

Question 16

16 A model of the core of a nuclear fission reactor is shown.



When the reactor is operating normally, the moderator, control rods and coolant work in combination to maintain a controlled nuclear reaction in the fuel rods.

The moderator is a liquid which slows down neutrons to increase the rate of fission. The control rods absorb free neutrons. The coolant reduces the core temperature.

A fault causes some of the moderator to leak out of the core.

Which action would compensate for the effect of the loss of moderator?

A. Withdraw the control rods from the core.

B. Lower the control rods further into the core.

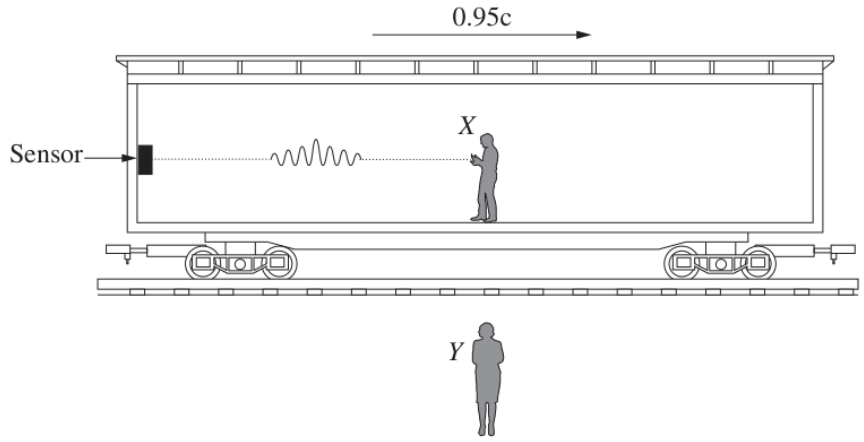
C. Pump the coolant through the core at a faster rate.

D. Reduce the temperature of the coolant before pumping it into the core.

Figure 16: Q16

Question 17

17 In a thought experiment, observer *X* is on a train travelling at a constant velocity of 0.95c relative to the ground. Observer *Y* is standing on the ground outside the train. As observer *X* passes observer *Y*, observer *X* sends a short light pulse towards the sensor.



Which statement about the light pulse is correct as observed by *X* or *Y* in their respective frames of reference?

A. Its velocity observed by *Y* is 0.05c.

B. *X* sees it travel a shorter distance to the sensor than *Y*.

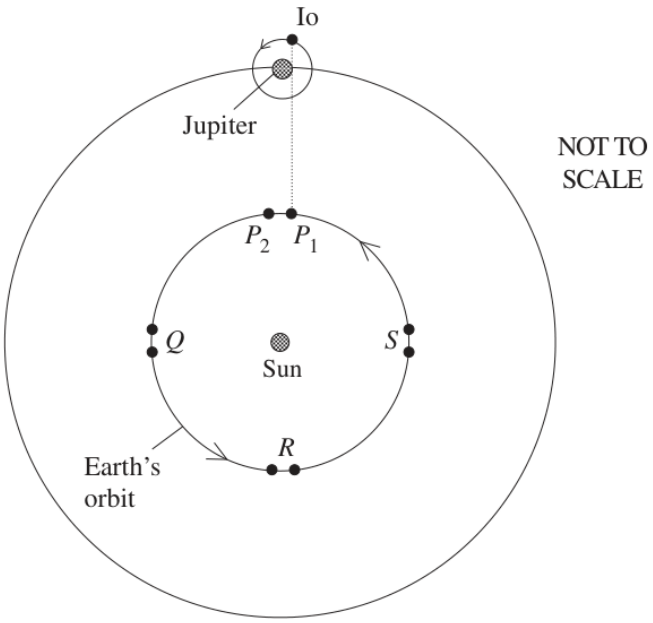
C. *X* sees it take a longer time to reach the sensor than *Y*.

D. Both *X* and *Y* see it travel the same distance in the same amount of time.

Figure 17: Q17

Question 18

18 An observer sees Io complete one orbit of Jupiter as Earth moves from P_1 to P_2, and records the observed orbital period as t_P. Similarly, the time for one orbit of Io around Jupiter was measured as Earth moved between the pairs of points at Q, R and S, with the corresponding measured periods of Io being t_Q, t_R and t_S.



Which measurement of the orbital period would be the longest?

A. t_P

B. t_Q

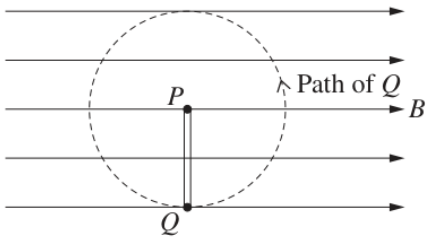
C. t_R

D. t_S

Figure 18: Q18

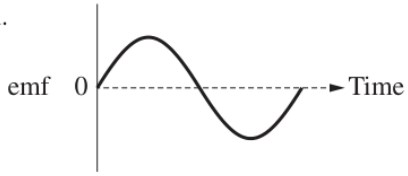
Question 19

19 A conductor PQ is in a uniform magnetic field. The conductor rotates around the end P at a constant angular velocity.

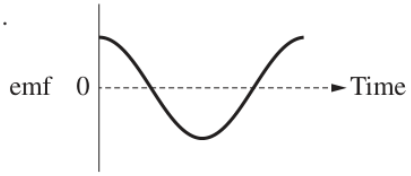


Which graph shows the induced emf between P and Q as the conductor completes one revolution from the position shown?

A.



B.



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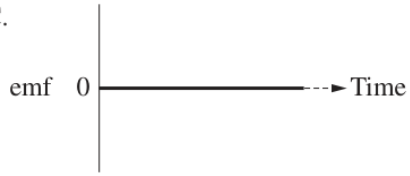

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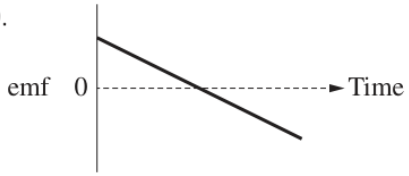
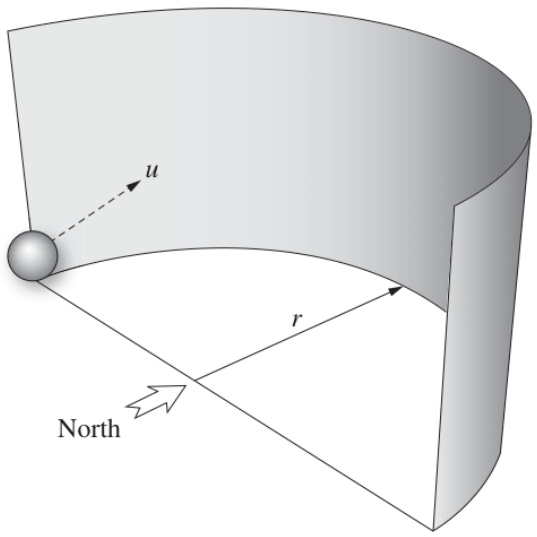


Figure 19: Q19

Question 20

20 The diagram shows a smooth, semi-circular, vertical wall with radius, r.

A ball is launched from the position shown with a velocity u towards north at an angle to the horizontal.



The ball follows a trajectory around the wall before landing on the ground, opposite its starting point. It does not reach the top of the wall.

Assume that there is no friction between the ball and the wall.

Which statement correctly describes the net force acting on the ball during its motion?

A. The magnitude of the net force remains constant.

B. The direction of the net force is vertically downwards.

C. The direction of the net force is perpendicular to the wall.

D. The magnitude of the net force reaches a minimum when the ball is at its highest point.

Figure 20: Q20

Section II: Extended Response

80 marks - Questions 21-34

Allow about 2 hours and 25 minutes for this section

Question 21 (5 marks)

Question 21 (5 marks)

(a) Calculate the wavelength of light emitted by an electron moving from energy level 3 to 2 in a Bohr model hydrogen atom. **2**

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(b) Describe the behaviour of electrons in the Bohr model of the atom with reference to the law of conservation of energy. **3**

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Figure 21: Q21

Question 22 (5 marks)

Question 22 (5 marks)

A capsule travelling at 12 900 m s^{-1} enters Earth's atmosphere, causing it to rapidly slow down to 400 m s^{-1}.

(a) During this re-entry, the capsule reaches a temperature of 3200 K. **2**

What is the peak wavelength of the light emitted by the capsule?

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(b) Outline TWO limitations of applying special relativity to the analysis of the motion of the capsule. **3**

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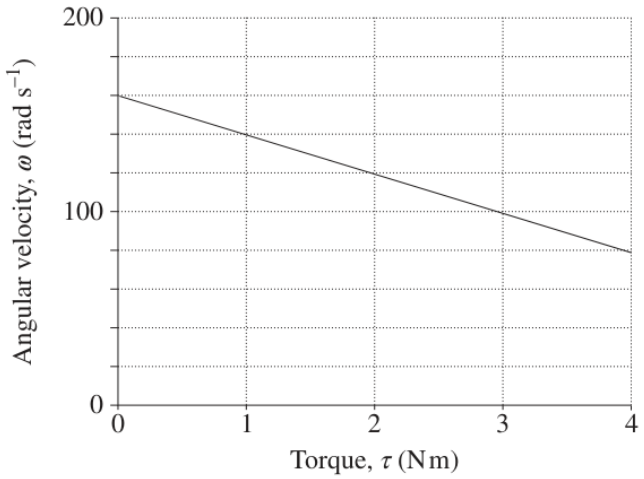
Figure 22: Q22

Question 23 (3 marks)

Question 23 (3 marks)

The graph shows data for a motor connected to a 240 V power supply. **3**



The equation for the torque, τ, produced by the motor is $\tau = \dfrac{VI\eta}{\omega}$

where τ = torque (N m)
V = voltage (V)
I = current (A)
η = efficiency = 0.3
ω = angular velocity (rad s^{-1})

A circuit breaker cuts the current to the motor if the current exceeds 5 A.

Determine what will happen when the motor produces a torque of 2.95 N m. Show relevant calculations.

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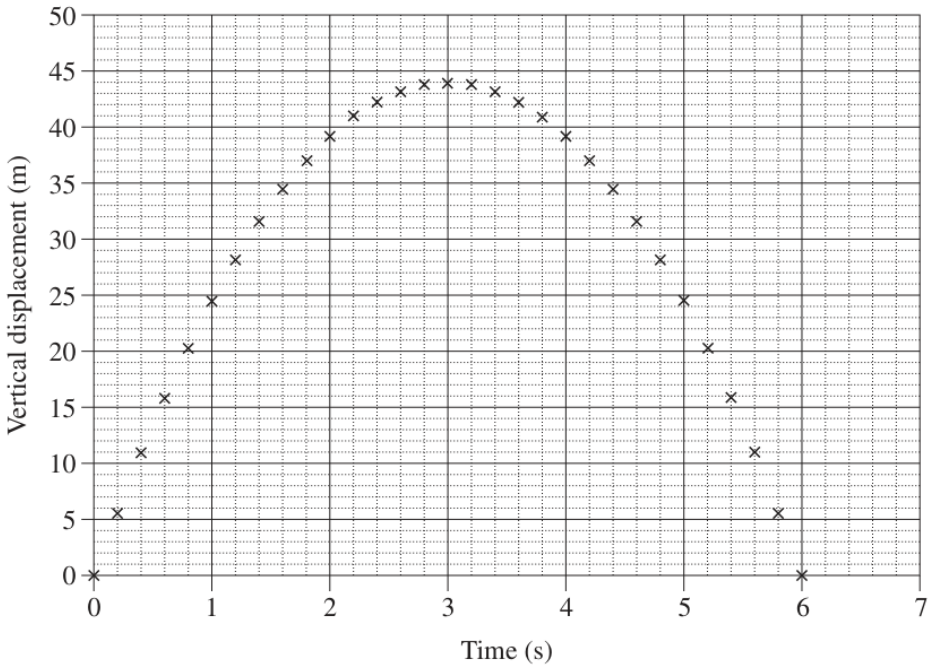
Figure 23: Q23

Question 24 (4 marks)

Question 24 (4 marks)

The graph shows the vertical displacement of a projectile throughout its trajectory. The range of the projectile is 130 m. **4**



Calculate the initial velocity of the projectile.

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Figure 24: Q24

Question 25 (4 marks)

Question 25 (4 marks)

Describe the hydrogen atom in terms of the Standard Model of matter. **4**

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Figure 25: Q25

Question 26 (8 marks)

Question 26 (8 marks)

(a) Describe the difference between the spectra of the light produced by a gas discharge tube and by an incandescent lamp. **2**

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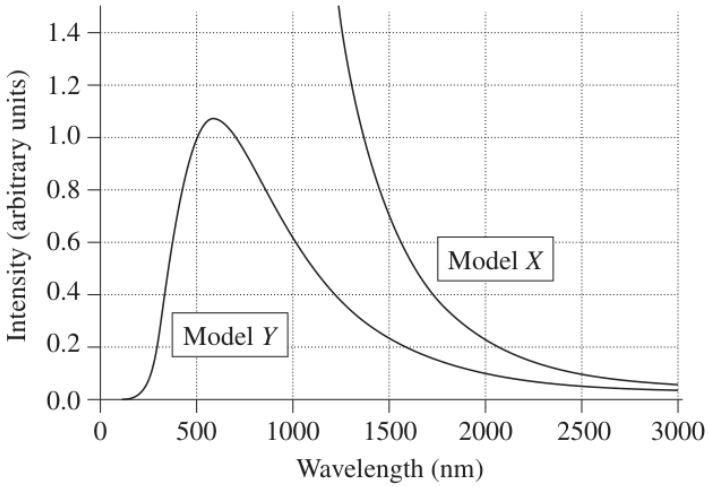
(b) The graph shows the curves predicted by two different models, *X* and *Y*, for the electromagnetic radiation emitted by an object at a temperature of 5000 K. **2**



Identify an assumption of EACH model which determines the shape of its curve.

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Question 26 continues on page 24

Figure 26: Q26

Part (a)

(a) Describe the difference between the spectra of the light produced by a gas discharge tube and by an incandescent lamp. **2**

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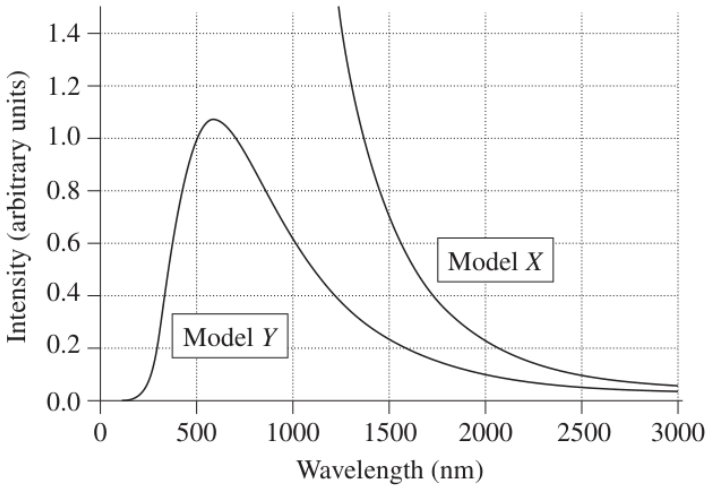
Figure 27: Q26a

Part (b)

(b) The graph shows the curves predicted by two different models, *X* and *Y*, for the electromagnetic radiation emitted by an object at a temperature of 5000 K. **2**



Identify an assumption of EACH model which determines the shape of its curve.

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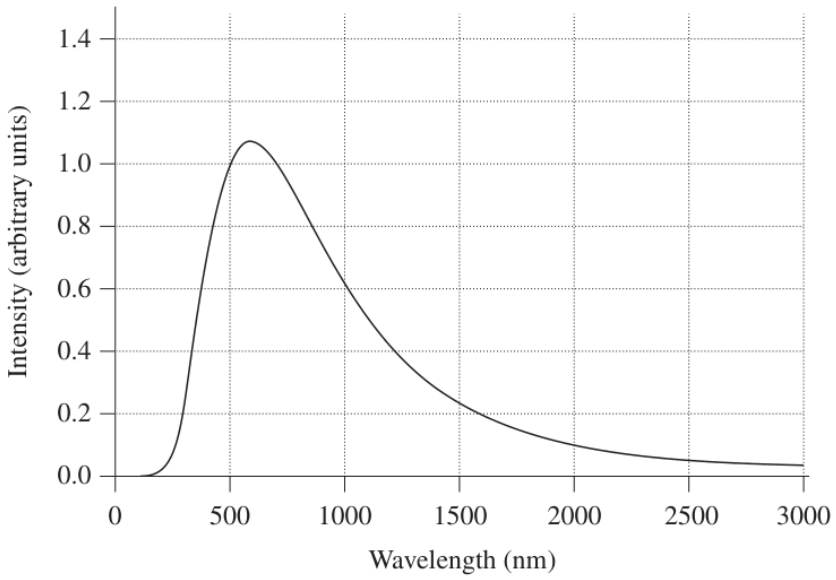
Question 26 continues on page 24

Figure 28: Q26b

Part (c)

(c) The diagram shows the radiation curve for a black body radiator at a temperature of 5000 K. **4**



On the same diagram, sketch a curve for a black body radiator at a temperature of 4000 K and explain the differences between the curves.

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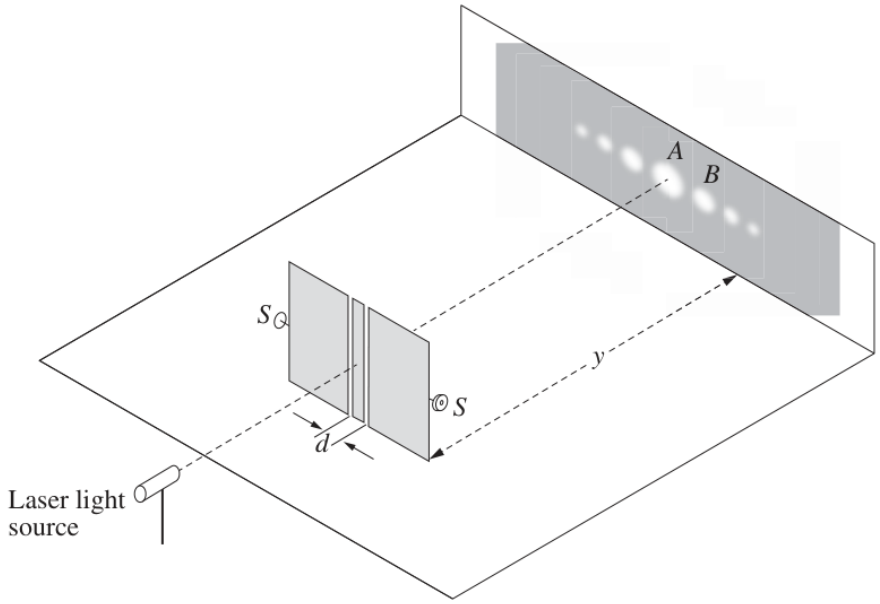
End of Question 26

Figure 29: Q26c

Question 27 (4 marks)

Question 27 (4 marks)

The following apparatus is used to investigate light interference using a double slit. **4**



The distance, y, from the slits to the screen can be varied. The adjustment screws (S) vary the distance, d, between the slits. The wavelength of the laser light can be varied across the visible spectrum. The diffraction pattern shown is for a specific wavelength of light.

Explain TWO methods of keeping the distance between the maxima at A and B constant when the wavelength of the laser light is reduced.

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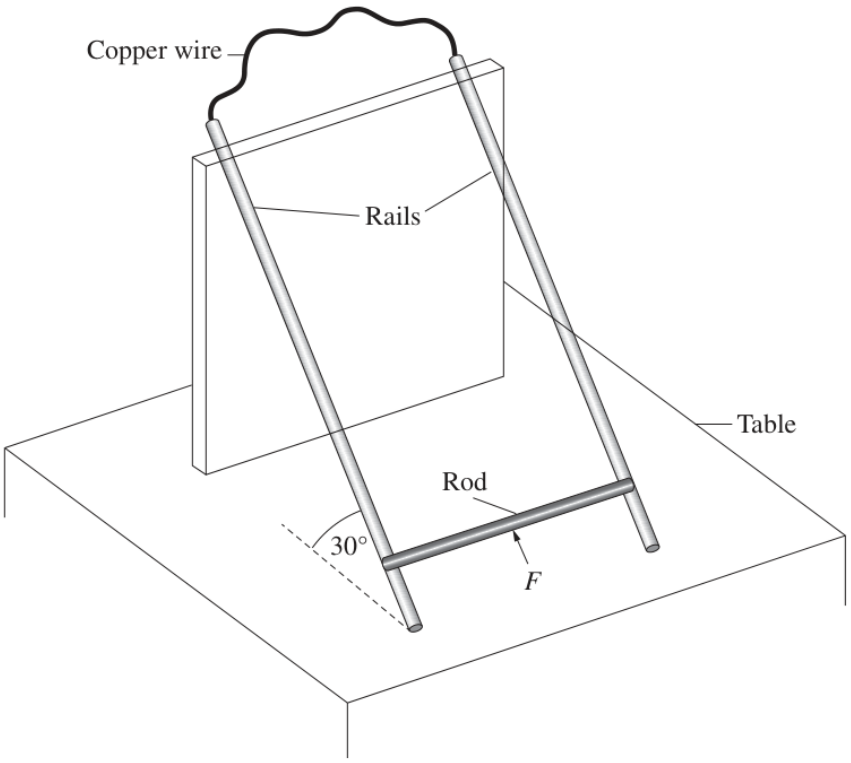
Figure 30: Q27

Question 28 (7 marks)

Question 28 (7 marks)

A metal rod sits on a pair of parallel metal rails, 20 cm apart, that are connected by a copper wire. The rails are at 30° to the horizontal.

The apparatus is in a uniform magnetic field of 1 T which is upward, perpendicular to the table.



A force, F, is applied parallel to the rails to move the rod at a constant speed along the rails. The rod is moved a distance of 30 cm in 2.5 s.

(a) Show that the change in magnetic flux through the circuit while the rod is moving is approximately 5.2×10^{-2} Wb. **2**

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Question 28 continues on page 27

Figure 31: Q28

Part (b)

(b) Calculate the emf induced between the ends of the rod while it is moving, and state the direction of flow of the current in the circuit. **2**

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Figure 32: Q28b

Part (c)

(c) The experiment is repeated without the magnetic field. **3**

Explain why the force required to move the rod is different without the magnetic field.

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End of Question 28

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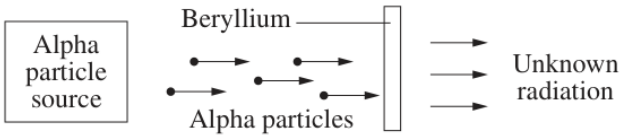
Figure 33: Q28c

Question 29 (5 marks)

Question 29 (5 marks)

In an experiment, alpha particles were fired into a thin sheet of beryllium. Unknown radiation was detected.



Further experiments were conducted in which it was observed that the unknown radiation:

- was not deflected by an electric field
- caused protons to be ejected from a block of paraffin
- could not produce the photoelectric effect.

Scientists debated the nature of this unknown radiation, hypothesising that it was gamma radiation.

(a) Explain why the hypothesis was proposed and then rejected, with reference to the observations. **3**

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(b) How did these experiments change the model of the atom? **2**

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Figure 34: Q29

Part (a)

(a) Explain why the hypothesis was proposed and then rejected, with reference to the observations. **3**

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Figure 35: Q29a

Part (b)

(b) How did these experiments change the model of the atom? **2**

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Figure 36: Q29b

Question 30 (7 marks)

Question 30 (7 marks)

(a) Explain, using an example, how a particle accelerator has provided evidence for the Standard Model of matter. **3**

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(b) (i) Calculate the wavelength of a proton travelling at 0.1c. **2**

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(ii) Explain the relativistic effect on the wavelength of a proton travelling at 0.95c. **2**

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Figure 37: Q30

Part (a)

(a) Explain, using an example, how a particle accelerator has provided evidence for the Standard Model of matter. **3**

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Figure 38: Q30a

Part (b)

(b) (i) Calculate the wavelength of a proton travelling at 0.1c. **2**

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(ii) Explain the relativistic effect on the wavelength of a proton travelling at 0.95c. **2**

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Figure 39: Q30b

(i)

(b) (i) Calculate the wavelength of a proton travelling at 0.1c. **2**

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Figure 40: Q30b_i

(ii)

(ii) Explain the relativistic effect on the wavelength of a proton travelling at 0.95c. **2**

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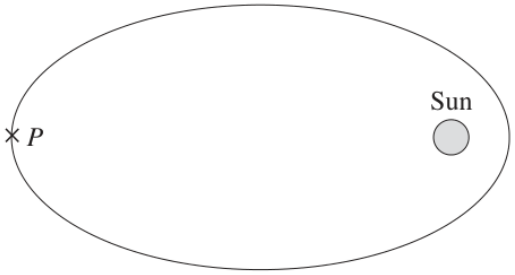
Figure 41: Q30b_ii

Question 31 (6 marks)

Question 31 (6 marks)

(a) The orbit of a comet is shown. **3**



Account for the changes in velocity of the comet as it completes one orbit from position P.

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(b) Two stars, A and B, of equal mass m, separated by a distance x, interact gravitationally such that the speed of A is constant. **3**

Derive an expression for the speed of B.

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Figure 42: Q31

Part (b)

(b) Two stars, A and B, of equal mass m, separated by a distance x, interact gravitationally such that the speed of A is constant. **3**

Derive an expression for the speed of B.

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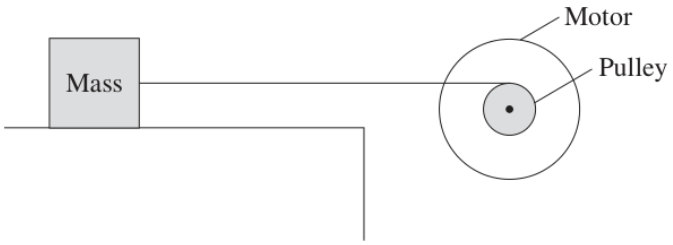
Figure 43: Q31b

Question 32 (7 marks)

Question 32 (7 marks)

A rope connects a mass on a horizontal surface to a pulley attached to an electric motor as shown. **7**



Explain the factors that limit the speed at which the mass can be pulled along the horizontal surface. Use mathematical models to support your answer.

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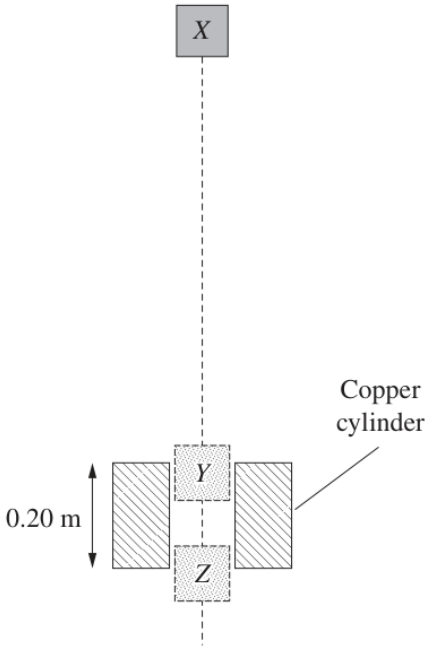
Figure 44: Q32

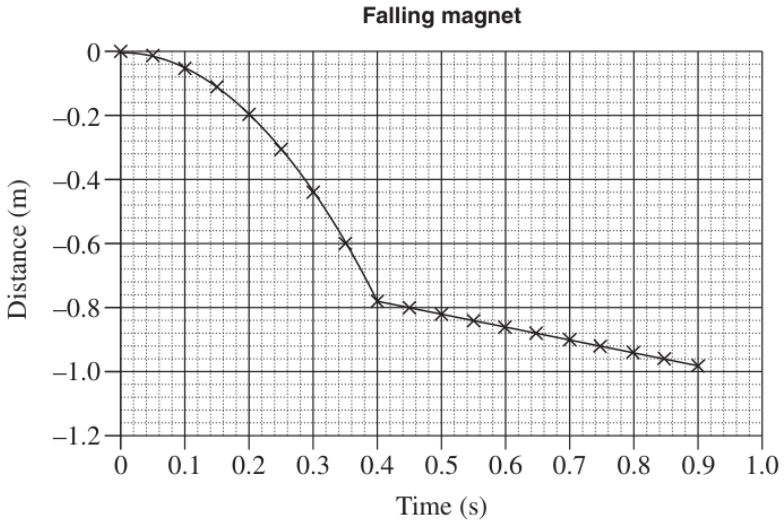
Question 33 (9 marks)

Question 33 (9 marks)

A strong magnet of mass 0.04 kg falls 0.78 m under the action of gravity from position *X* above a hollow copper cylinder. It then travels a distance of 0.20 m through the cylinder from *Y* to *Z* before falling freely again. **9**



The magnet takes 0.5 seconds to pass through the cylinder. The displacement–time graph of the magnet is shown.



Question 33 continues on page 33

Figure 45: Q33

Question 34 (6 marks)

Question 34 (6 marks)

A charged particle, q_1, is fired midway between oppositely charged plates X and Y, as shown in Figure 1. The voltage between the plates is V volts.

The particle strikes plate Y at point P, a horizontal distance s from the edge of the plate. Ignore the effect of gravity.

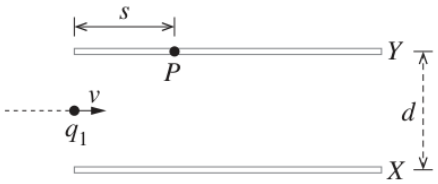


Figure 1

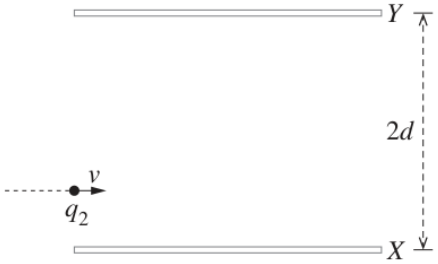


Figure 2

Plate Y is then moved to the position shown in Figure 2, with the voltage between the plates remaining the same.

An identical particle, q_2, is fired into the electric field at the same velocity, entering the field at the same distance from plate X as q_1.

(a) Compare the work done on q_1 and q_2. **3**

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Question 34 continues on page 35

Figure 46: Q34

Part (b)

(b) Compare the horizontal distances travelled by q_1 and q_2 in the electric field. **3**

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Figure 47: Q34b