JAMES RUSE AGRICULTURAL HIGH SCHOOL

2019

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

General Instructions

• Reading time – 5 minutes

• Working time – 3 hours

• Write using black pen

• Draw diagrams using pencil

• NESA approved calculators may be used

• A data sheet, formulae sheet and Periodic Table are provided at the back of this paper

• For questions in Section II, show all relevant working in questions involving calculations

Section I – 20 marks (pages 2–10) • Attempt Questions 1–20

• Allow about 35 minutes for this section

Section II – 80 marks (pages 12–33) • Attempt Questions 21–35

• Allow about 2 hours and 25 minutes for this section

Section I
20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section
Use the multiple-choice answer sheet for Questions 1–20.

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1. For a particle moving in a circle with uniform speed, which one of the following statements is correct?

A. The kinetic energy of the particle is constant.

B. The net force on the particle is in the same direction as the direction of motion of the particle.

C. The momentum of the particle is constant.

D. The displacement of the particle is in the direction of the net force.

2. The diagram shows two positions, X and Y, at different heights on the surface of the Earth.

Which of the following gives the correct comparisons at X and Y for gravitational potential and angular velocity?

	Gravitational potential energy at X compared with Y	Angular velocity at X compared with Y
A.	greater	greater
B.	greater	same
C.	greater	smaller
D.	same	same

5. Which one of the following statements concerning radioactive decay is true?

A. The half-life of a radioactive isotope depends on the amount of radioactive material present.

B. The activity of a radioactive isotope is inversely proportional to its decay constant.

C. The half-life increases as more of the isotope decays.

D. The half-life is inversely proportional to the decay constant.

6. In experiments supervised by Rutherford, a very thin gold foil was bombarded with alpha particles.
Which of the following observations was correct?

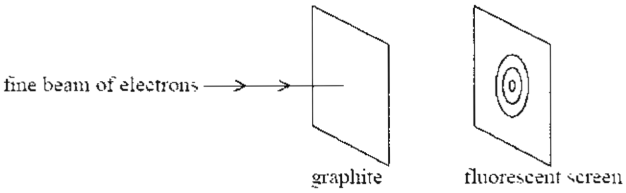
A. All of the α particles passed through the foil without significant deflection.

B. All of the α particles passed through the foil and were deflected through large angles.

C. Most of the α particles passed through the foil with negligible deflection but some were deflected through large angles.

D. The α particles were linearly polarized after passing through the foil.

7. When electrons of suitable energy travel through a thin layer of graphite, a pattern of concentric circles is produced on a screen.



The production of this pattern is evidence for:

A. The wave nature of the electron

B. The nuclear model of the atom

C. The particle nature of the electron

D. The existence of X-rays

8. The energy released by the nuclear bomb that destroyed Hiroshima was equivalent to 12.4 kilotonnes of the explosive TNT. This is equivalent to 9.0×10^{26} MeV.

What was the mass that was converted into energy in this explosion?

A. 1.6 kg

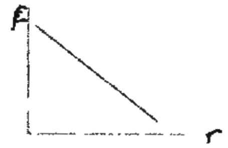
B. 1.6×10^{-3} kg

C. 1.4×10^{14} kg

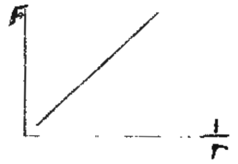
D. 1.1×10^{10} kg

3. Which one of the following graphs correctly shows the relationship between the gravitational force F, between two masses, and the distance, r, between them?

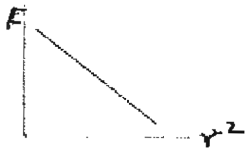
A.



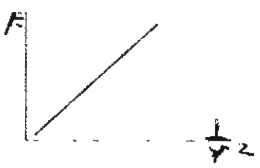
B.



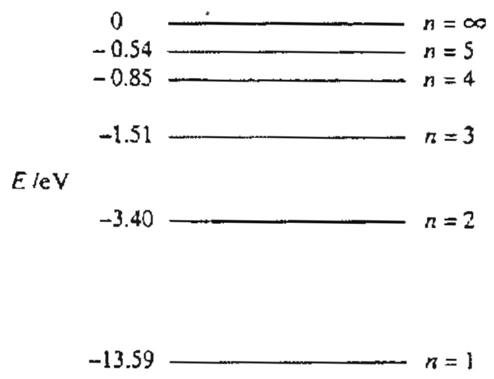
C.



D.



4. Some of the energy levels of the H atom are shown below.



Electrons are excited to the -0.85 eV level.
How many different photon frequencies will be possible in the emission spectrum of hydrogen in this case?

A. 3

B. 4

C. 5

D. 6

9. Which of the following is a correct statement about Hubble's discovery?

A. The recessional velocity of a galaxy is directly proportional to its distance from the Earth.

B. The recessional velocity of a galaxy is inversely proportional to its distance from the Earth.

C. The faster a spiral galaxy's rotational speed, the more luminous it is.

D. The faster a spiral galaxy's rotational speed, the less luminous it is.

10. Light, with intensity I_0, passes through a sheet of Polaroid material that reduces the light intensity to $0.5I_0$. The optical axis of the Polaroid material is vertical. The light then passes through a second sheet of Polaroid material with its face parallel to that of the first.

At what angle should the optical axis of the second sheet (relative to the optical axis of the first sheet) be placed to reduce the intensity of the light to 30% of I_0?

A. $\theta = \cos^{-1}\sqrt{\frac{3}{5}}$

B. $\theta = \sin^{-1}\sqrt{\frac{3}{5}}$

C. $\theta = \cos^{-1}\frac{3}{5}$

D. $\theta = \sin^{-1}\frac{3}{5}$

11. What is the magnitude of the momentum (in kg m s^{-1}) of an electron travelling at $0.8c$?

A. 2.19×10^{-22}

B. 3.64×10^{-22}

C. 4.89×10^{-22}

D. 5.99×10^{-22}

12 The length of a spaceship is measured to be exactly one-third of its rest length as it passes by an observing station.

What is the speed of this spaceship, as determined by the observing station, expressed as a multiple of c?

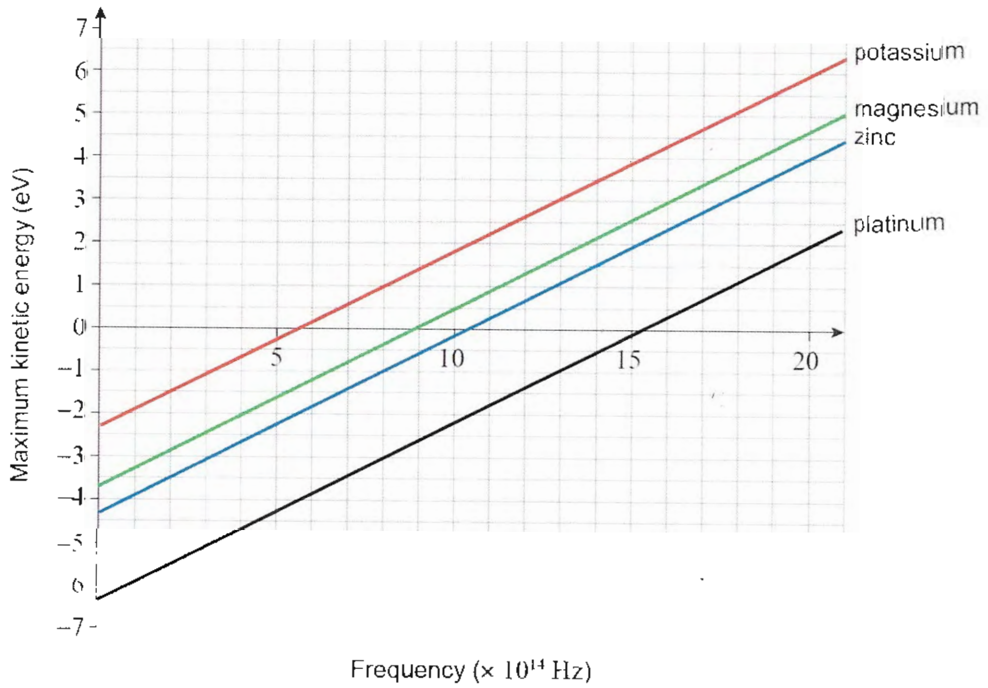
A. $\frac{8}{9}c$

B. $\sqrt{\frac{8}{9}}c$

C. $8c$

D. $\sqrt{8}c$

13 In a photoelectric experiment, the maximum kinetic energy of the photoelectrons was determined and plotted for various frequencies for 4 different metals, as shown in the graph below.



Which option shows the metals arranged in increasing work function?

A. potassium, magnesium, zinc, platinum

B. platinum, zinc, magnesium, potassium

C. zinc, magnesium, platinum, potassium

D. platinum, potassium, magnesium, zinc

14. Which of the following is a correct expression for the charge on an oil drop balanced in a Millikan oil drop Experiment, where the symbols have their usual meaning?

A. $Q \quad \frac{mg}{Vd}$

B. $Q = \frac{Vd}{mg}$

C. $Q = \frac{mgd}{V}$

D. $Q = \frac{V}{mgd}$

15. Which of these nuclear equations is the correct representation of β minus decay?

A. $^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}\beta + \bar{\nu}$

B. $^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}\beta + \nu$

C. $^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}\beta + \bar{\nu}$

D. $^{1}_{0}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}\beta + \nu$

16. In an experiment, light of a particular wavelength is incident on a metal surface, and electrons are emitted from the surface as a result. To produce more electrons per unit time with less kinetic energy per electron, which row of the table will achieve this result?

	Intensity of light	*Wavelength of light*
A.	increase	decrease
B.	increase	increase
C.	decrease	increase
D.	decrease	decrease

17. After a DC motor is switched on, its speed gradually increases.

Which quantity also increases as the speed increases?

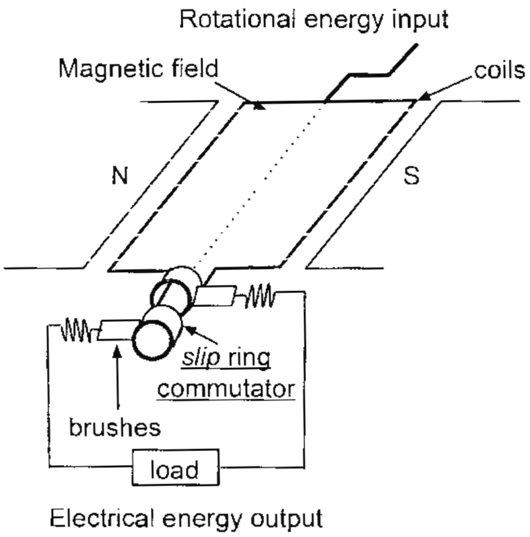
A. Torque

B. Current

C. Back emf

D. Resistance

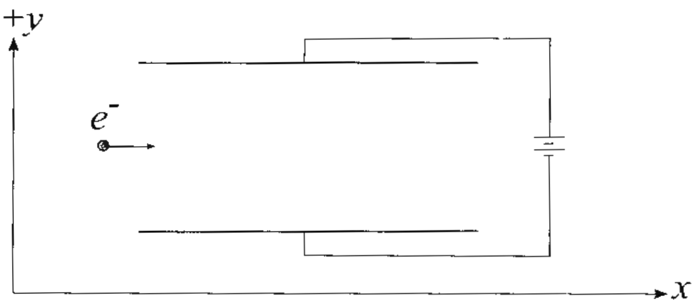
18. The diagram below shows a type of generator.



Which of the following correctly identifies the type of generator shown, and the relative magnitude of the induced emf at the position shown?

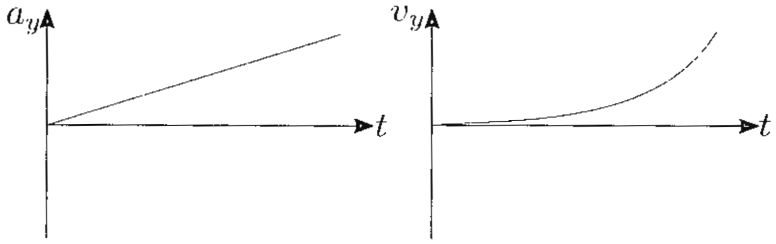
	Type of Generator	*Induced emf at position shown*
A.	AC	Maximum
B.	AC	Minimum
C.	DC	Maximum
D.	DC	Minimum

19. An electron travelling in the positive x-direction enters a uniform electric field, as shown below.

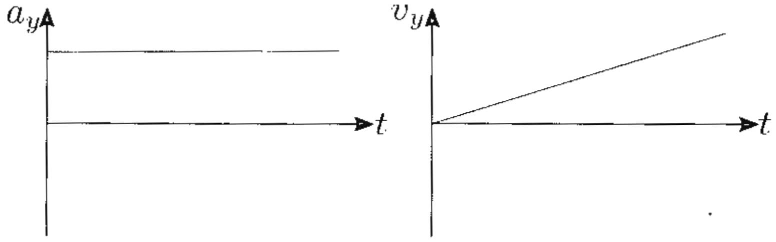


Which of the follows pairs of graphs correctly show the acceleration and velocity of the electron in the y-direction once it enters the electric field?

A.



B.



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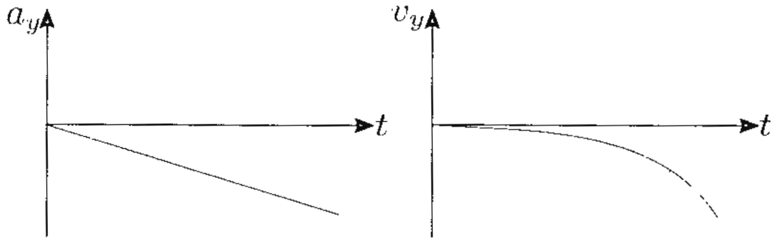
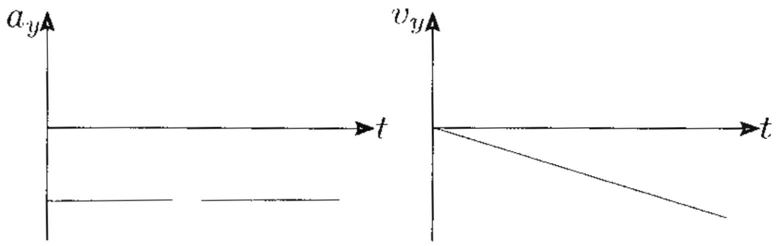
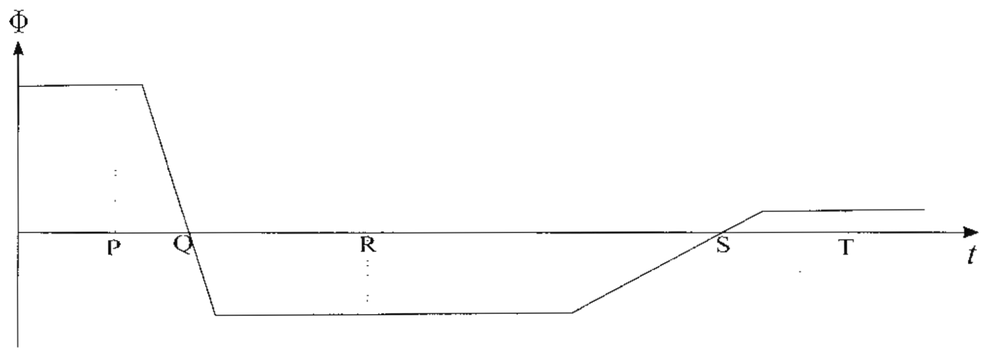


D.



20. The graph below shows how the magnetic flux through a loop of wire varies with time. Five particular times are marked with symbols: P, Q, R, S, T.

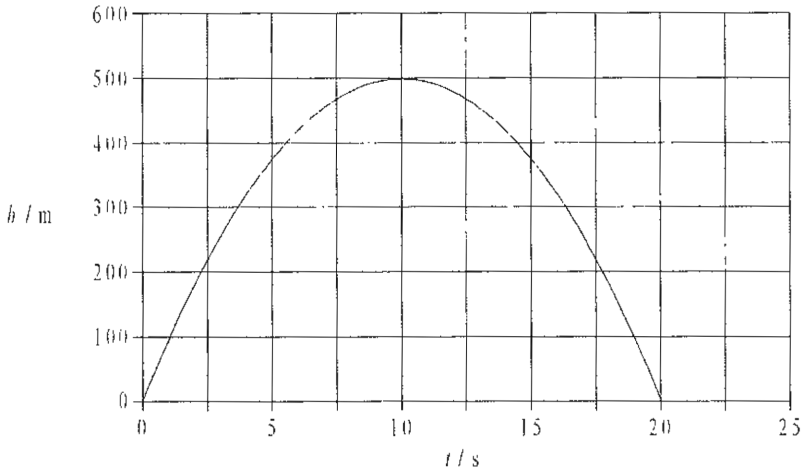


Which of the following correctly compares the magnitude of the induced emf these times?

	Largest emf	*Smallest non-zero emf*	*emf = 0*
A.	P	R	Q, S
B.	P	T	Q, S
C.	S	Q	P, R, T
D.	Q	S	P, R, T

Question 21 (4 Marks)

The barrel of a rifle is held at an angle θ to the horizontal. A bullet fired from the rifle leaves the barrel at time $t = 0$ with a speed, u, 200 m s^{-1}. The graph below shows the variation with time t of the vertical height h of the bullet.



(a) Using the axes below, draw a sketch graph to show the variation of h with the horizontal distance x travelled by the bullet. **1**

*(**Note:** this is a sketch graph; you do not have to add any values to the axes.)*

(b) State the expression for the initial vertical component of speed V_y in terms of the initial speed of the bullet and the angle θ . **1**

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(c) Use data from the graph to deduce that the angle θ = 30°. **2**

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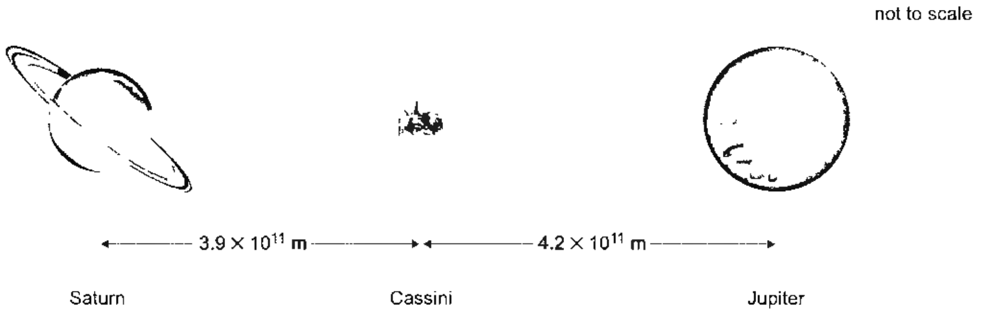
Question 22 (4 Marks)

In 2002, NASA's space probe, Cassini, was between Jupiter and Saturn as shown in the figure below. Cassini's mission was to deliver a probe to one of Saturn's moons, Titan, and then orbit Saturn collecting data.



Below is astronomical data that you may find useful when answering this question.

mass of Cassini 2.2×10^3 kg	mass of Jupiter 1.9×10^{27} kg
mass of Saturn 5.7×10^{26} kg	Saturn day 10.7 hours

(a) Calculate the magnitude of the total gravitational field strength experienced by Cassini when it was 4.2×10^{11} m from Jupiter and 3.9×10^{11} m from Saturn, ignoring the gravitational effects of the Sun. **2**

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(b) Indicate the direction of the gravitational field strength at Cassini, determined from (a) on the figure above. **1**

When Cassini arrived in the vicinity of Saturn, in 2017, scientists wanted it to remain above the same point on Saturn's equator throughout one complete Saturn day. This is called a 'stationary' orbit.

(c) What is the period in seconds of this 'stationary' orbit? **1**

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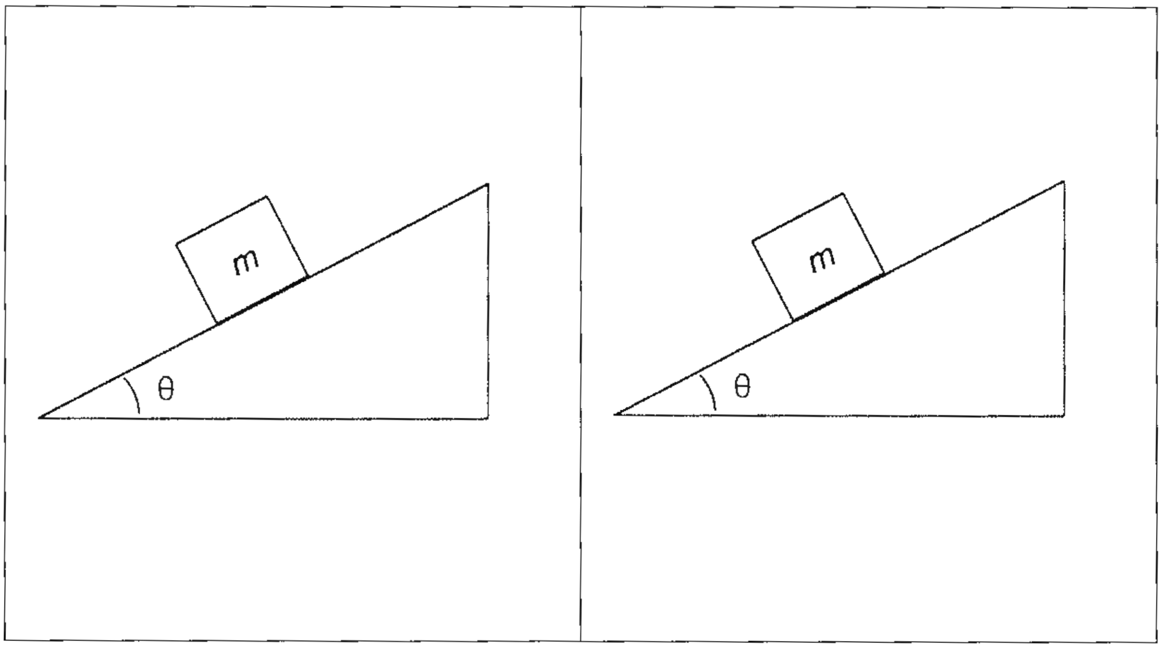
Question 23 (6 Marks)

(a) Draw and use appropriate labels to show the forces acting on a car, mass, *m*, moving around a banked track: **4**

(i) with no friction (ii) with friction



(b) A road with a turn of radius 125 m is being designed for a speed of 18.0 m s^{-1}. **2**

At what angle should the turn be banked?

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Question 24 (6 Marks)

The Hubble space telescope was launched in 1990 into a circular orbit near to the Earth. It travels around the Earth once every 97 minutes.

(a) Calculate the angular speed of the Hubble telescope. **2**

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(b) (i) Given the relationship between angular speed and linear speed is $\omega = v/r$, calculate the radius of the orbit of the Hubble telescope. **2**

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(ii) The mass of the Hubble telescope is 1.1×10^4 kg. **2**

Calculate the magnitude of the centripetal force that acts on it.

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Question 25 (8 Marks)

Both Niels Bohr and de Broglie contributed to developing a model of the atom. **8**

By analysing the evidence, justify the acceptance of de Broglie's model of the atom instead of Bohr's model at that time.

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Question 25 continued on the next page

Question 26 (2 Marks)

Calculate the average binding energy per nucleon for $^{56}_{26}Fe$, the most common stable isotope of iron, given the nuclear mass of Fe 56 is 55.934940 u

mass of proton = 0.997825 u

mass of neutron = 1.008665 u

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Question 27 (4 Marks)

Analyse, with TWO suitable examples, how sustained and controlled amounts of energy can be produced from nuclear reactions. **4**

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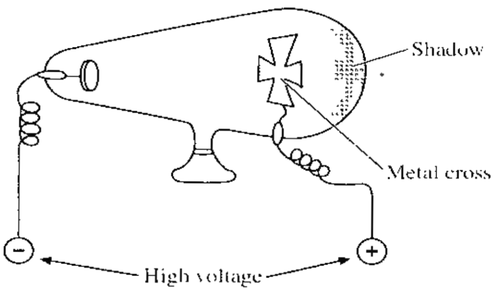
Question 28 (6 Marks)

Crookes developed a gas discharge tube to investigate the electrical nature of matter. When a high voltage is applied to this tube, the glass behind the metal cross glows (fluoresces) and a shadow of the cross appears as shown.



Christian D & Crossley W, Studymate HSC Physics, McGraw-Hill 1991, p 167. Reproduced with permission of Science Press.

(a) Explain how this shadow is formed. **2**

(b) When a magnet is moved towards this gas discharge tube, the shadow of the cross is observed to move across the glass. **2**

Explain this observation.

Question 28 continued on the next page

(c) State ONE way in which work involving gas discharge tubes contributed contributed to the understanding of atomic structure. **2**

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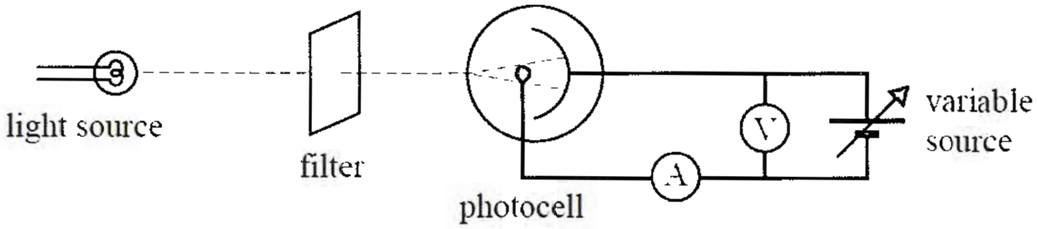
Question 29 (4 Marks)

Emily is conducting an experiment to investigate the photoelectric effect. The apparatus is shown in the figure below. It consists of a light source, a filter and a photocell (a metal plate with a collecting electrode in a vacuum tube). **8**

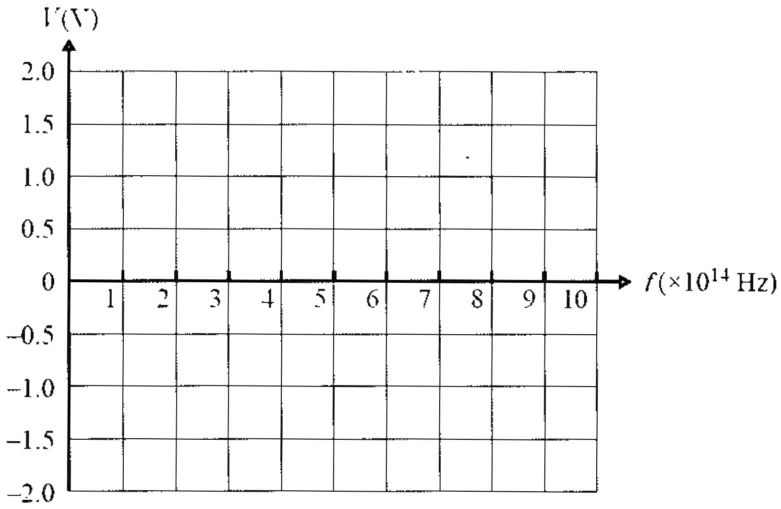


Emily uses various filters to shine a particular wavelength on the photocell.
She increases the voltage (V) until the current just goes to zero and records this voltage.
Emily repeats this process for different frequencies.

Her results are shown in the table below.

Frequency ($\times 10^{14}$ *Hz*)	*Voltage (V)*
6.0	0.16
7.0	0.52
8.0	0.88
9.0	1.20

(a) On the axes below, plot Emily's data and draw the graph of voltage versus frequency. **1**



Question 29 continued on the next page

(b) From the graph, determine the value Emily would have found for each of the following. **3**

Planck's constant	eVs
Threshold frequency	Hz
Work function of the metal	eV

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Question 30 (8 Marks)

Outline the contributions of Newton and Huygens in the development of the model of light, and analyse the subsequent experimental evidence that supported the wave model of light. **8**

Question 30 continued on the next page

Question 31 (4 Marks)

Describe how the spectrum of a star can be used to determine its temperature, and chemical composition. 4

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Question 32 (4 Marks)

Outline TWO pieces of evidence have been gathered to quantitively support the phenomena of time dilation. 4

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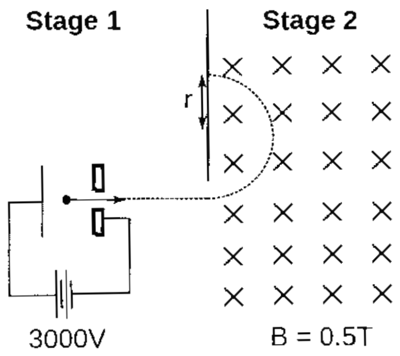
Question 33 (6 Marks)

Mass spectrometers are devices designed to separate charged particles according to their mass. A diagram of a simplified mass spectrometer is shown below.
In Stage 1, charged particles are accelerated to a high speed by a voltage difference between a cathode and an anode. A hole in the anode allows some of the accelerated particles to pass through into Stage 2, in which a magnetic field bends the path of the particles, so they move in the arc of a circle with a radius that depends on their mass.



(a) If a proton is accelerated through 3000V in stage 1, show that it emerges with a speed of $7.6 \times 10^5 \text{ms}^{-1}$. **2**

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(b) Determine the radius of the path followed by the proton from part (a) when it enters the magnetic field (2 marks) **2**

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Question 33 continued on the next page

Deuterium is an isotope of hydrogen with a nucleus consisting of one proton and one neutron, which is double the mass of the nucleus of ordinary hydrogen.

A mix of singly ionised hydrogen (protons) and singly ionised deuterium (which carries the same charge as a proton) is accelerated by stage 1 and enters stage 2.

(c) Find an exact expression for the ratio of the radius of curvature of deuterium ions in the magnetic field, r_D, to the radius of curvature of the protons, r_P. **2**

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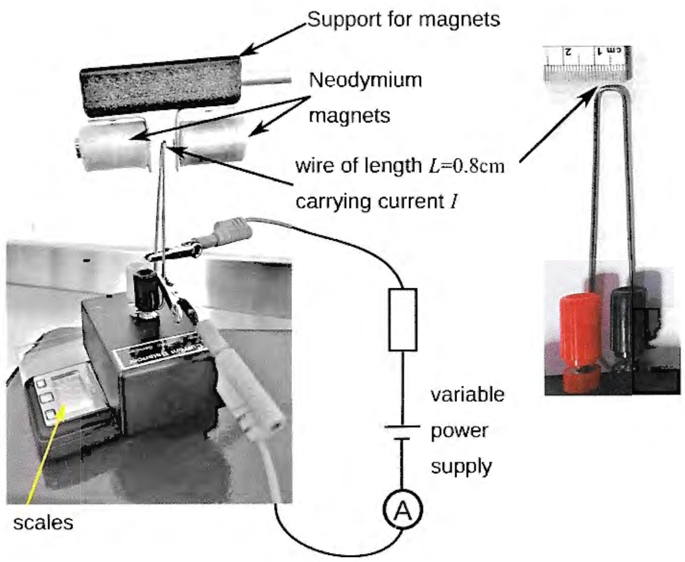
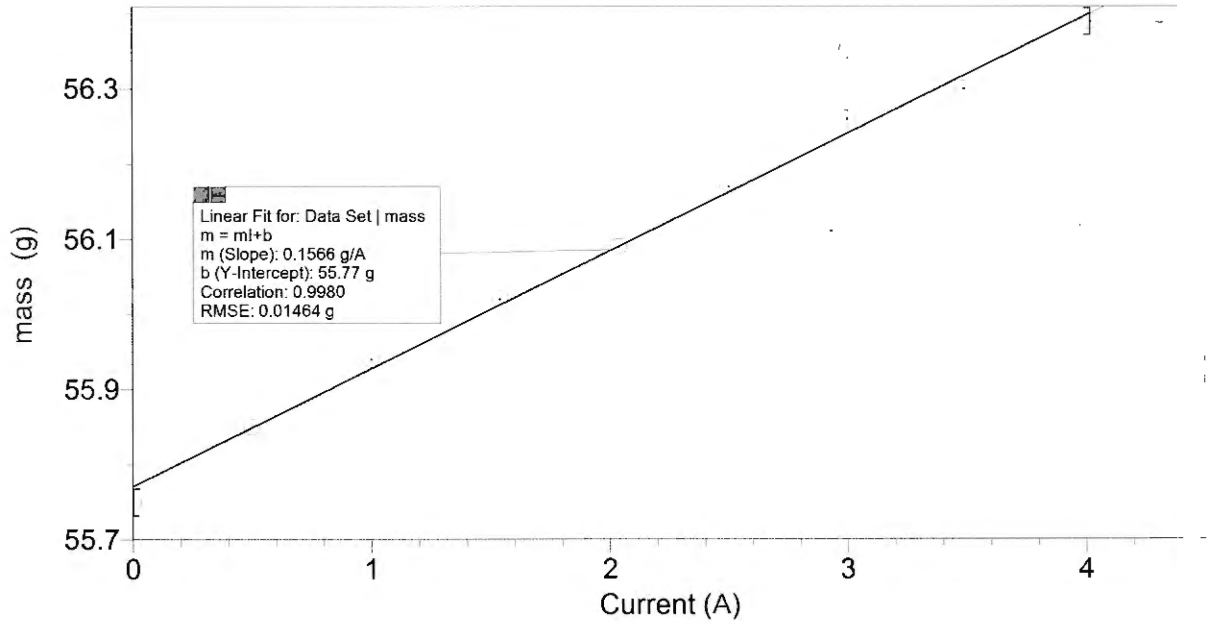
Question 34 (6 Marks)

A wire was placed between two strong neodymium magnets and connected to an external circuit consisting of a resistor, a variable power supply and an ammeter. The wire is supported by a plastic box, which is placed on scales, as shown in the photo below. **6**

The length of wire that is horizontal and perpendicular to the magnetic field is 0.8 cm.



The current flowing through the wire was varied and the mass reading on the scales was recorded. The results have been plotted in the graph below.



Question 34 continued on the next page

(a) Explain why the y-intercept of the graph is not zero, even though the current is zero. **1**

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(b) Using a diagram and a relevant equation, explain why the reading on the scales increases as the current flowing through the wire increases. **2**

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(c) By what factor should the vertical axis be multiplied so that it measures the force exerted upwards by the scale, in Newtons? **1**

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(d) Use the gradient of the line of best fit to determine the magnetic field strength in the region between the Neodymium magnets. **2**

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Question 35 (8 Marks)

(a) A student is supplied with the following equipment: **4**

- a power supply with both AC and DC outputs,
- an iron core,
- AC and DC voltmeters,
- AC and DC ammeters,
- coils of 300 turns of copper wire,
- coils with 600 turns of copper wire
- several connecting wires.

Using a selection of the above equipment, draw a labelled diagram of the experimental set-up to demonstrate the operation of a step-up transformer.

Question 35 continued on the next page

(b) Using equations explain how Faraday's law applies to the operation of an ideal transformer. **2**

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(c) Explain how and why the results of the student's investigation would be expected to differ from those expected for an ideal transformer. **2**

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END OF EXAM

JAMES RUSE AGRICULTURAL HIGH SCHOOL

2019

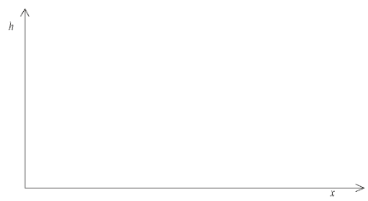
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics **ANSWERS**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	B	D	D	D	C	A	B	A	A	B	B	A	C	A	B	C	A	B	D

Question 21 (4 Marks)

(a) *(**Note:** this is a sketch graph; you do not have to add any values to the axes.)*



(a) Parabola similar to that shown in graph, starting at (0,0) and ending at h=0. (1 mark)

(b) Vy= 200 sin θ (or u sin θ and 200 sin θ - gt) (1 mark)

(c) 200 sin θ = gt **OR** time of flight = 20 s **OR** meas. of gradient at t=0. (2 marks)

200 sin θ = 100 | 200 sin θ x t = ½ gt^2 | = 100 ms^{-1}

θ = 30° | 200 sin θ = 100 | = 200 sin θ

θ = 30° | to give θ = 30°

Question 22 (5 Marks)

(a)

Marking criteria	*Marks*
Gravitational field strength (g) due to each planet and net field	2
Gravitational force (F) for each planet and net force	1

Subtract the gravitational field strength (g) due to Saturn from that due to Jupiter according to the equation.
Giving a value for the gravitational field strength (g) of 4.7 x 10^{-7} N kg^{-1} ($g = GM_J/R_J^{\ 2} - GM_S/R_S^{\ 2}$).

(b)

Marking criteria	*Marks*
For one arrow at Cassini correctly pointing to Saturn	2
For two arrows at Cassini pointing in opposite directions	1

Students are expected to show an arrow in the direction at the position Cassini.
Drawing two arrows, a small one to the left and a larger one to the right is incorrect.

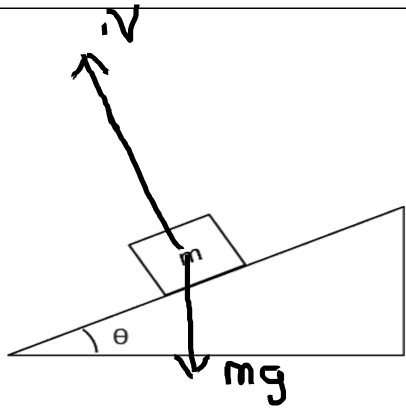
(c)

To remain above the same point on Saturn's equator the satellite would be required to have a period of 10.7 hours, or 3.85×10^4 s.

Question 23 (5 Marks)

(a)

Marking criteria	*Marks*
For each arrow correctly labelled	2
For one arrow correctly labelled	1



(b)

Marking criteria	*Marks*
Correct substitution into equation, calculation and units	3
Correct substitution into equation and calculation	2
Correct substitution into equation	1

Vertical = N cos ð = mg

Horizontal = N sin ð = mv^2/r

$$\frac{N \sin ð}{N \cos ð} = \frac{mv^2/r}{mg}$$

$$\tan ð = \frac{mv^2}{mgr}$$

v^2 = gr tan ð

V = 12.55 ms^{-1}
= 13 ms^{-1}

Question 24 (6 Marks)

(a)

Marking criteria	*Marks*

Correct substitution into equation and units	1

(a) $\omega \left(= \frac{2\pi}{T}\right) = \frac{2\pi}{97 \times 60}$ [or $\omega\left(= \frac{360}{T}\right) = \frac{360}{97 \times 60}$]

$= 1.1 \times 10^{-3}$ (1.08×10^{-3}) **(1)** [$= 6.2$ $(6.19) \times 10^{-2}$]

rad s^{-1} [accept s^{-1}] **(1)** [degree s^{-1}]

(b)

Marking criteria	*Marks*
Correct substitution into equation, calculation and units	3
Correct substitution into equation and calculation	2
Correct substitution into equation	1

$\frac{GMm}{r^2} = m\omega^2 r$ or $r^3 = \frac{GM}{\omega^2}$ **(1)**

gives $r^3 = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(1.08 \times 10^{-3})^2}$ **(1)**

$\therefore r = 6.99 \times 10^6$ (m) **(1)**

(ii)

Marking criteria	*Marks*
Correct substitution into equation, calculation, units and sig figs	2
Correct substitution into equation and calculation, incorrect sig figs	1

,

$F (= m\omega^2 r) = 1.1 \times 10^4 \times (1.08 \times 10^{-3})^2 \times 6.99 \times 10^6$ **(1)**

$= 9.0 \times 10^4$ (8.97×10^4) (N) **(1)**

[or $F\left(= \frac{GMm}{r^2}\right) = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 1.1 \times 10^4}{(6.99 \times 10^6)^2}$ **(1)**

$= 9.0 \times 10^4$ (8.98×10^4) (N) **(1)**]

Question 25 (8 Marks)

Marking criteria	*Marks*
Thorough outline of Bohr model of atom based on 3 postulates Limitations of the Bohr model of the atom Broglie's proposal of wave-particle duality Proof for matter waves through diffraction Confirmation of Broglie's proposal by Davisson and Germer Implications of de Broglie'e electron wave model (it formed the foundation of the new quantum mechanics)	7-8
Marks awarded for any of the above depending on the level of depth	

Proposed by Danish physicist Niels Bohr in 1913, this model depicts the atom as a small, positively charged nucleus surrounded by electrons that travel in circular orbits (defined by their energy levels) around the nucleus.

Bohr's model refined certain elements of the Rutherford model that were problematic. These included the problems arising from classical mechanics, which predicted that electrons would release emr while orbiting a nucleus. Because of the loss in energy, the electron should have rapidly spiraled inwards and collapsed into the nucleus. The model also predicted that as electrons spiraled inward, their emission would rapidly increase in frequency as the orbit got smaller and faster

Bohr resolved this by proposing that electrons orbiting the nucleus in ways that were consistent with Planck's quantum theory of radiation. In this model, electrons can occupy only certain allowed orbitals with a specific energy. Furthermore, they can only gain and lose energy by jumping from one allowed orbit to another, absorbing or emitting electromagnetic radiation in the process

Bohr postulated that:

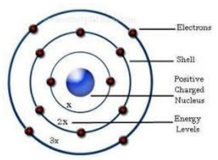
1. An atom can exist only in special states with discrete (step-like) values of energy. (Electrons in an atom can exist only in certain special orbits.) Bohr called these special states (or orbits) stationary states.
2. When an atom makes a transition from one stationary state to another, it emits or absorbs radiation whose frequency ν, is given by the frequency condition

$$h\nu = E' - E'',$$

where E' and E'' are the energies of these stationary states.

The Bohr model successfully predicted the energies for the hydrogen atom, but had significant **failures**.

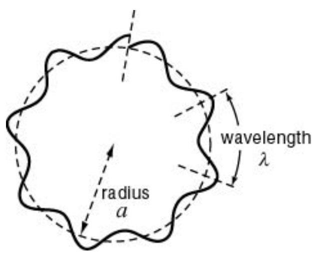
These included:



1. Bohr's explanation and prediction of wavelength works only for H and only the H spectrum is fully predicted by the Rydberg equation.
2. Bohr's model could not explain the varying intensities of the spectral lines.
3. Bohr's model could not explain the Zeeman effect. (splitting of spectral lines)
4. Bohr's model could not explain the hyperfine spectral lines.

Bohr model was a helpful step along the way to developing a quantum mechanical model for hydrogen

De Broglie in 1924 used the idea of electrons as waves to propose that the allowed electron orbits were those that fitted standing waves in them. The theory of wave--particle duality developed by de Broglie eventually explained why the Bohr model was successful with atoms or ions that contained one electron. It also provided a basis for understanding why this model failed for more complex systems. When an object behaves as a particle in motion, it has an energy proportional to its mass (m) and speed with which it moves through space.



De Broglie's Equation

$$\lambda = \frac{h}{mv}$$

Where
λ = wavelength in meters
v = the velocity in meters/sec
m = the mass in kilograms
h = Plancks's constant in J/Hz

de Broglie proposed his **hypothesis** stating that *any moving particle or object had an associated wave*.

De Broglie applied his theory of wave--particle duality to the Bohr model to **explain why** only certain orbits are allowed for the electron. He argued that only certain orbits allow the electron to satisfy both its particle and wave properties at the same time because only certain orbits have a circumference that is an integral multiple of the wavelength of the electron, as shown below.

The fact that only certain orbits are allowed in the Bohr model of the atom can be explained by assuming that the circumference of the orbit must be an integral (n = 1, 2, 3, 4 . . .) multiple of the wavelength of the electron. When it is not, the electron cannot simultaneously satisfy its wave and particle behaviour.
De Broglie concluded that most particles are too heavy to observe their wave properties. When the mass of an object is very small, however, the wave properties can be detected experimentally.

Broglie predicted that the mass of an electron was small enough to exhibit the properties of the electron wave.

Bohr's stable electron orbits can now be explained by considering the wave nature of the electron. Orbits are stable only if their circumference is an integral number of wavelengths of the electron wave. . It is only this condition that results in stable standing electron waves. All other circumferences result in destructive interreference and the orbit is unstable.

In 1927 this prediction was confirmed when the diffraction of electrons was observed experimentally by **Davisson and Germer.**

Question 26 (2 Marks)

Marking criteria	*Marks*
Calculation of mass defect, total binding energy and BE per nucleon	2
Calculation of mass defect, total binding energy	1

Fe 56 has 26 protons and 30 neutrons.
26 1.007276 u) = 26.189176 u
30 (1. 008664 u) = 30.259920
Total = 56.449096 u

Subtract mass of Fe 56 25: -55.9349 u.
∆ m = 0.514159 u

The total BE is thus
(0.5286 u) (931.5) = 478.9391085 MeV

Average BE per nucleon = 478.9391085 / 56 = 8.552484 MeV

Question 27 (4 Marks)

Marking criteria	*Marks*
Two examples of controlled nuclear reactions eg fission and/or fusion Principle of controlled fission chain reaction in a nuclear reactor Principle of fusion reactions in main sequence stars, fusing H into He via the p-p chain or the CNO reaction at very high temperatures.	4
One example of controlled nuclear reactions eg fission or fusion Principle of controlled chain reaction in a nuclear reactor Or Principle of fusion reactions in main sequence stars, fusing H into He via the p-p chain or the CNO reaction at very high temperatures.	2

Fission, the splitting of a large nucleus into two smaller nuclei, releases energy in accordance of Einstein's mass-energy equivalence equation, $E=mc^2$. A fission chain reaction can be controlled in a nuclear reactor and this produces energy at a constant rate. Slightly enriched U is used as fuel, a moderator to slow the neutrons increases the probability that they will initiate fission reactions. The control rods absorb the neutrons such that the rate of reaction remains constant.
Fusion is the process by which nuclei of low atomic weight such as H combine to form nuclei of higher atomic weight such as He. Fusion occurs in the Sun and other stars. At very high temperatures, the elements become plasma. In the fusion process, some of the mass of the original nuclei is lost and transformed to energy in the form of high energy particles.

Question 28 (6 Marks)

(a) Explain how this shadow is formed. **2**

Marking criteria	*Marks*
Correct description and origin of cathode rays (cause) and linking this to the effect	2
One of the above	1

Sample Answer:

Cathode rays are produced by the cathode due to the high voltage between it and the anode. They travel in straight lines and are thus blocked by the solid metallic cross. As they are unable to strike the glass surface behind the cross, a shadow is cast on the inside of the evacuated tube, behind the cross.

(b)

Marking criteria	*Marks*
Correct explanation for the cause and linking this to the effect	2
One of the above	1

Sample Answer:

As perpendicularly moving charged particles (charge q, speed v) are deflected in an external magnetic field (B), the cathode rays experiences a force (F) using $F = qvB$. Hence the shadow moves as a result of the deflection by the field provided by the magnet.

(c)

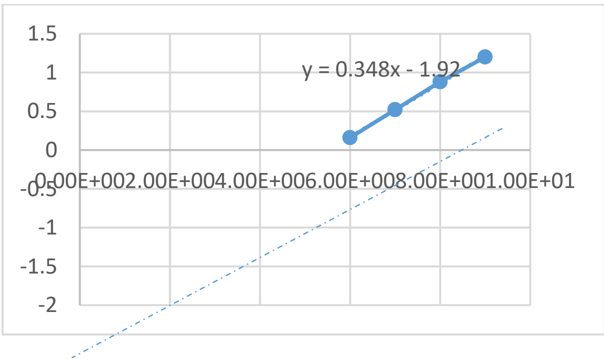
Marking criteria	Marks
Correctly identifies an experiment and describes the purpose	2
Any one of the above	1

Sample Answer:

- Enabled the charge to mass ratio $\left(\frac{q}{m}\right)$ to be determined (Thomson's e/m experiment)
- Enabled the nature of the charge of the nucleus to be determined (Rutherford's Gold Foil Experiment)
- Helped to observe and understand electron transitions between energy levels (Line emission spectra in gas discharge tubes)

Question 29 (4 Marks)

(a)



Marking criteria	Mark
Correctly plotted point line of best fit, with x, y intercepts	1

(b) From the graph, determine the value Emily would have found for each of the following. **3**

Marking criteria	Mark
3 correct values	3
Any two correct	2
Any one correct	1

Planck's constant	3.6×10^{-15} eVs
Threshold frequency	5.5×10^{14} Hz
Work function of the metal	$2.0\ eV$

$$\boldsymbol{E_k = hf - \phi}$$
$$\boldsymbol{V_0 = \left(\frac{h}{q}\right) f - \frac{\phi}{q}}$$

So slope is $\frac{h}{q}$

Hence $h = slope \times q$

$= 0.348 \times 10^{-14} \times 1.602 \times 10^{-19}$

$= 5.57 \times 10^{-34}\ V\ s$

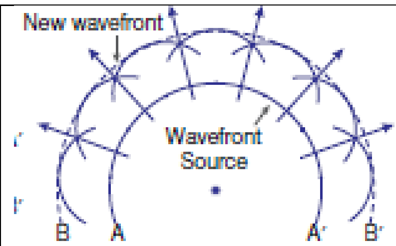
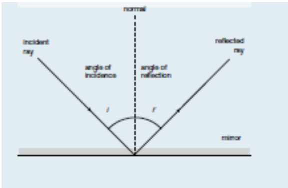
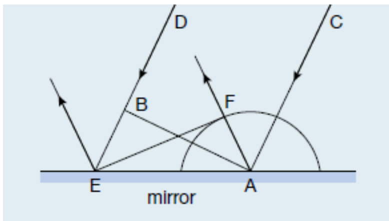
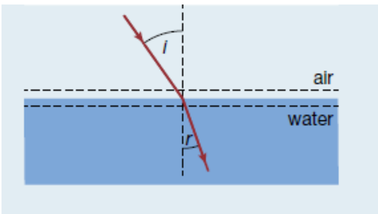
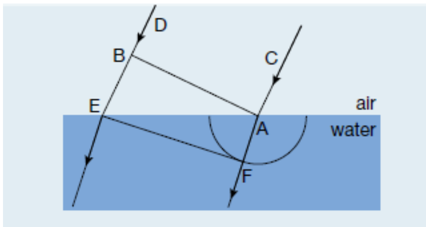
$= 3.5 \times 10^{-15}\ eV\ s$

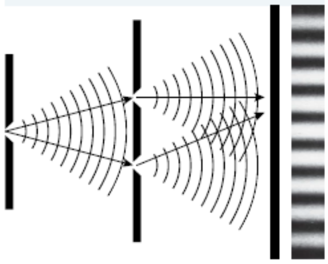
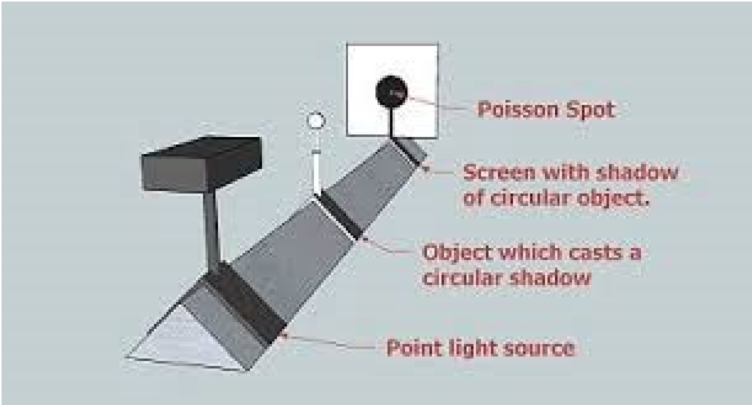
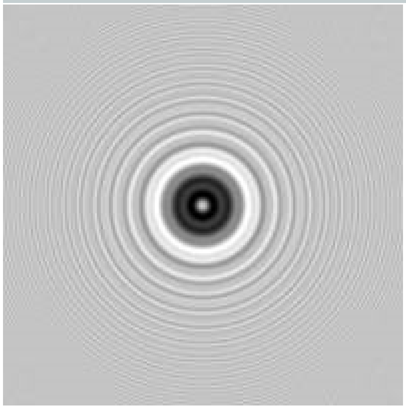
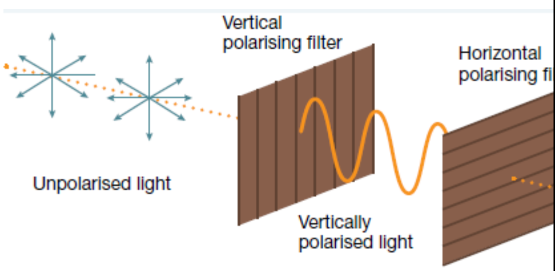
Accepted $\phi = hf_0$, from which $h = \frac{2.0\ eV}{5.5\times10^{14}\ s^{-1}} = 3.6 \times 10^{-15}\ eV\ s$

Question 30 (8 Marks)

Marking criteria	*Mark*
Provides an outline of Newtons (N1) and Huygen's Model of light (H1) , including a description of the reflection (N2 and H2) and refraction (N2 and H2) properties each suggested (2 X 2); Analyses at least 2 experiments (Young's double slit (E1) **OR** Arago/Poisson (E2) Spot **OR** Polarisation (E3) (2 X 2) **AND** Foucault's Experiment to resolve the speeds of light in new media (N2/H2)	8
One of the above omitted	7
Two of the above omitted	6
Three of the above omitted	5
Four of the above omitted	4
Five of the above omitted	3
Six of the above omitted	2
Seven of the above omitted	1

Property/Theory	**Newton**	**Huygens**
	Corpuscular theory • light consists of tiny particles called corpuscles, • travels in straight lines **1 MARK (N1)**	Huygens's Principle ✓ every point on a wavefront is a source of secondary waves, with the tangent to these wavelets forming new wavefronts which then propagates forwards ✓ longitudinal wave **1 MARK (H1)**

		
Reflection	As the particles hits a surface, a force slows down and reverses the normal, reflecting the particle with $i = r$ 	Reflected wavelets are formed when wavefronts hit a surface, $i = r$ 
Refraction	As particles approach a denser medium, the normal component of its velocity increases, bending them towards the normal (change in direction)  **1 Mark (N2)**	When wavefront meets an heavier medium, the wavefronts slows down, causing it to change direction, bending towards the normal.  **1 Mark (H2)**
Partial Resolution of conflict between Newton's and Huygen's model of light (COMPULSORY)	**Experimental Evidence 1** Foucault and Fizeau measure the speed of light in water and shows that it slows down. **1 Mark (E1)**	
Diffraction and interference	**Experimental Evidence 2 (2 Marks each)** Young's double slit experiment OR Arago/Poisson Spot	

	  	
polarisation	**Experimental Evidence 2 (2 marks)** 	

Question 31 (4 Marks)

Marking criteria	*Marks*
Comprehensive description of Wien's law (temperature determination); comparison of absorption spectra with line emission spectra of known elements (chemical composition)	4
Moderate description	3-4
Superficial description	1-2

Sample Answer:

Using the radiation curves for Blackbody Radiation, the wavelengths at which the intensity peaks can be obtained. From Wien's Law, $\lambda_{max}T = constant$, the temperature of the star can be determined.

The chemical composition of stars can be found by comparing their absorption spectra with the line emission spectra of known elements/ions/compounds.

Question 32 (4 Marks)

Marking criteria	*Marks*
Outlines two pieces of experimental evidence that supports the concept of time dilation in relativity (2 X 2) Outline must include: (a) Hafele Keating (atomic clocks) (high speed jets, accurate, precise, synchronised clocks, time difference showing moving clocks running slower) (b) Rossi-Hall (Detection of muons) (proper time and dilated time, detectors, percentage of muons with and without relativity effects considered) (c) Transition rates (particle accelerators, comparison of rates of transition)	4
Moderate outline	3
Superficial outline	2
Some relevant information	1

Sample Answer

Hafele Keating Experiment:

This experiment involved flying highly accurate, precise and synchronised caesium-atomic clocks on commercial airliners (high speed jets) to compare the time elapsed with one that remained on the ground.

Although the reference frames were not strictly inertial as the clocks were all travelling in circles about the centre of the Earth, and they were under the influence of gravity, the differences in time measured by the clocks was sufficiently large to detect the time dilation effects and they agreed with Einstein's prediction.

Three sets of clocks were used: one that remained on the ground (control clock); one that had a relatively higher speed as it went in planes that travelled around the world in an easterly direction; and one that had a relatively lower speed as it was in planes that circled the globe in a westerly direction.

When the effects of gravity and orbital accelerations were taken into account, these very accurate clocks indicated different amounts of time passing, in keeping with the predictions of Einstein's ideas of time dilation.

The two inflight clocks recorded a smaller time than the clocks on the ground i.e. it showed moving clocks were running slower, and that the time on clocks on the ground showed a longer time – hence time was dilated.

Rossi-Hall Experiment

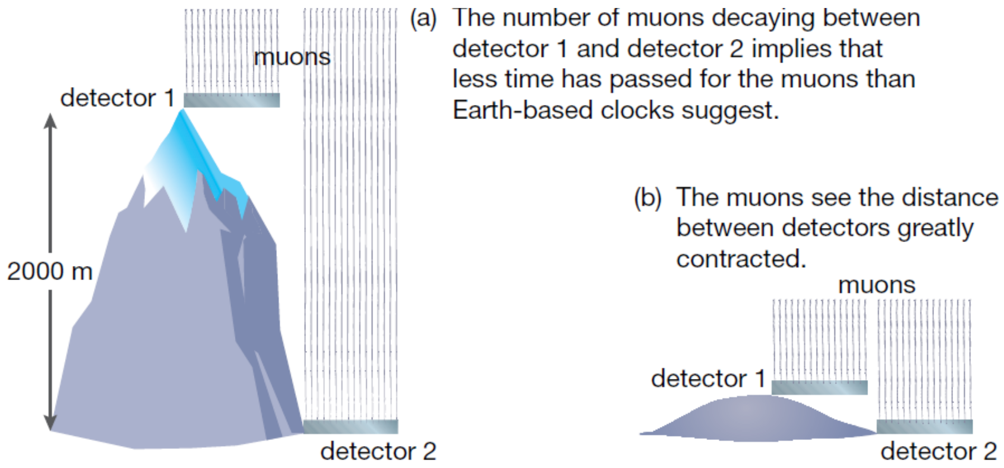
Bruno Rossi and David Hall performed an experiment in 1941, the results of which are consistent with both time dilation and length contraction. Earth is constantly bombarded by energetic radiation from space, known as cosmic radiation. These rays collide with the upper atmosphere, producing particles known as muons. Muons are known to have a very short half-life, measured in the laboratory to be 1. 56 microseconds.

Given the speed at which they travel and the distance they travel through the atmosphere, the vast majority of muons would decay before they hit the ground.

The Rossi–Hall experiment involved measuring the number of muons colliding with a detector on top of a tall mountain and comparing this number with how many muons were detected at a lower point. They found that far more muons survived the journey through the atmosphere than would be predicted without time dilation.

The muons were travelling so fast relative to Earth that the muons decayed at a much slower rate for observers on Earth than they would at rest in the laboratory. The journey between the detectors took about 6. 5 microseconds according to Earth-based clocks, but the muons decayed as though only 0. 7 microseconds had passed.

Due to length contraction, the muons did not see the tall mountain but, rather, a small hill. Rossi and Hall were not surprised that the muons survived the journey at all.



Transition Rates

More recent experiments have tested time dilation predictions to high precision. For example, in 2014 a team of physicists published their work using particle accelerators. They measured the rates of transitions between energy states of atoms moving at one-third the speed of light in the particle accelerator. They were then able to compare these rates with the rates of transitions of the same atoms at rest in the laboratory. The difference in rates matched Einstein's predictions to the highest levels of precision achieved to date.

Question 33 (6 Marks)

(a) The change in kinetic energy is equal to the work done by the field $\Delta KE = qV$, so $v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2\times1.6\times10^{-19}\times3000}{1.67\times10^{-27}}} = 7.6\times10^{5} ms^{-1}$

Marking Criteria	*Marks*
- $\Delta KE = qV$ - Correct substitution and solution	2
- $\Delta KE = qV$	1

(b)

The centripetal force is provided by the force due to the magnetic field, so $\sum F = ma$ becomes

$qvB = m\frac{v^2}{r}$ and $r = \frac{mv}{qB} = 1.6\times10^{-2} m$

Marking Criteria	*Marks*
- $qvB = m\frac{v^2}{r}$ - Correct substitution and solution	2
- $qvB = m\frac{v^2}{r}$	1

(c)

The ratio of the velocities of the deuterium ions and protons after passing through stage 1 is

given by $\frac{v_D}{v_P} = \sqrt{\frac{2qV}{m_D}} / \sqrt{\frac{2qV}{m_p}} = \sqrt{\frac{m_p}{m_D}} = \sqrt{2}$.

The ratio of the radii in the magnetic field is then $\frac{r_D}{r_p} = \frac{m_D v_D}{qB} / \frac{m_p v_p}{qB} = \frac{2v_D}{v_P} = \frac{2}{\sqrt{2}} = \sqrt{2}$

Marking Criteria	Marks
- Obtains $\frac{r_D}{r_p} = \sqrt{2}$	2
- Obtains ratio of radii as $\frac{r_D}{r_p} = \frac{m_D v_D}{qB} / \frac{m_p v_p}{qB}$ but mistakenly sets $v_P = v_D$ to obtain $\frac{r_D}{r_p} = 2$	1

Question 34 (6 Marks)

(a) Sample answer: The scale was not 'tared' before beginning the experiment AND/OR The y-intercept is the mass of the plastic box and wire.

Marking Criteria	Marks
The scale was not 'tared' before beginning the experiment AND/OR The y-intercept is the mass of the plastic box and wire (or similar)	1

(b) Sample answer:
The force acting on the wire is given by the equation F = BIL sinθ, so increases in magnitude as the current increases. The current flowing in the wire is perpendicular to the direction of the field, so sinθ=1. Using the orientation of the field and wire in the diagram, by the right hand rule the force acting on the wire is downwards (**This could be communicated effectively using a diagram**).
The normal force provided by the scale increased until it balances the sum of the weight and magnetic force downwards, so the reading on the scale increases as the current increases.

Criteria	Marks
Uses the equation F = BIL sinθ to explain that: - the force is perpendicular to both the direction of the current and the field so is directed downwards (sinθ=1). - The force is proportional to the magnitude of the current	2
Explains one of the above	1

(c) Sample answer:
The vertical axis should be multiplied by a factor of $9.8/10^3$ in order to read the upward 'normal' force provided by the scale.

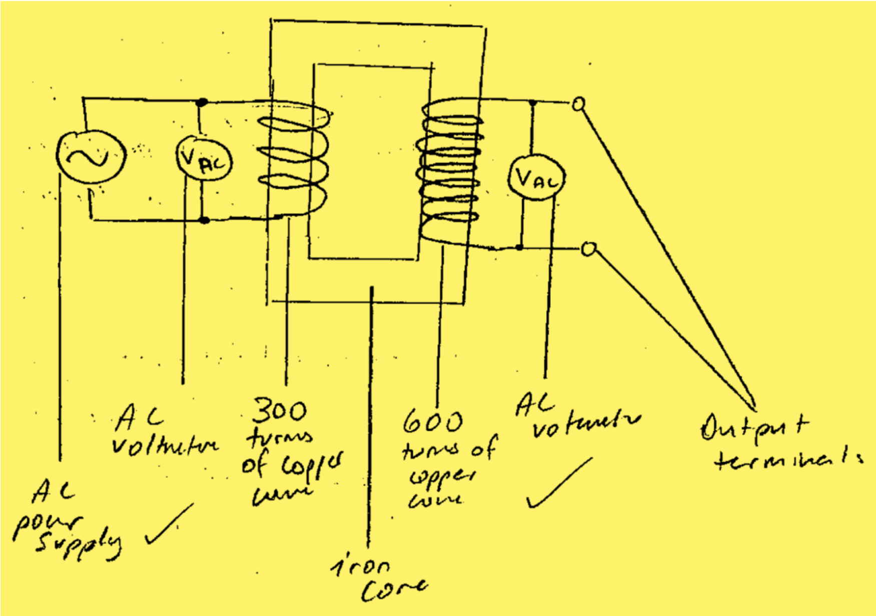
Marking Criteria	Marks
Correct factor	1

(d) Sample answer:
$\sum F = N - BIL = 0$, so $B = \frac{N}{I}\frac{1}{L} = 9.8 \times 10^{-3} \times \frac{gradient}{L} = 9.8 \times 10^{-3} \times \frac{0.1566}{0.008} = 0.19\,T$

Marking Criteria	Marks
- Correct use of F = BIL sinθ and Newton's 2^{nd} law to obtain an expression for the magnetic field involving the gradient of the graph (Note that $\sum F = ma$ where a = 9.8 is not correct) - Correct substitution of the gradient and information provided in the question to obtain the correct answer (a carry forward error was given for the value used for the gradient when the factor given in part (c) was incorrect)	2
- Correct equation (as above) OR - Correct substitution of gradient and information provided into an "almost correct" equation	1

Question 35 (8 Marks)

(a) Sample answer:



Marking Criteria	Marks
Diagram has: - 300 turn coil connected to a power supply and 600 turn coil connected to a meter (demonstrating understanding of the concept of a step up transformer) - AC power supply and meters (demonstrating understanding of the need for a changing magnetic flux in a transformer) - The 300 turn and 600 turn coils wound on a single iron core (demonstrating an understanding of the need for flux linkage between the coils) - A *functional* primary circuit (e.g. it cannot have a voltmeter in series with the power supply, or an ammeter in parallel with the power supply). Notes: Ammeters and voltmeters which were incorrectly placed but did not interfere with the operation of the primary circuit were ignored. It was not required in the marking, but at school it would be essential to also measure the voltage across the power supply using a voltmeter (as the reading on the dial is often substantially off the true voltage supplied by the power supply) - A *functional* secondary circuit which measures the voltage across the secondary coil (e.g. this circuit may not have a short circuit, or an ammeter in parallel with the coil (which is a short circuit))	4
- 4 of the above	3
- 3 of the above	2
- 2 or 1 of the above	1

(a) Sample answer: Faraday's law, $\varepsilon = -\frac{\Delta\phi}{\Delta t}$, states that a changing magnetic flux through a loop of wire will produce an emf across the ends of the loop. In a transformer, two coils with different numbers of turns are wound on a common iron core so that an alternating current through one coil will produce a changing magnetic flux, and so an emf, through the other.

As the rate of change of magnetic flux through both coils is the same for an ideal transformer, the emf per turn is the same, so that $\varepsilon = \frac{V_P}{N_P} = \frac{V_S}{N_S}$, and the voltage is stepped up (if $V_P < V_S$) or stepped down (if $V_P > V_S$).

Marking Criteria	Marks
- Describes Faraday's law - Describes how this applies to an ideal transformer using the transformer equation Notes: $I_P V_P = I_S V_S$ is not acceptable without the transformer equation – it only explains how conservation of energy applies to an ideal transformer, not how/why the voltages are different in the first place Word versions of the equations were accepted (it is expected that you use equations in physics, particularly when the question asks for equations)	2
- One of the above	1

(b) Sample answer: The ideal transformer equation assumes complete flux linkage between the two coils. For non-ideal transformers, there are losses not only due to incomplete flux linkage, but also due to heating produced by eddy currents in the iron core, and ohmic heating in the coils. In the students' investigation the non-ideality of the transformer constructed would mean that the measured secondary voltage would be lower than that predicted by the ideal transformer equation.

Marking Criteria	Marks
- Identifies at least one mechanism for power loss in a non-ideal transformer (e.g. incomplete flux linkage or eddy currents in the core) (That is, answers the "why" aspect of the question) - Identifies how the students' measured results would be different from those expected for an ideal transformer.	2
- One of the above	1