2021 HSC Physics Examination

NSW Education Standards Authority

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Exam Overview

Year	2021
Total Marks	100
Section I	20 marks (Questions 1-20, Multiple Choice)
Section II	80 marks (Questions 21-35, Extended Response)

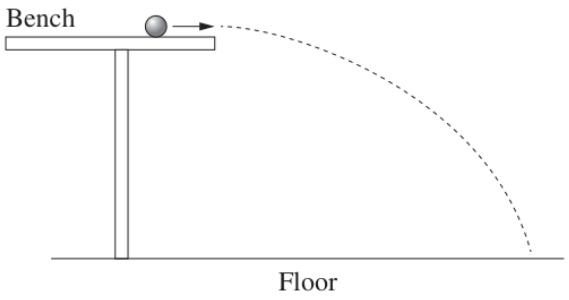
Section I: Multiple Choice

20 marks - Questions 1-20

Allow about 35 minutes for this section

Question 1

1 A marble is rolled off a horizontal bench and falls to the floor.



Rolling the marble at a slower speed would

A. increase the range.

B. decrease the range.

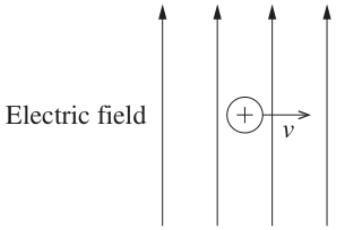
C. increase the time of flight.

D. decrease the time of flight.

Figure 1: Q1

Question 2

2 A positively charged particle is moving at velocity, v, in an electric field as shown.



What is the direction of the force acting on the particle due to the electric field?

A. Into the page

B. Out of the page

C. Up the page

D. Down the page

Figure 2: Q2

Question 3

3 Which of the following is NOT a fundamental particle in the Standard Model of matter?

A. Electron

B. Gluon

C. Muon

D. Proton

Figure 3: Q3

Question 4

4 An astronaut is travelling towards Earth in a spaceship at $0.8c$. At regular intervals, a radio pulse is sent from the spaceship to an observer on Earth.

Which quantity would the astronaut and the observer measure to be the same?

A. Length of the spaceship

B. Speed of the radio pulses

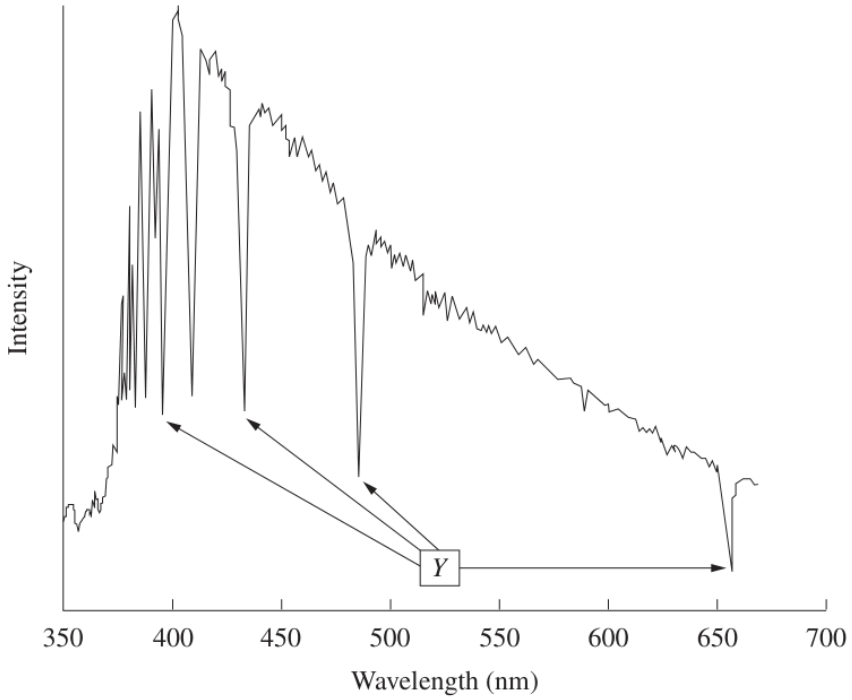
C. Momentum of the astronaut

D. Time interval between the radio pulses

Figure 4: Q4

Question 5

5 The spectrum of an object is shown.



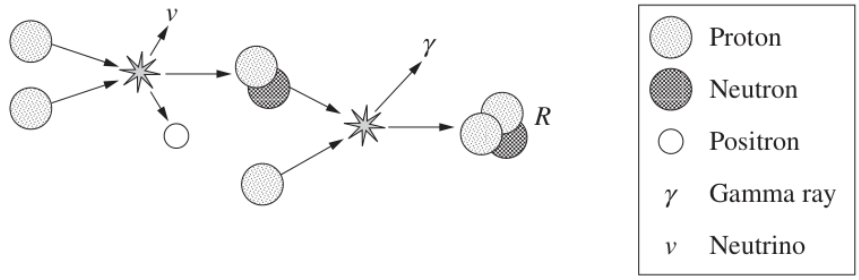
Which row of the table correctly identifies the most likely source of the spectrum and the features labelled *Y*?

	Source of spectrum	*Features labelled Y*
A.	Star	Absorption lines
B.	Discharge tube	Absorption lines
C.	Star	Emission lines
D.	Discharge tube	Emission lines

Figure 5: Q5

Question 6

6 The diagram shows part of a nuclear fusion process that occurs in stars.



What is the isotope labelled *R*?

A. H-2

B. He-2

C. H-3

D. He-3

Figure 6: Q6

Question 7

7 In a certain ideal transformer, the current in the secondary coil is four times as large as the current in the primary coil.

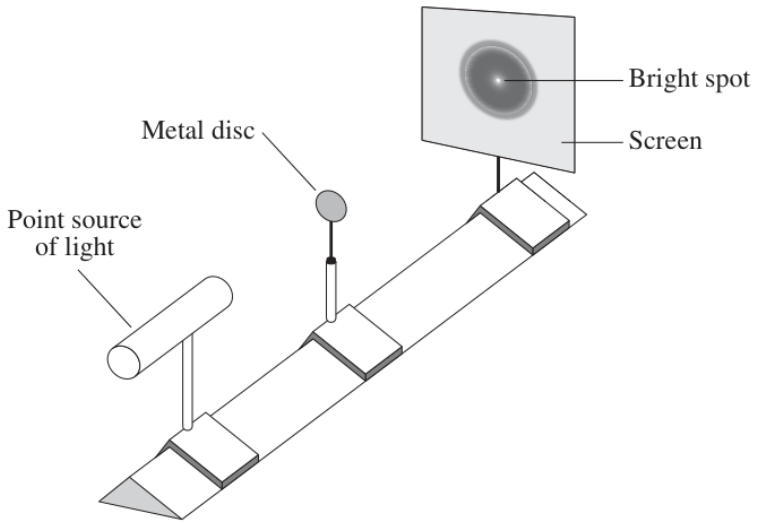
Which row of the table correctly identifies the type of transformer and the ratio of turns?

	Type of transformer	*Ratio of turns in primary coil to turns in secondary coil*
A.	Step up	4 : 1
B.	Step up	1 : 4
C.	Step down	4 : 1
D.	Step down	1 : 4

Figure 7: Q7

Question 8

8 Light from a point source is incident upon a circular metal disc, forming a shadow on a screen as shown. A bright spot is observed in the centre of the shadow.



The bright spot is caused by a combination of

A. interference and refraction.

B. refraction and polarisation.

C. polarisation and diffraction.

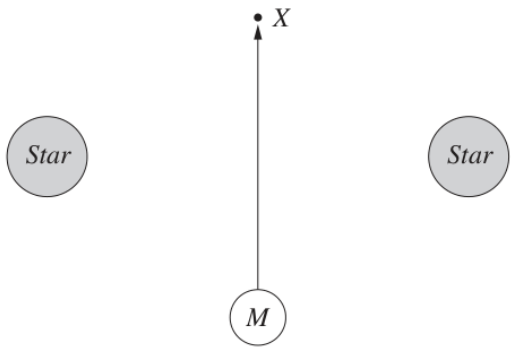
D. diffraction and interference.

Figure 8: Q8

Question 9

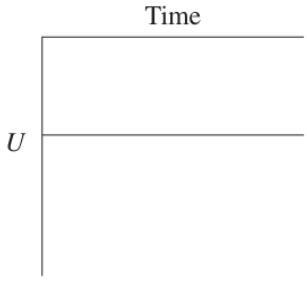
9 A mass, M, is positioned at an equal distance from two identical stars as shown.

The mass is then moved to position X.

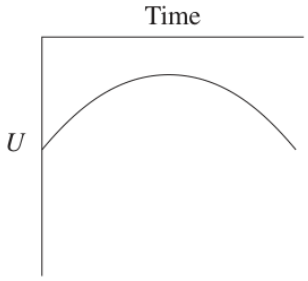


Which graph best represents the gravitational potential energy, U, of the mass during this movement?

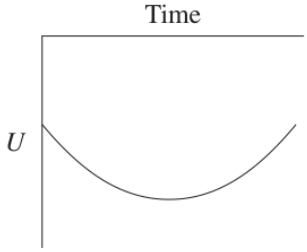
A.



B.



C.



D.

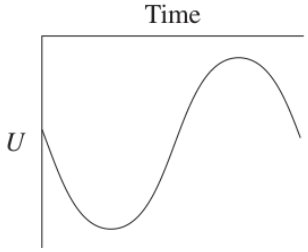
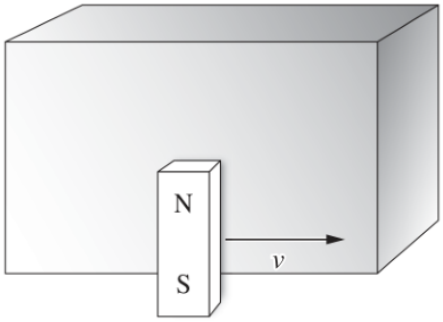


Figure 9: Q9

Question 10

10 A strong magnet is moved past a copper block at a constant speed as shown.



What is the direction of the force acting on the copper block?

A. To the left

B. To the right

C. Into the page

D. Out of the page

Figure 10: Q10

Question 11

11 What is the peak wavelength of electromagnetic radiation emitted by a person with a body temperature of 37°C (310 K)?

A. 9.3×10^{-6} m

B. 7.8×10^{-5} m

C. 9.3×10^{-3} m

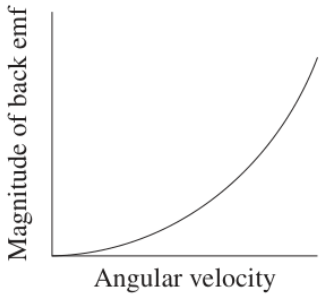
D. 7.8×10^{-2} m

Figure 11: Q11

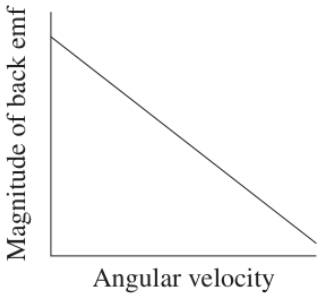
Question 12

12 Which graph shows the magnitude of back emf induced in a DC motor rotating continuously at different angular velocities?

A.



B.



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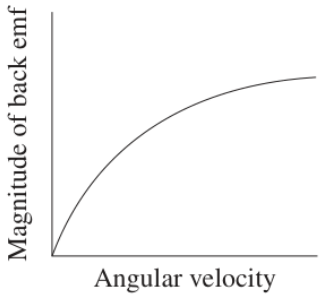


D.

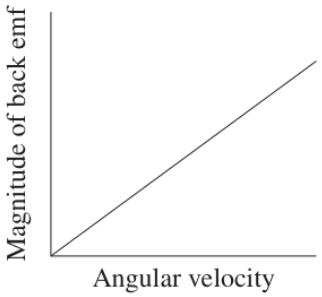
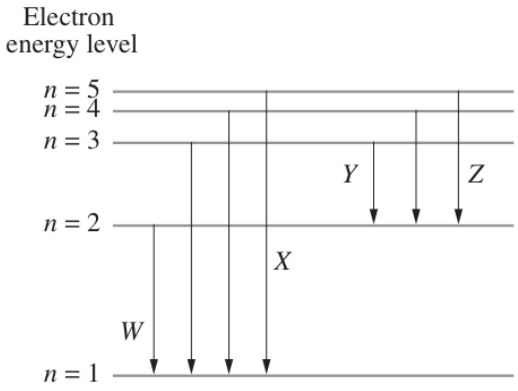


Figure 12: Q12

Question 13

13 The diagram shows electron transitions in a Bohr-model hydrogen atom.



Which transition would produce the shortest wavelength of light?

A. *W*

B. *X*

C. *Y*

D. *Z*

Figure 13: Q13

Question 14

14 Which of the following statements correctly describes the gravitational interaction between the Earth and the Moon?

A. The Earth accelerates towards the Moon.

B. The net force acting on the Earth is zero.

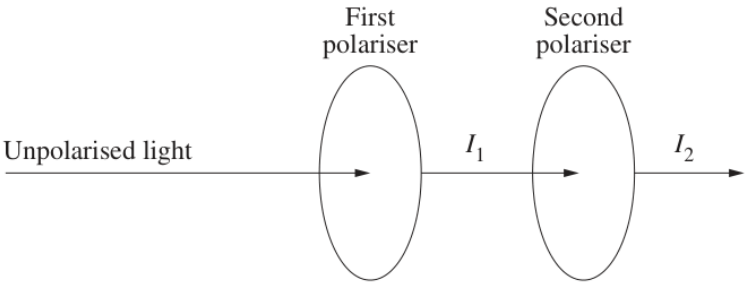
C. The Moon and Earth experience equal and opposite accelerations.

D. The force acting on the Moon is smaller than the force acting on the Earth.

Figure 14: Q14

Question 15

15 Unpolarised light is incident upon two consecutive polarisers as shown. The second polariser has a fixed transmission axis which cannot be rotated. I_1 is the intensity of light after the first polariser, and I_2 is the intensity of light after the second polariser.



How would I_1 and I_2 be affected if the transmission axis of the first polariser was rotated?

A. Both would change.

B. Only I_1 would change.

C. Only I_2 would change.

D. Neither would change.

Figure 15: Q15

Question 16

16 The Sun has an energy output of 3.85×10^{28} W.

By how much does the Sun's mass decrease each minute?

A. 4.28×10^{11} kg

B. 2.57×10^{13} kg

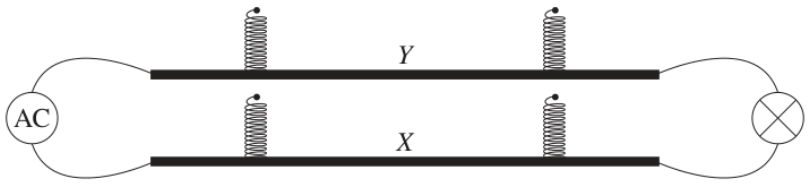
C. 1.28×10^{20} kg

D. 7.70×10^{21} kg

Figure 16: Q16

Question 17

17 Two long, parallel conductors *X* and *Y* are connected to a light bulb and an AC power supply. The conductors are suspended horizontally from fixed points using sensitive spring balances. *X* is positioned directly below *Y*.



Which statement correctly compares the forces measured by the spring balances?

A. The forces measured on *X* and *Y* will always be equal.

B. The force measured on *Y* will be greater than or equal to that on *X*.

C. The force measured on *X* will be greater than or equal to that on *Y*.

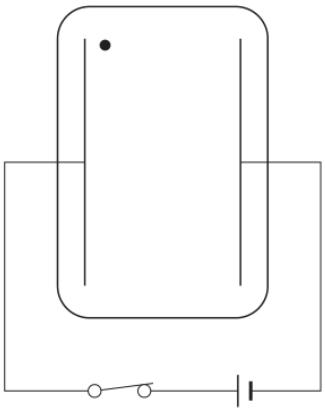
D. There will be a continuous reversal of which measured force is greater.

Figure 17: Q17

Question 18

18 An evacuated chamber contains a pair of parallel plates connected to a power supply and a switch which is initially closed.

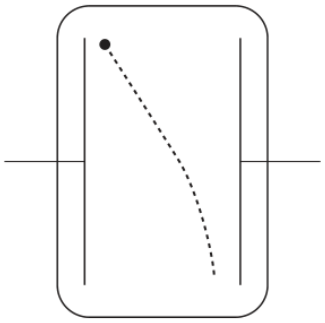
A positively charged mass (•) falls within the chamber, under the influence of gravity, from the position shown.



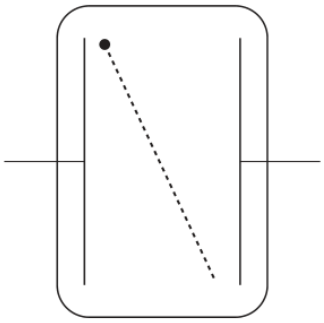
When the mass has fallen half the height of the chamber, the switch is opened.

Which of the following correctly shows the trajectory of the mass?

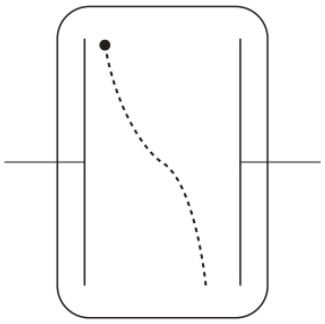
A.



B.



C.



D.

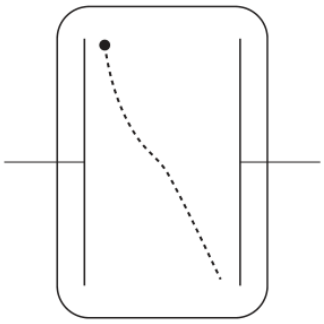
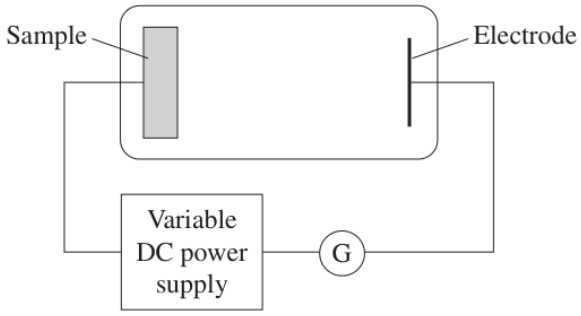


Figure 18: Q18

Question 19

19 Rh-106 is a metallic, beta-emitting radioisotope with a half-life of 30 seconds.

A sample of Rh-106 and an electrode are placed inside an evacuated chamber. They are connected to a galvanometer and a variable DC power supply.



A student measures the current, I, when the power supply is set to zero. They then measure the stopping voltage, V_s. The stopping voltage is the minimum voltage needed to prevent current flowing.

A few minutes later, these measurements are repeated.

How do the TWO sets of measurements compare?

A. Only I changes.

B. Only V_s changes.

C. Both I and V_s change.

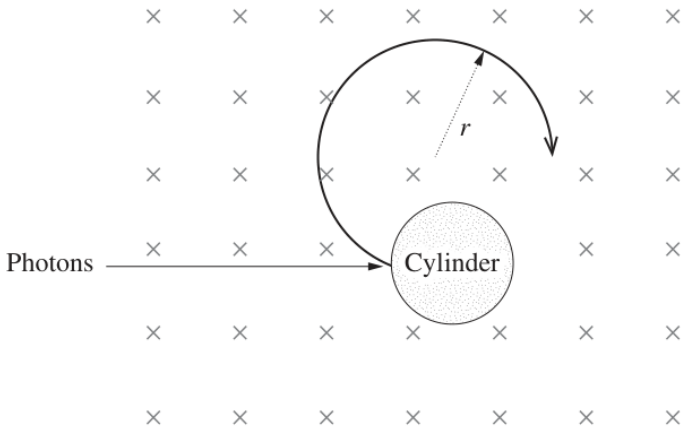
D. Neither I nor V_s changes.

Figure 19: Q19

Question 20

20 A metal cylinder is located in a uniform magnetic field. The work function of the metal is ϕ.

Photons having an energy of 2ϕ strike the side of the cylinder, liberating photoelectrons which travel perpendicular to the magnetic field in a circular path. The maximum radius of the path is r.



If the photon energy is doubled, what will the maximum radius of the path become?

A. $2r$

B. $3r$

C. $\sqrt{2}r$

D. $\sqrt{3}r$

Figure 20: Q20

Section II: Extended Response

80 marks - Questions 21-35

Allow about 2 hours and 25 minutes for this section

Question 21 (4 marks)

Question 21 (4 marks)

A DC motor is constructed from a single loop of wire with dimensions 0.10 m × 0.07 m. The magnetic field strength is 0.40 T and a current of 14 A flows through the loop.

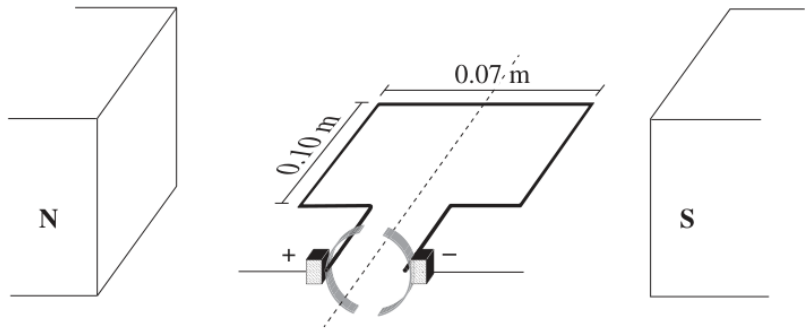


Figure 21: Q21

(a) Calculate the magnitude of the maximum torque produced by the motor. **2**

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(b) Describe how the magnitude of the torque changes as the loop moves through half a rotation from the position shown. **2**

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Part (a)

(a) Calculate the magnitude of the maximum torque produced by the motor. **2**

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Figure 22: Q21a

Part (b)

(b) Describe how the magnitude of the torque changes as the loop moves through half a rotation from the position shown. **2**

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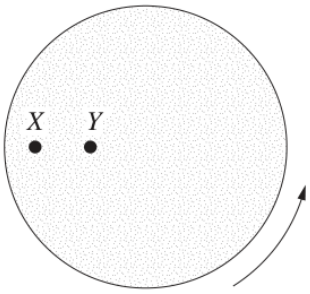
Figure 23: Q21b

Question 22 (3 marks)

Question 22 (3 marks)

A horizontal disc rotates at a constant rate as shown. Two points on the disc, X and Y, are labelled. X is twice as far away from the centre of the disc as Y. **3**



Compare the angular and instantaneous velocities of X with those of Y.

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Figure 24: Q22

Question 23 (4 marks)

DO NO

Question 23 (4 marks)

Describe how Millikan and Thomson each used fields to determine properties of the electron. **4**

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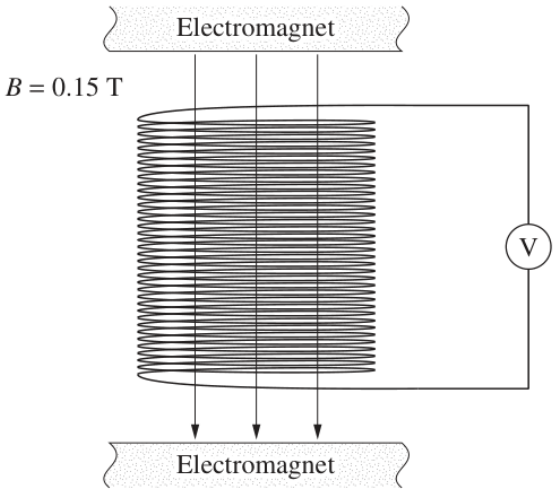
Figure 25: Q23

Question 24 (3 marks)

Question 24 (3 marks)

A stationary coil of 35 turns and cross-sectional area of 0.02 m^2 is placed between two electromagnets, and connected to a voltmeter as shown. The electromagnets produce a uniform magnetic field of 0.15 T through the coil. **3**



The magnitude of the magnetic field is then reduced to zero at a constant rate over a period of 0.4 s.

Calculate the magnitude of the emf induced in the coil.

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Figure 26: Q24

Question 25 (5 marks)

Question 25 (5 marks)

A satellite is launched from the surface of Mars into an orbit that keeps it directly above a position on the surface of Mars.

Mass of Mars = 6.39×10^{23} kg

Length of Martian day = 24 hours and 40 minutes

(a) Identify TWO energy changes as the satellite moves from the surface of Mars into orbit. **2**

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(b) Calculate the orbital radius of the satellite. **3**

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Figure 27: Q25

Part (a)

(a) Identify TWO energy changes as the satellite moves from the surface of Mars into orbit. **2**

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Figure 28: Q25a

Part (b)

(b) Calculate the orbital radius of the satellite. **3**

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Figure 29: Q25b

Question 26 (6 marks)

Question 26 (6 marks)

A student performs an experiment to measure Planck's constant, h, using a device that emits specific frequencies of light when specific voltages are applied.

The voltage, V, needed to produce each frequency, f, is given by

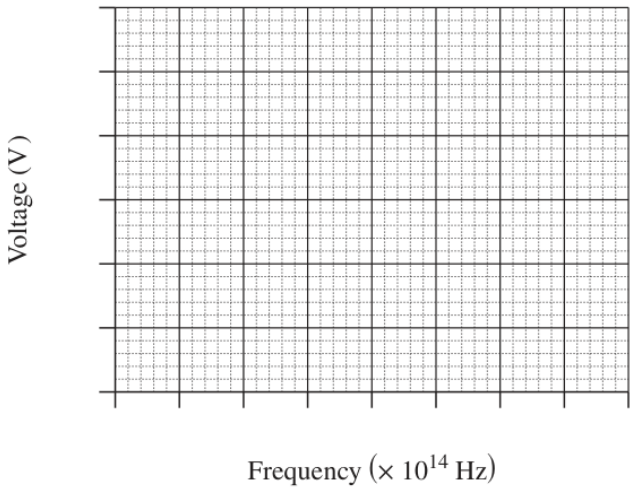
$$V = \frac{hf}{q_e}$$

where q_e is the charge on an electron.

Data from the experiment is shown.

Data point	*Frequency* ($\times 10^{14}$ Hz)	*Voltage* (V)
1	3.5	1.3
2	4.8	1.7
3	5.3	1.9
4	7.0	2.6

(a) Graph this data on the axes provided. Include a line of best fit. **3**

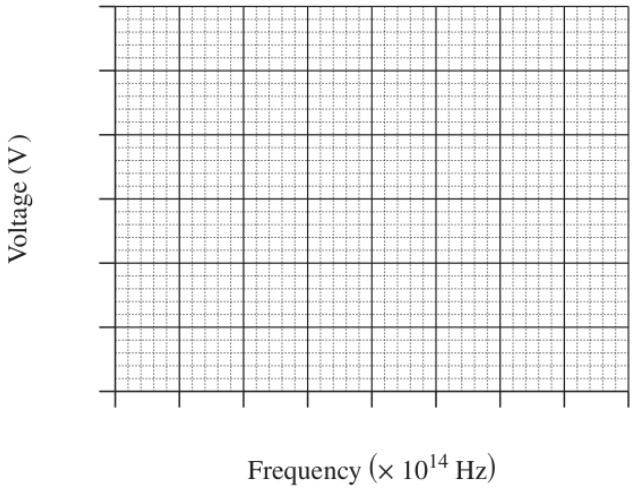


Question 26 continues on page 23

Figure 30: Q26

Part (a)

(a) Graph this data on the axes provided. Include a line of best fit. **3**



Question 26 continues on page 23

Figure 31: Q26a

Part (b)

(b) The student proposes using data point 1 to calculate a value for Planck's constant. **3**

Justify a better method to calculate Planck's constant from the experimental data provided.

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End of Question 26

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Figure 32: Q26b

Question 27 (6 marks)

Question 27 (6 marks)

A student is considering how to levitate a thin metal rod in a strong magnetic field of 1.2 T. The current flowing through the rod will be 2.3 A.

(a) Use a labelled diagram to show a suitable orientation of the current and the magnetic field to achieve this outcome. Include relevant forces in your diagram. **3**

(b) Explain why the maximum mass per unit length of the rod cannot exceed 0.282 kg m^{-1}. Support your answer with a calculation. **3**

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Figure 33: Q27

Part (a)

(a) Use a labelled diagram to show a suitable orientation of the current and the magnetic field to achieve this outcome. Include relevant forces in your diagram. **3**

Figure 34: Q27a

Part (b)

(b) Explain why the maximum mass per unit length of the rod cannot exceed 0.282 kg m^{-1}. Support your answer with a calculation. **3**

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Figure 35: Q27b

Question 28 (5 marks)

Question 28 (5 marks)

A spaceship travels to a distant star at a constant speed, v. When it arrives, 15 years have passed on Earth but 9.4 years have passed for an astronaut on the spaceship.

(a) What is the distance to the star as measured by an observer on Earth? **3**

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(b) Outline how special relativity imposes a limitation on the maximum velocity of the spaceship. **2**

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Figure 36: Q28

Part (a)

(a) What is the distance to the star as measured by an observer on Earth? **3**

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Figure 37: Q28a

Part (b)

(b) Outline how special relativity imposes a limitation on the maximum velocity of the spaceship. **2**

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Figure 38: Q28b

Question 29 (5 marks)

Question 29 (5 marks)

Bohr, de Broglie and Schrödinger EACH proposed a model for the structure of the atom. **5**

How does the nature of the electron proposed in each of the three models differ?

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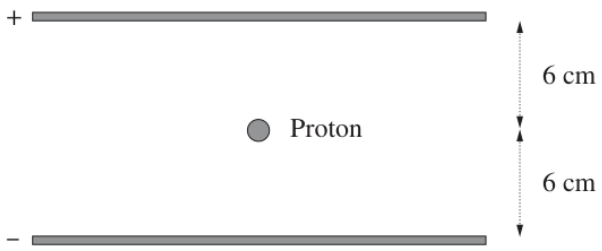
Figure 39: Q29

Question 30 (5 marks)

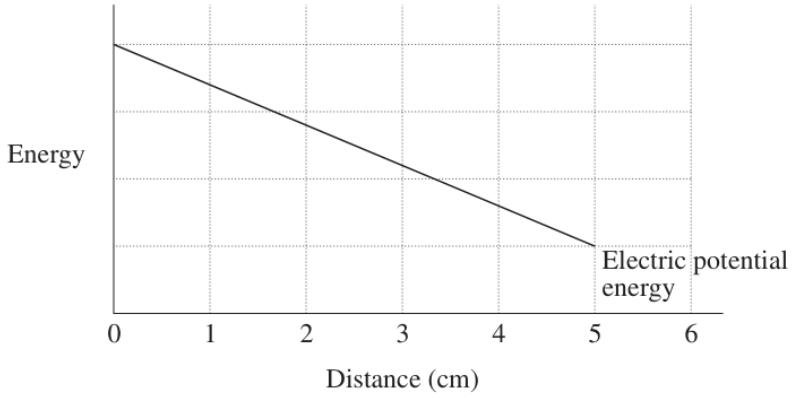
Question 30 (5 marks)

In an experiment, a proton accelerates from rest between parallel charged plates. The spacing of the plates is 12 cm and the proton is initially positioned at an equal distance from both plates, as shown. Ignore the effect of gravity.



(a) The electrical potential energy of the proton is recorded in the following graph for the first 5 cm of its motion. **2**

On the graph, sketch the corresponding kinetic energy of the proton over the same distance.



(b) The experiment is repeated using an electron in the place of the proton. **3**

Explain how the motion of the electron would differ from that of the proton.

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Figure 40: Q30

Part (a)

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(a) The electrical potential energy of the proton is recorded in the following graph for the first 5 cm of its motion. **2**

On the graph, sketch the corresponding kinetic energy of the proton over the same distance.

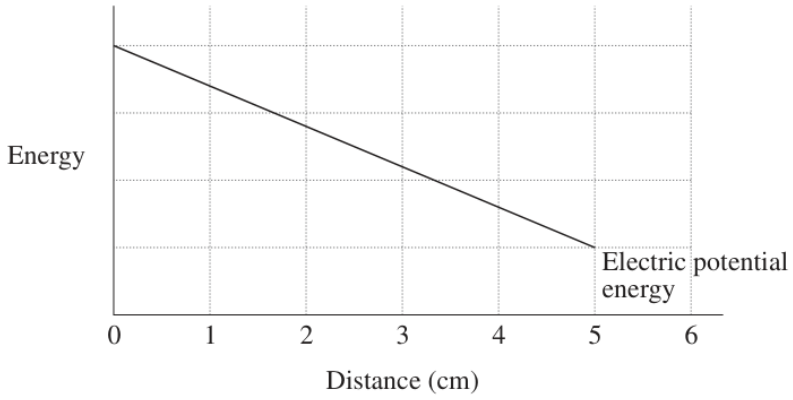

Figure 41: Q30a

Part (b)

(b) The experiment is repeated using an electron in the place of the proton. **3**

Explain how the motion of the electron would differ from that of the proton.

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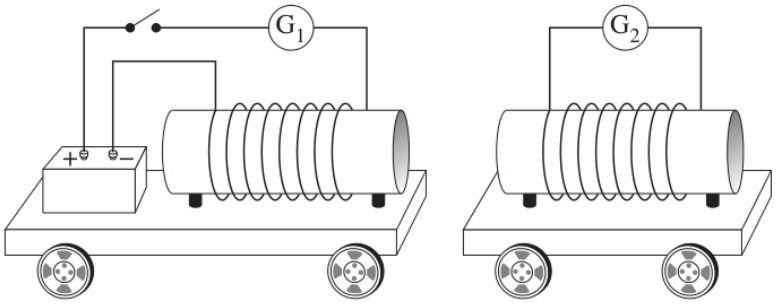
Figure 42: Q30b

Question 31 (7 marks)

Question 31 (7 marks)

Two identical solenoids are mounted on carts as shown. Each solenoid is connected to a galvanometer, and the solenoid on cart 1 is also connected to an open switch and a battery. The total mass of cart 1 is twice that of cart 2. **7**



Cart 1 Cart 2

Explain what would be observed when the switch on cart 1 is closed. In your answer, refer to the current in each galvanometer and the initial movement of the carts.

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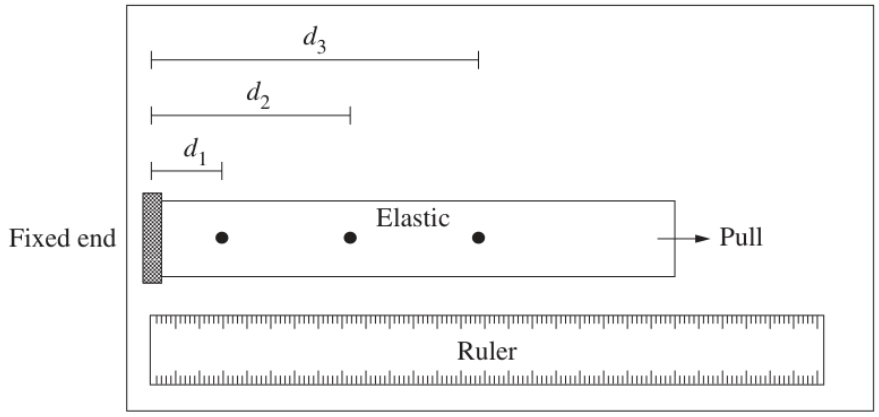
Figure 43: Q31

Question 32 (5 marks)

Question 32 (5 marks)

Two students perform an investigation with a piece of elastic laid out straight on a table. The elastic is fixed at one end and has three markings at regular intervals. The distances from each marking to the fixed end, d_1, d_2 and d_3, are measured as shown. **5**



Top view of table

A student pulls the elastic to extend it, and the new values of d_1, d_2 and d_3 are measured. The student observes that each value has doubled.

How well do the observations from this investigation model the evidence that led to Hubble's discovery of the expansion of the universe? Justify your answer.

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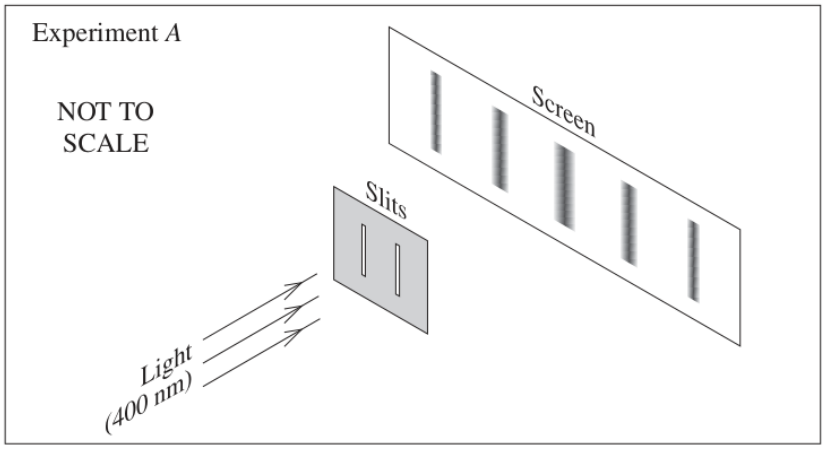
Figure 44: Q32

Question 33 (9 marks)

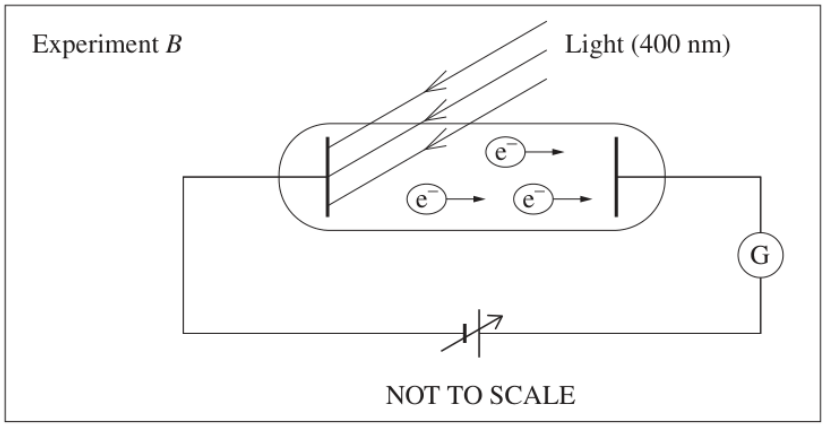
Question 33 (9 marks)

Two experiments are performed with identical light sources having a wavelength of 400 nm. **9**

In experiment *A*, the light is incident on a pair of narrow slits 5.0×10^{-5} m apart, producing a pattern on a screen located 3.0 m behind the slits.



In experiment *B*, the light is incident on different metal samples inside an evacuated tube as shown. The kinetic energy of any emitted photoelectrons can be measured.



Some results from experiment *B* are shown.

Metal sample	*Work function* (J)	*Photoelectrons observed?*
Nickel	8.25×10^{-19}	No
Calcium	4.60×10^{-19}	Yes

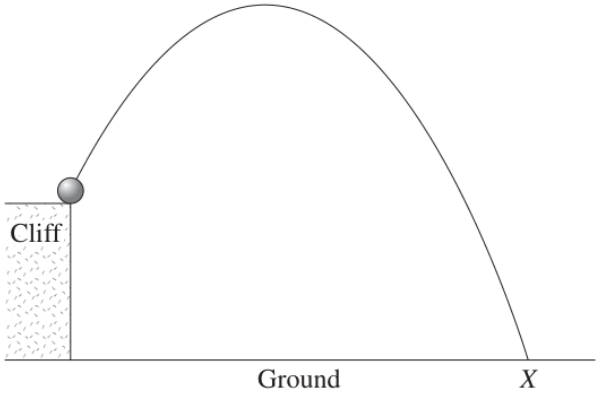
Question 33 continues on page 31

Figure 45: Q33

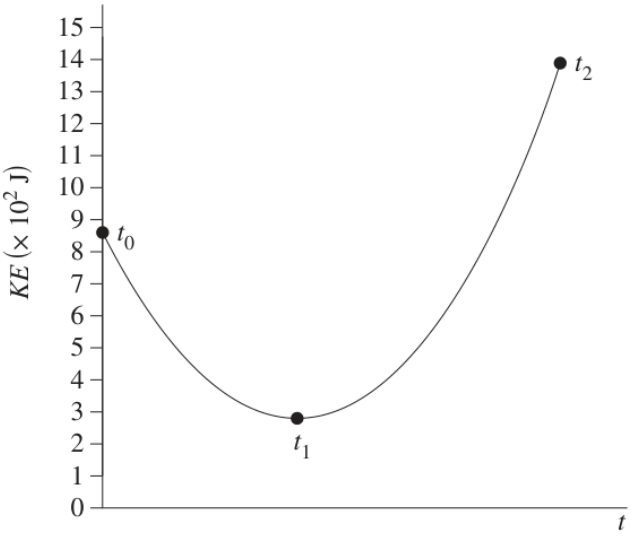
Question 34 (7 marks)

Question 34 (7 marks)

A 3.0 kg mass is launched from the edge of a cliff.



The kinetic energy of the mass is graphed from the moment it is launched until it hits the ground at X. The kinetic energy of the mass is provided for times t_0, t_1 and t_2.



Time (t)	*KE* (J)
t_0	864
t_1	284
t_2	1393

Question 34 continues on page 33

Figure 46: Q34

Part (a)

(a) Account for the relative values of kinetic energy at t_0, t_1 and t_2. **4**

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s area.

Figure 47: Q34a

Part (b)

(b) The horizontal component of the velocity of the mass during its flight is $13.76\ \mathrm{m\,s^{-1}}$. **3**

Calculate the time of flight of the mass.

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End of Question 34

Please turn over

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Figure 48: Q34b

Question 35 (6 marks)

Question 35 (6 marks)

A spacecraft is powered by a radioisotope generator. Pu-238 in the generator undergoes alpha decay, releasing energy. The decay is shown with the mass of each species in atomic mass units, u.

$$^{238}\text{Pu} \longrightarrow {}^{234}\text{U} + \alpha$$

$$238.0495u \qquad 234.0409u \qquad 4.0026u$$

(a) Show that the energy released by one decay is 9.0×10^{-13} J. **3**

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(b) At launch, the generator contains 9.0×10^{24} atoms of Pu-238. The half-life of Pu-238 is 87.7 years. **3**

Calculate the total energy produced by the generator during the first ten years after launch.

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Figure 49: Q35

Part (a)

(a) Show that the energy released by one decay is 9.0×10^{-13} J. **3**

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Figure 50: Q35a

Part (b)

(b) At launch, the generator contains 9.0×10^{24} atoms of Pu-238. The half-life of Pu-238 is 87.7 years. **3**

Calculate the total energy produced by the generator during the first ten years after launch.

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Figure 51: Q35b