2024
Higher School Certificate
Trial Examination

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A data sheet, formulae sheets and Periodic Table are provided
- Write your student number and/or name at the top of every page

Total marks – 100

Section I (Pages 2–12)
20 marks
- Attempt Questions 1–20
- Allow about 35 minutes for this part

Section II (Pages 13–32)
80 marks
- Attempt Questions 21–35
- Allow about 2 hours and 25 minutes for this section

This paper MUST NOT be removed from the examination room

STUDENT NUMBER/NAME:.....

STUDENT NUMBER/NAME.....

Section I
20 marks

Attempt Questions 1–20
Allow about 35 minutes for this section

Select the alternative A, B, C or D that best answers the question and indicate your choice with a cross (X) in the appropriate space on the grid below.

	A	B	C	D
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	A	B	C	D
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STUDENT NUMBER/NAME.....

1 An object weighs 256 N on Earth and 92 N on planet X.

What is the magnitude of the acceleration due to gravity on planet X?

A. 3.0×10^{-2} m s^{-2}

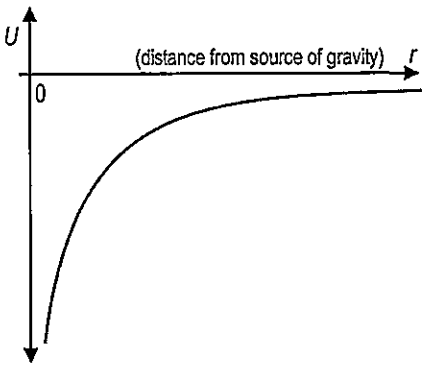
B. 3.0×10^{-1} m s^{-2}

C. 2.8 m s^{-2}

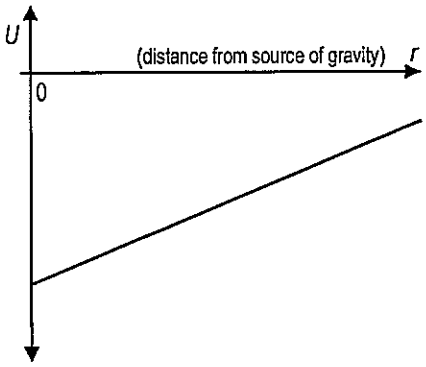
D. 3.5 m s^{-2}

2 Which graph best shows the gravitational potential energy (U) of an object in space versus distance r from a source of gravity?

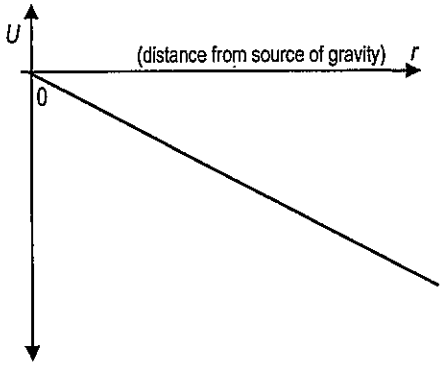
A.



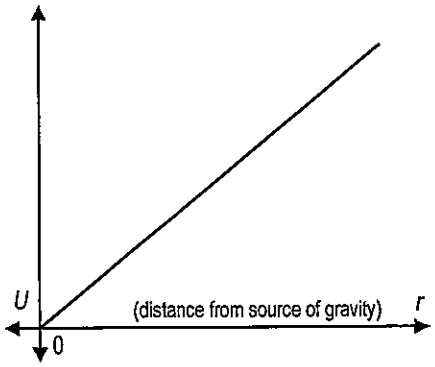
B.



C.



D.



3 A student places a basketball in the middle of a car's back seat before the car makes a right-hand turn.

Which observation correctly describes the movement of the ball?

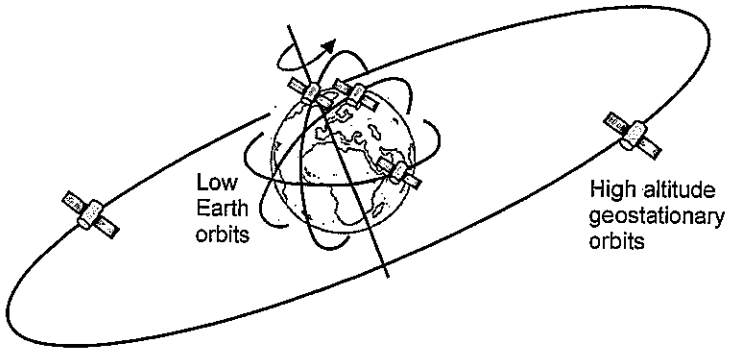
A. The ball is observed to move to the right of the car due to the centrifugal force acting.

B. The ball is observed to move to the left of the car seat due to inertia.

C. The ball is observed to move to the left of the car seat due to the centripetal force acting.

D. The ball is observed to move to the right of the car seat due to a frictional force acting.

4 Satellites in Low Earth orbits are more likely to suffer orbital decay than satellites in geostationary orbits.



Which of the following provides the correct reason for the difference?

A. The Low Earth orbit satellite has stronger gravitational force acting on it.

B. The Low Earth orbit satellite is moving faster.

C. The Low Earth orbit satellite is moving through denser air.

D. The Low Earth orbit satellite is moving more slowly.

5 Kepler's Law of Periods, summarised in the equation $T^2 = kR^3$, shows the relationship between the orbital period and radius of a planet orbiting a star.

In which of the following situations would a change in the value of the constant, k, be needed?

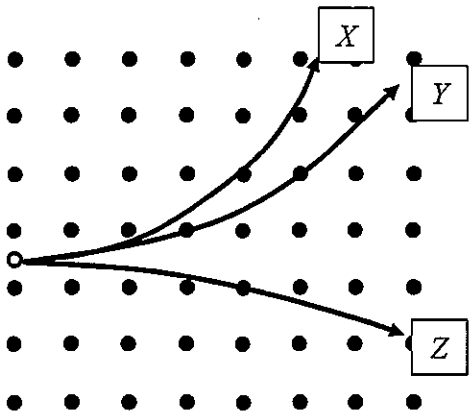
A. For a planet of greater orbital period

B. For a planet of smaller orbital radius

C. For an identical planet orbiting a different star

D. For a planet of different mass orbiting the same star

6 Three charged particles *X*, *Y* and *Z* moving at the same speed enter a uniform magnetic field.



Which statement about these charges is correct?

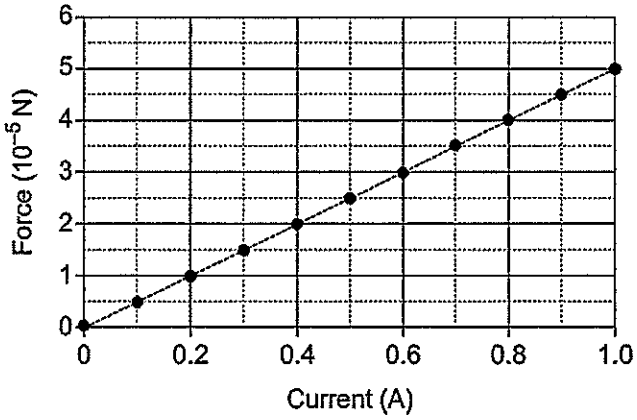
A. Charges *X* and *Y* are both positively charged.

B. If the charge of particles *X* and *Y* is the same charge, then particle *X* must have more mass than particle *Y*.

C. If particles *X* and *Z* have the same mass, then *Z* must have a larger charge than *X*.

D. The charge to mass ratio (*q*/*m*) is greatest for particle *X*.

7 A section of length *L* of a straight, current-carrying wire is placed in a region of constant magnetic field *B*. The graph shows the force acting on the wire as the current is changed.



What quantity is equal to the gradient of the line?

A. The length of the wire *L*

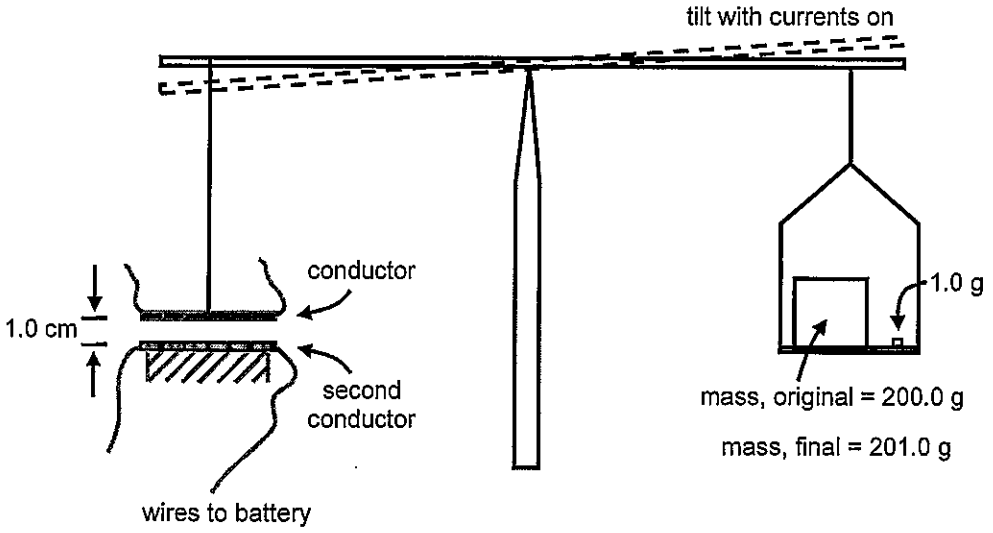
B. The magnetic field strength *B*

C. The product of magnetic field strength *B* and length *L*

D. The resistance of the wire

8 A conducting rod 40 cm long was attached to a pivoted balance beam and required 200.0 g for the beam of the balance to remain horizontal.

A second 40 cm conducting rod was placed 1.0 cm below, as shown. When the rods conducted equal currents, the beam tilted and it was necessary to add 1.0 g to the pan to return the beam to horizontal.



What was the current in the conducting rods?

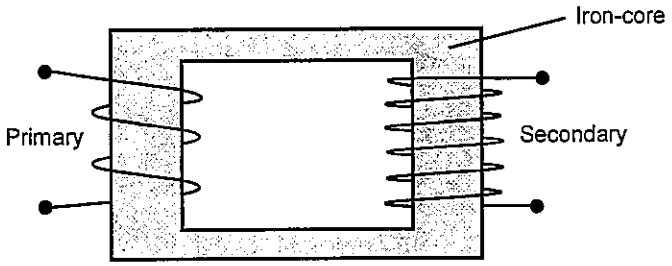
A. 1.3×10^{-3} A

B. 35 A

C. 4.9×10^{2} A

D. 1.1×10^{4} A

9 An ideal transformer is shown in the diagram below.



Which statement about the secondary coil compared to the primary coil is correct?

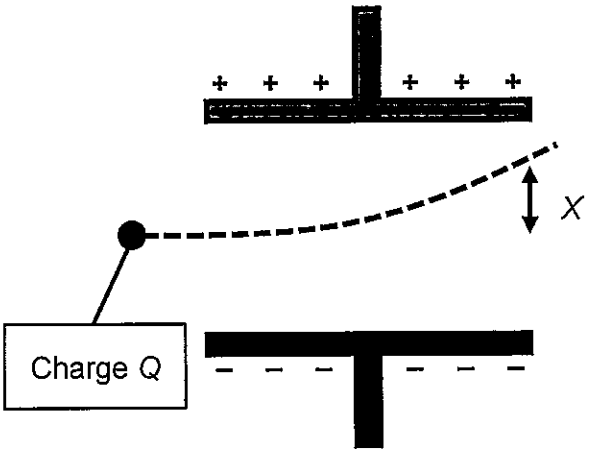
A. The secondary coil will develop more power.

B. The secondary coil will have a higher voltage.

C. The secondary coil will have a higher current.

D. The secondary coil must have a lower resistance.

10 A charge Q of mass m and with a horizontal velocity v enters the electric field of strength E between 2 plates of length L.



What is the distance X by which the charge has moved from its horizontal path when it exits the electric field?

A. $\frac{QEL^2}{mv^2}$

B. $\frac{QE}{mv}$

C. $\frac{QEL^2}{2mv^2}$

D. $\frac{QEL}{2mv}$

11 When coherent light is passed through double slits, the pattern below can be observed on a screen.

Which choice best accounts for this observation?

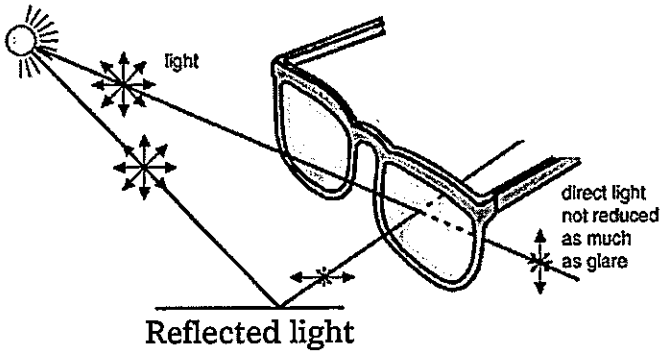
A. The wave nature of light

B. The ratio of the width of the slits and the distance between them

C. Light being composed of packets of photons

D. The use of a coherent light source

12 The diagram shows the transmission of light through sunglasses.



Which phenomenon is responsible for the reduction of glare from reflected light by some sunglasses?

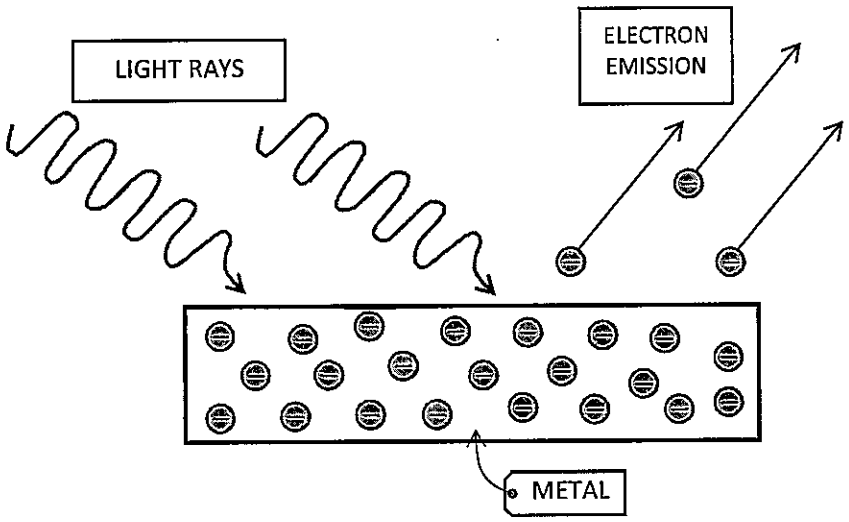
A. Refraction

B. Polarisation

C. Diffraction

D. Total internal reflection

13 The diagram shows the emission of electrons from a metal by the photoelectric effect.



Which change would increase the maximum kinetic energy of an electron ejected from a metallic surface by the greatest amount?

A. Using a positively ionised metal emitter

B. Using a photoemitter with a larger work function

C. Increasing the intensity of the incident light

D. Decreasing the wavelength of the incident light

14 In relativity, what is the definition of proper time for an event?

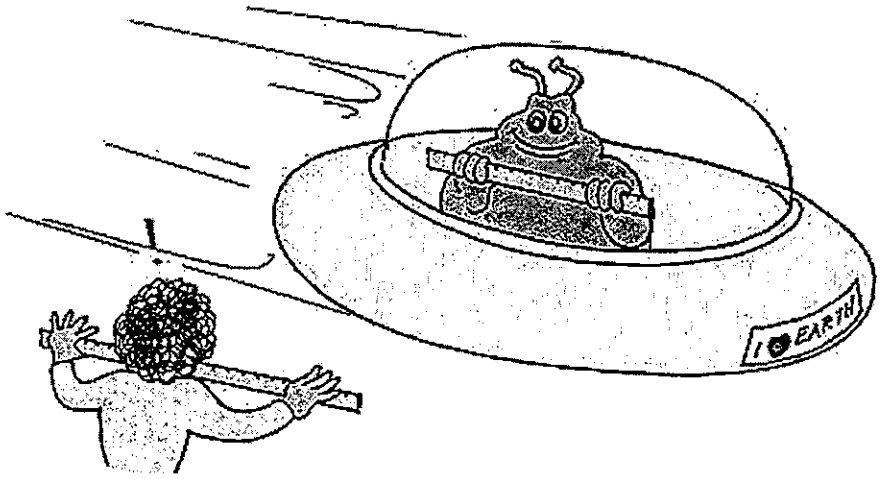
A. Proper time is measured by a clock that has the same motion as the event observer.

B. Proper time is measured on a clock that is not moving.

C. Proper time is the time agreed on by two observers in different frames of reference.

D. Proper time is measured by any clock that is moving at constant velocity.

15 A spaceship with a velocity of 5.0×10^7 m s^{-1} is measured to be 150 m in length by an observer standing on a stationary space platform as the spaceship flies past.



What is the best estimate of the length of the spaceship as measured by somebody on board the spaceship?

A. 125 m

B. 130 m

C. 152 m

D. 157 m

16 What was the significance of previous discoveries about the hydrogen spectrum to Bohr developing his model of the atom?

A. Previous work had provided the energy values associated with electron transfers.

B. It provided stimulus and direction for Bohr's developing ideas.

C. Physics principles had been used to explain the wavelength of the spectral lines.

D. Bohr knew that orbiting electrons did not emit electromagnetic radiation.

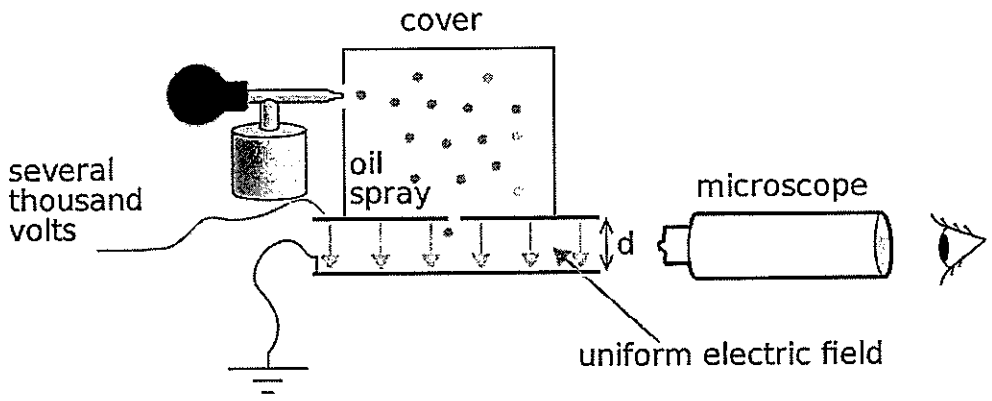
17 A student wrote the following descriptions of three spectra that were demonstrated in her Physics lesson.

Spectrum *X*: Looks like a rainbow
Spectrum *Y*: A series of coloured lines against a black background
Spectrum *Z*: Looks like a rainbow with black lines

Which choice correctly identifies each spectrum type?

	X	*Y*	*X*
A.	Continuous	Absorption	Emission
B.	Absorption	Emission	Continuous
C.	Absorption	Continuous	Emission
D.	Continuous	Emission	Absorption

18 The diagram below shows the equipment used for a crucial Physics experiment.



What was the purpose of this experiment?

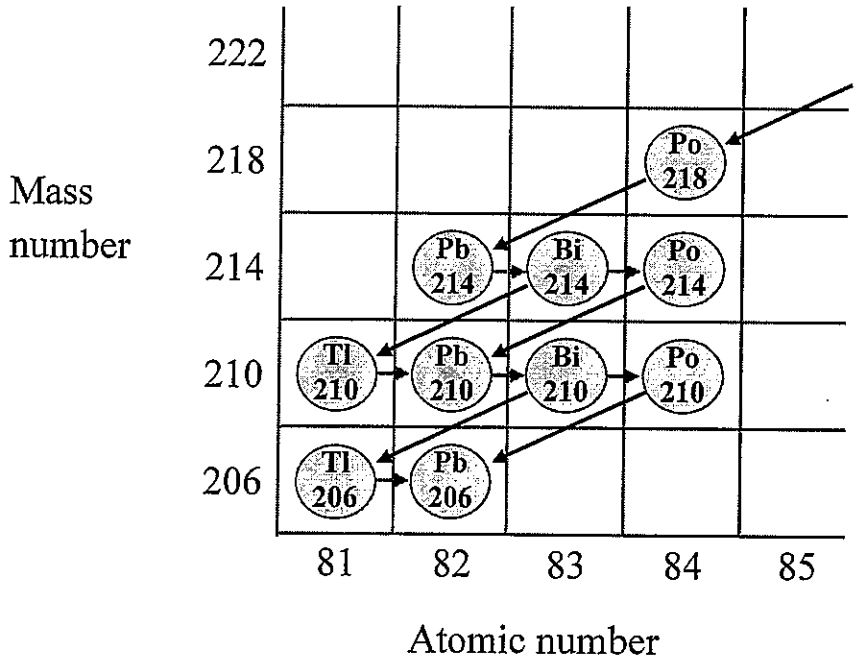
A. To observe electrons

B. To find the charge on an alpha particle

C. To determine if electrons were positively or negatively charged

D. To determine the magnitude of the charge on electrons

19 The final stages in the decay series of uranium to lead is shown in the graph below.



Which alternative lists the correct order of radiation emitted when polonium 218 decays to polonium 214?

A. Gamma decay, 2 beta decays

B. Beta decay, 2 alpha decays

C. Alpha decay, 2 beta decays

D. Alpha decay, 2 gamma decays

20 Which meson is responsible for the force that holds quarks together?

A. Gluon

B. Graviton

C. Photon

D. W boson

STUDENT NUMBER/NAME.....

Section II

80 marks
Attempt Questions 21–35
Allow about 2 hours and 25 minutes for this section

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (4 marks)

Explain why the total energy of a satellite orbiting the Earth is always negative. **4**

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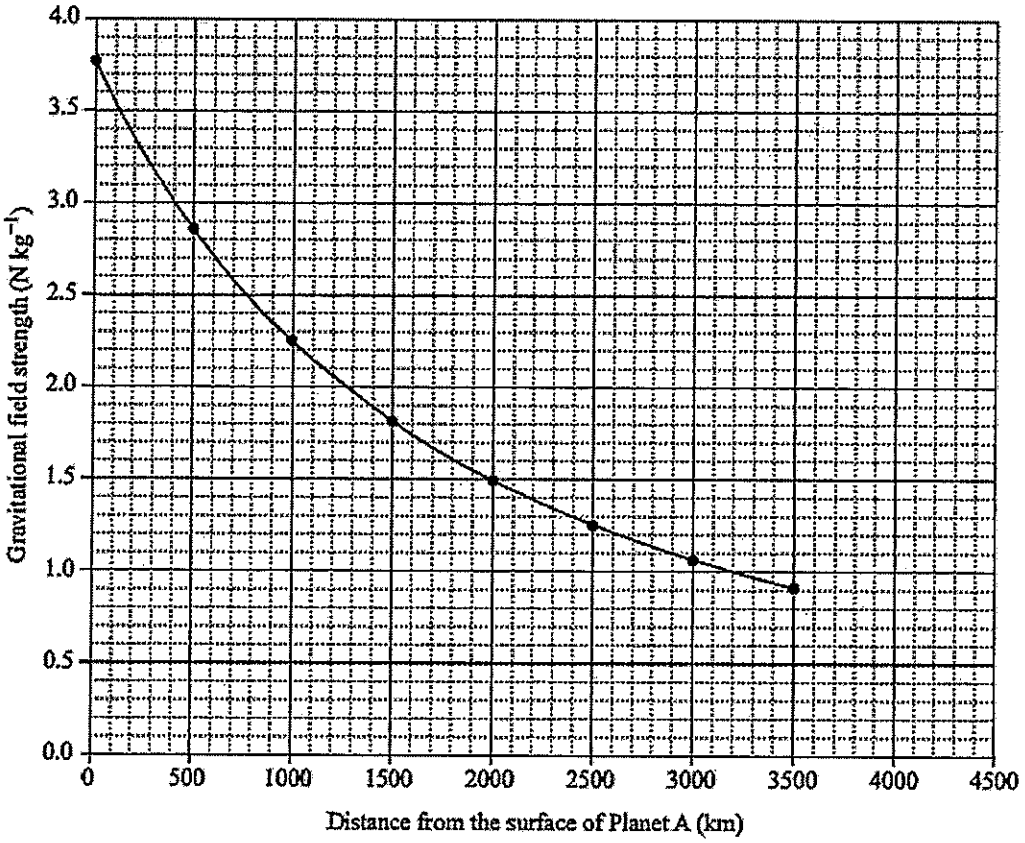
Question 22 (3 marks)

The incomplete graph shows the gravitational field strength at various distances from the surface of planet *A* with a 3400 km radius.



(a) Predict the strength of the gravitational field at a distance of 4500 km from the surface. 1

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(b) Use the graph to calculate the mass of the planet. 2

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Question 23 (8 marks)

Outline ONE early method and ONE recent method used to determine the speed of light and the importance of this quantity to the measurement of distance. **8**

Question 24 (7 marks)

The table shows results for a projectile fired at different angles with the same speed.

The teacher asked students to plot results below to determine the relationship between the range of a projectile and the cosine of the angle of elevation at launch.

Angle of elevation (°)	*Range (m)*			*Average range (m)*	*Cosine of angle of elevation*
9	4.5	4.7	4,6	4.6	0.99
18	17.6	17.5	17.7	17.6	0.95
27	37.7	37.5	37.5	37.6	0.89
36	60.0	60.8	60.4	60.4	0.81
45	91.5	92.0	91.8	91.8	0.71

(a) Plot results relating the cosine of angle of elevation to the range. **3**

Question 24 continues on page 17

Question 24 (continued)

(b) The teacher suggested that the range of a projectile is inversely proportional to the cosine of its angle of elevation. **4**

Assess the validity of the conclusion using your knowledge of graphing and projectile motion. Justify your answer.

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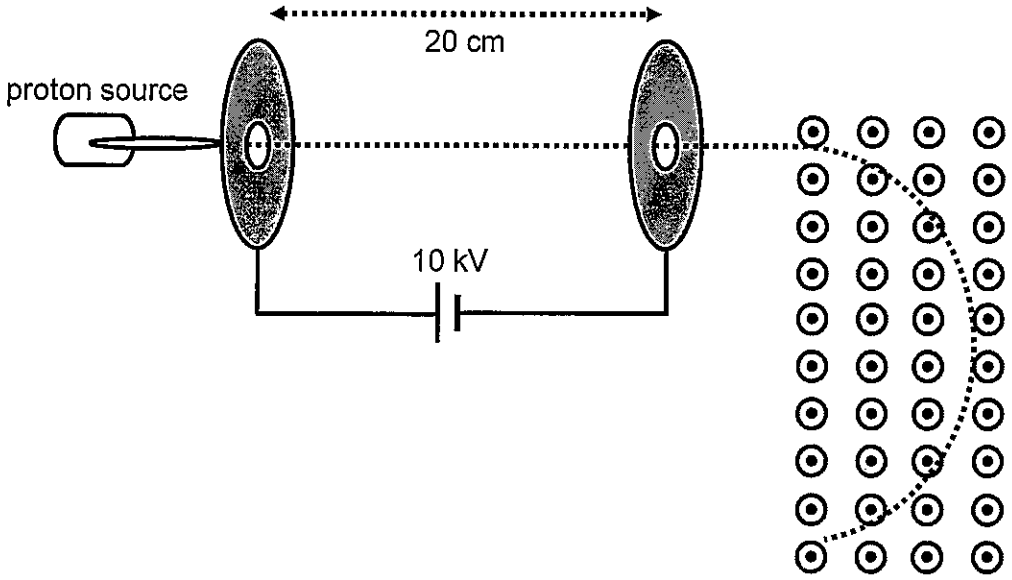
End of Question 24

Question 25 (4 marks)

In a vacuum chamber, a proton is emitted into the electric field between two plates which have a potential difference of 10 kV. **4**

The proton exits into a region of uniform magnetic field of strength 2.0×10^{-2} T directed out of the page perpendicular to the proton's velocity.



Calculate the radius of curvature of the proton in the magnetic field assuming that the proton had negligible velocity when it entered the electric field.

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Question 26 (5 marks)

To study electromagnetic induction, students passed a square loop, at constant speed, from the initial position *P* between the poles of a magnet until the front edge of the loop reached position *T*, as shown in Figure *A*.

Figure *B* shows the same experiment as viewed from above.

The width of the square coil is equal to half of the horizontal width of the magnetic field.

Figure *A* – side view

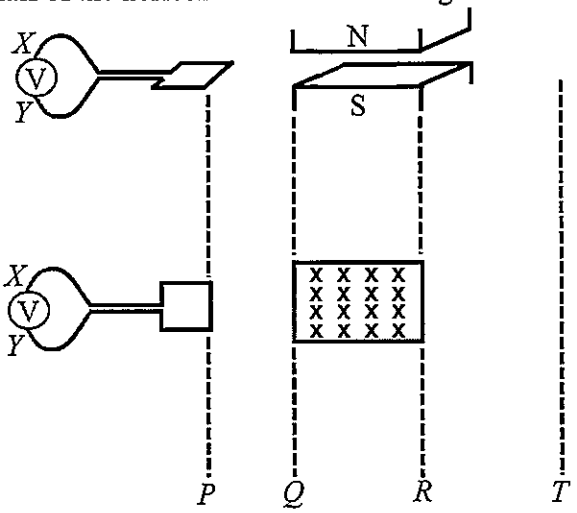
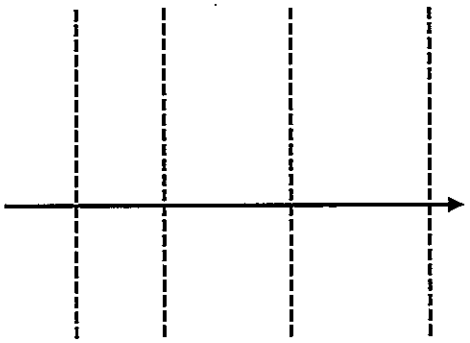
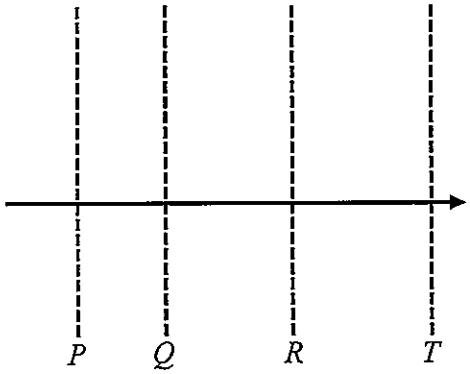


Figure *B* – view from above

(a) On the axis line drawn (right) sketch how the magnetic flux through the square loop changes as it moves from *P* to *T*. Note that the dotted position lines have been extended to help you do this more accurately. **2**



(b) On the axis line drawn (right) sketch the emf induced in the coil changes as the square loop moves from *P* to *T*. Note that the dotted position lines have been extended to help you do this more accurately **2**



(c) Determine the direction of the current as the loop enters the magnetic field. Express your answer as clockwise or anticlockwise when viewed from above. **1**

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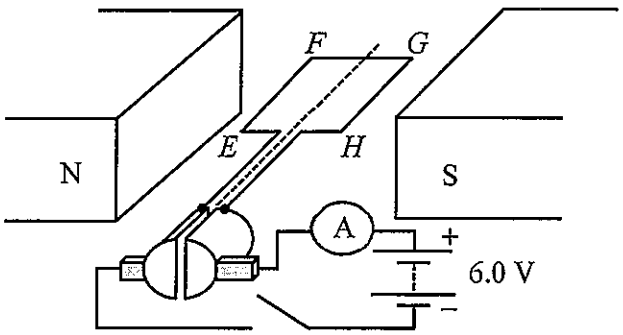
STUDENT NUMBER/NAME.....

Question 27 (5 marks)

The diagram shows a DC motor consisting of a rectangular loop of 100 turns with a commutator. The coil is positioned in a uniform magnetic field with a battery providing the current. **5**



Explain why rotation of the coil of a simple DC motor occurs when the switch is closed.

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Question 28 (7 marks)

Diagram 1 shows a small section of the spectrum for a mixture of gaseous elements. 7

Diagram 1

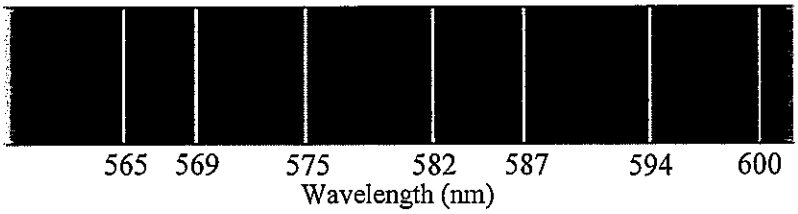
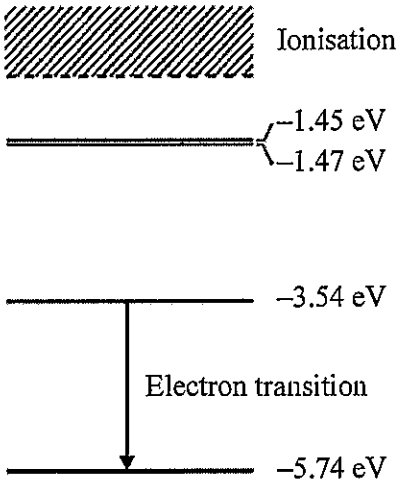


Diagram 2 shows the electron energy levels for a gaseous element *X*.

Diagram 2



A physics student states that the spectral line produced when an electron falls from the –3.54 eV energy level to the –5.74 eV level proves that element *X* is one of the gases in the mixture.

Critically evaluate the student's statement using your understanding of how spectral lines are produced.

Spaces to answer Question 28 is provided on page 22

Question 28 (continued)

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End of Question 28

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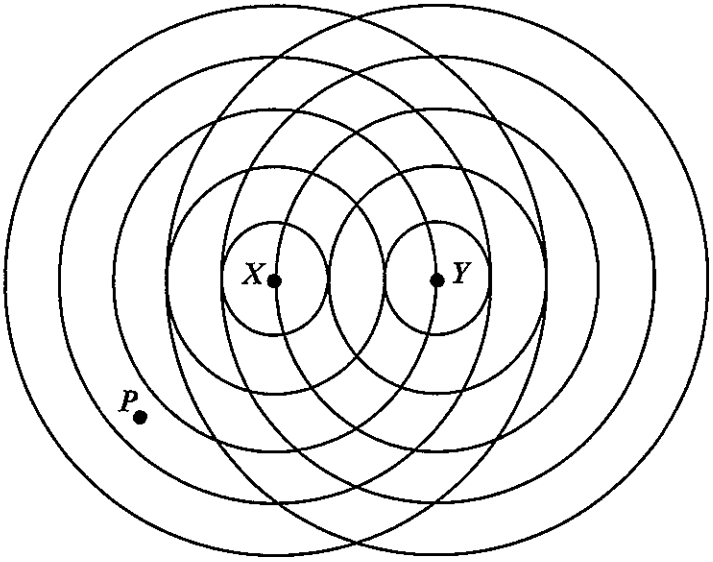
Question 29 (6 marks)

Two in-phase point sources, X and Y, are 0.30 m apart and produce identical waves with amplitude 0.26 m. Point P, midway between wavefronts from X, has been marked on the diagram.



(a) Predict the amplitude of the interference of the waves at point P at the instant shown. Justify your answer. **2**

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(b) Discuss how interference patterns were used to provide the evidence for the nature of both light and matter. **4**

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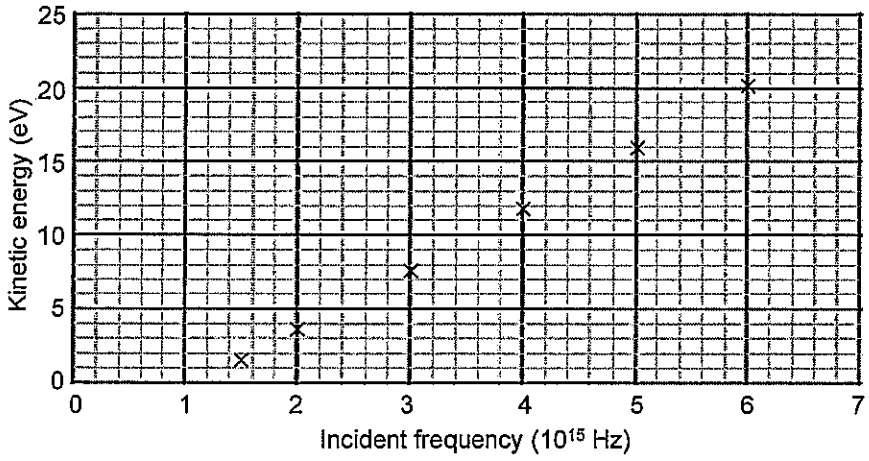
Question 30 (4 marks)

A photoelectric effect experiment was conducted by shining different frequencies of light on a plate of an unknown metal. The metal used was one of the four metals in the table below.

Metal	*Work function (eV)*
Bismuth	4.3
Chromium	4.5
Copper	4.7
Gold	5.1

The graph shows the average kinetic energies of ejected photoelectrons for the five different frequencies of incident light used in the experiment.



(a) Explain how the graph **could** be used to decide which metal was used without using a frequency value. (You do not have to identify the metal.) **1**

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(b) Describe how frequency affects the photoelectric current. **3**

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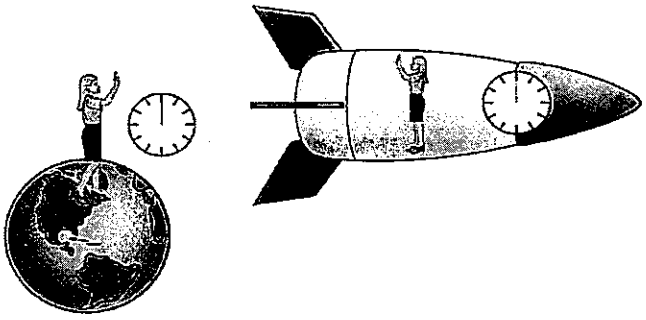
STUDENT NUMBER/NAME.....

Question 31 (4 marks)

(a) Two physics students the same age discussed an experiment where one travels with velocity close to the speed of light to a distant planet, while the other stays on Earth. **2**

They wonder how they would appear to each other if they had face-time during such a lengthy journey.



Explain how each student would appear to the other.

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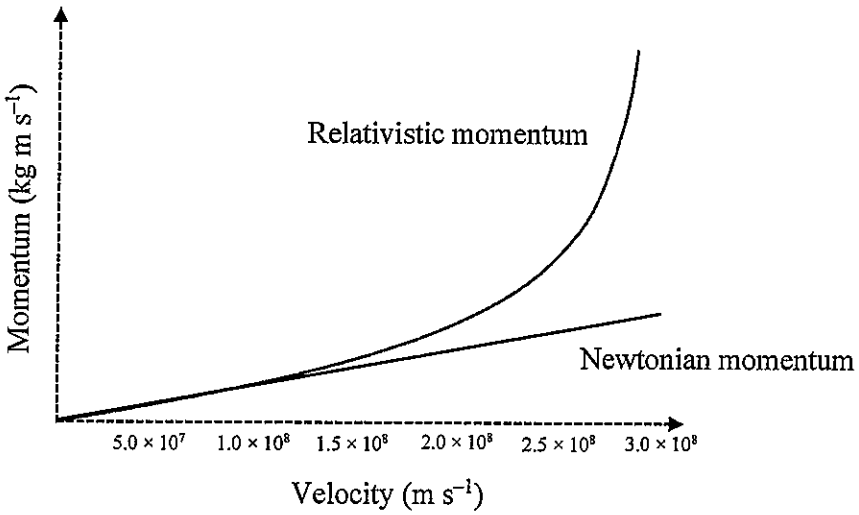
Question 31 continues on page 26

Question 31 (continued)

(b) The graph shows how the relativistic and Newtonian momentum of the same object moving at increasing velocities differ. **2**



Account for the difference between the 2 graphs.

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End of Question 31

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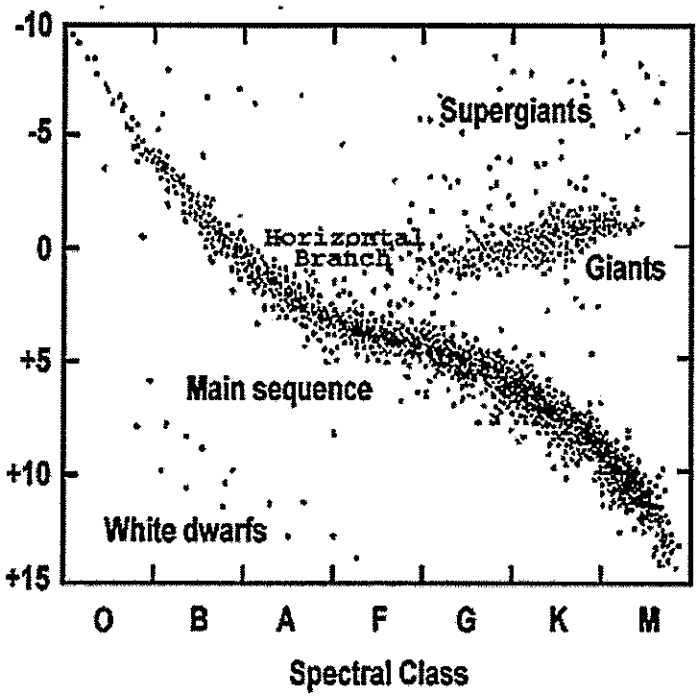
Question 32 (5 marks)

The Hertzsprung-Russell diagram below has had some labels removed from its axes.



(a) Account for the different time spent on the Main Sequence by stars at the top and bottom of the Main Sequence. **3**

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(b) Compare the main energy source of Main Sequence stars and red giants. **2**

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STUDENT NUMBER/NAME.....

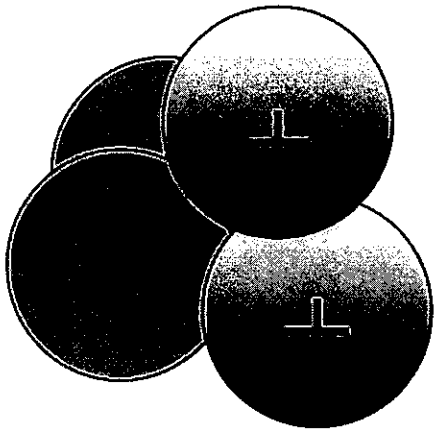
Question 33 (6 marks)

Outline the experiment done by J. J. Thomson in 1897 and its importance to developing ideas in Physics. **6**

STUDENT NUMBER/NAME.....

Question 34 (7 marks)

The diagram shows a helium atom nucleus in which two protons and two electrons are bound together. This nucleus has both a mass defect and an amount of binding energy.



(a) Explain the relationship between the binding energy and mass defect of a nucleus. **3**

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(b) Calculate the average binding energy per nucleon in joules for the depicted helium nucleus of mass 4.0015 μ. **4**

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Question 35 (5 marks)

Outline the role of particle accelerators in the work of physicists. **5**

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Section II extra writing space

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STUDENT NUMBER/NAME.....

Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	**340 m s^{-1}**
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} A^2 s^4 kg^{-1} m^{-3}
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^6 m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R **(hydrogen)**	**1.097** $\times 10^7$ m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^3 kg m^{-3}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}
Wien's displacement constant, b	2.898×10^{-3} m K

STUDENT NUMBER/NAME.....

FORMULAE SHEET

Motion, forces and gravity

$$s = ut + \frac{1}{2}at^2$$

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$\Delta U = mg\Delta h$$

$$W = F_{||}s = Fs\cos\theta$$

$$P = \frac{\Delta E}{\Delta t}$$

$$K = \frac{1}{2}mv^2$$

$$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$$

$$P = F_{||}v = Fv\cos\theta$$

$$\Delta\vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$\omega = \frac{\Delta\theta}{t}$$

$$a_c = \frac{v^2}{r}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$F_c = \frac{mv^2}{r}$$

$$v = \frac{2\pi r}{T}$$

$$F = \frac{GMm}{r^2}$$

$$U = -\frac{GMm}{r}$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

Waves and thermodynamics

$$v = f\lambda$$

$$f_{\text{beat}} = \left|f_2 - f_1\right|$$

$$f = \frac{1}{T}$$

$$f' = f\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

$$d\sin\theta = m\lambda$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$n_x = \frac{c}{v_x}$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$I = I_{\max}\cos^2\theta$$

$$I_1r_1^2 = I_2r_2^2$$

$$Q = mc\Delta T$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

STUDENT NUMBER/NAME.....

Electricity and magnetism

$$E = \frac{V}{d}$$

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 NI}{L}$$

$$\Phi = B_{||}A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\vec{F} = q\vec{E}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$I = \frac{q}{t}$$

$$V = IR$$

$$P = VI$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_p I_p = V_s I_s$$

Quantum, special relativity and nuclear

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

$$K_{max} = hf - \phi$$

$$\lambda_{max} = \frac{b}{T}$$

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

$$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$N_t = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

STUDENT NUMBER/NAME.....

NSW INDEPENDENT TRIAL EXAMS – 2024
PHYSICS – TRIAL HSC EXAMINATION
MARKING GUIDELINES

Section I

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

Section II

Question 21

Criteria	Marks
• Demonstrates a clear understanding of zero reference point, how negative values for U result, comparison of kinetic and gravitational energy of a satellite and total energy	4
• Identifies zero reference point, consequent negative value for U and comparison of kinetic and gravitational energy of a satellite	3
• Identifies TWO of the following: zero reference point, consequent negative value for U and comparison of kinetic and gravitational energy of a satellite	2
• Identifies ONE of the following: zero reference point, consequent negative value for U and comparison of kinetic and gravitational energy of a satellite	1

Sample answer:

The zero-reference point for gravitational potential energy, U, is infinity. At any other position, the value of U must be less, as work done moving an object to infinity increases its potential energy. The total energy of a satellite is the sum of its gravitational potential energy which is always negative, and its kinetic energy, K. Because U for an orbiting object is always twice the magnitude of the K, the total will always have a negative value.

Question 22(a)

Criteria	Marks
• Provides appropriate magnitude from graph with units	1

Sample answer:

0. 7 N kg^{-}1 (or be close to 0.7 N kg^{-1})

Question 22(b)

Criteria	Marks
• Calculates mass correctly	2
• Provides working for mass calculation with one error	1

Sample answer:

From $g = \frac{GM}{r^2}$, choosing altitude 2000 km

$$M = \frac{1.5 \times (3\,400\,000 + 2\,000\,000)^2}{6.67 \times 10^{-11}}$$

$M = 6.6 \times 10^{23}$ kg

Question 23

Criteria	Marks
• Provides clear outline of an early method and of a recent method and shows a deep understanding of relevance of speed of light to the unit of distance	7–8
• Provides outline of an early method and of a recent method and definition of metre	5–6
• Provides outline of an early method OR of a recent method and definition of metre	3–4
• Provides some relevant information	1–2

Sample answer:

In the 1700's one scientist determined the speed of light using stellar parallax. He used the angle of apparent displacement of stars from their true position by comparing directions of observations of a star made from Earth when in different positions of its orbit about the Sun. He used this information and the relative velocity of Earth to calculate the speed of light to be close to 300 000 km s^{-1}.

More recently, lasers with high spectral stability have been used to measure the speed of light more accurately. In this method, a laser source is fired at a half-silvered mirror which splits the light ray into two perpendicular rays that travel to and back from two stationary mirrors which are equidistant from the half-silvered mirror. When they meet in the middle, they undergo constructive interference.

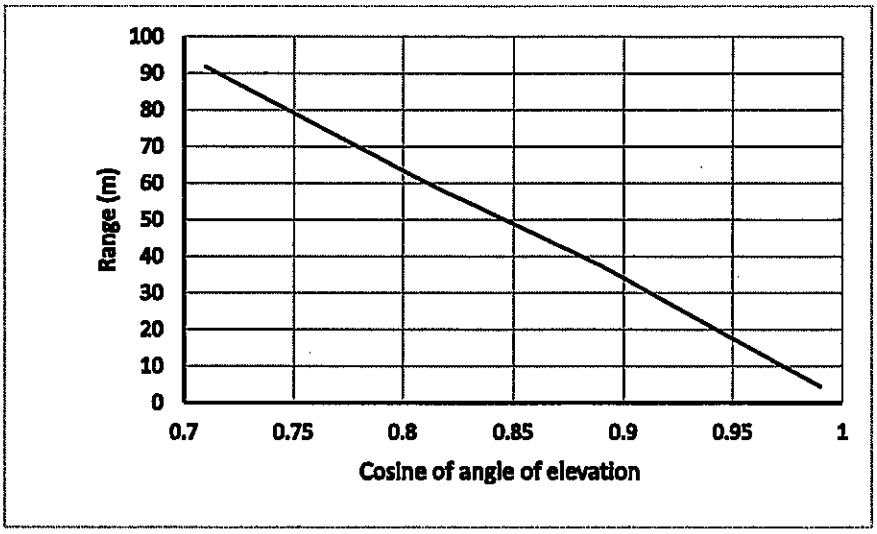
The same experiment is repeated but this time one of the stationary mirrors is moved back until the distance between it and the half-silvered mirror is increased until the two waves to undergo destructive interference, exactly half a wavelength of the light wave. Speed is found using the measured wavelength and the known frequency of the laser.

Scientists now realise distance and time are not constant as they change with frames of reference. This is due to Albert Einstein's Theory of Special Relativity and his postulate which states that speed of light is constant in a vacuum, regardless of the observer. Today, due to the constancy of light's speed, one standard metre is defined as the distance travelled by light in a vacuum in 1/c of a second, using the constant speed of light c.

Question 24(a)

Criteria	Marks
• Uses appropriate scale, labels axes with name and units, correctly plots all data points, rules line of best fit	3
• Provides THREE of the following: appropriate scale, labels axes with name and units, correctly plots all data points, draws line of best fit	2
• Provides TWO of the following: appropriate scale, labels axes with name and units, correctly plots all data points, draws line of best fit	1

Sample answer:



Question 24(b)

Criteria	Marks
• Provides correct judgement on conclusion, reason based on graph shape, range formula and derivation	4
• Provides THREE of the following: correct judgement on conclusion, reason based on graph shape, range formula and derivation	3
• Provides TWO of the following: correct judgement on conclusion, reason based on graph shape, range formula and derivation	2
• Provides ONE of the following: correct judgement on conclusion, reason based on graph shape, range formula and derivation	1

Sample answer:

Inversely proportional graphs are curves (hyperbole). Therefore, the conclusion is incorrect as the graph is a straight line.

In projectile motion, using $v = u + at$ for vertical component of motion, time to top where $v = 0$,

$$t = \frac{u \sin \theta}{g}$$

$$\text{Total time} = \frac{2\, u \sin \theta}{g}$$

$$\text{Range} = \text{horizontal speed} \times \text{time} = u \cos \theta \times \frac{2\, u \sin \theta}{g} = 2\, u^2 \times \frac{\sin \theta \cos \theta}{g}$$

This shows that range is proportional to $\cos \theta \times \sin \theta$ (or $\sin 2\theta$) and not $\cos \theta$. The results are not valid for making any conclusions about range of a projectile.

Question 25

Criteria	Marks
• Correctly calculates the radius of curvature	4
• Calculates the radius of curvature with ONE substitution error	3
• Calculates velocity of charge entering magnetic field	2
• Provides some relevant information	1

Sample answer:

Work done by the field, $W = qV = 1.6 \times 10^{-19} \times 10\ 000$
$= 1.6 \times 10^{-15}$ J

$=$ kinetic energy gained, $\frac{1}{2} mv^2$

Therefore, $v = \sqrt{\frac{2 \times 1.6 \times 10^{-15}}{1.673 \times 10^{-27}}}$

$= 1.38 \times 10^6$ m s^{-1}

Centripetal force = magnetic force
$mv^2/r = Bqv =$
Therefore, $r = \frac{mv}{Bq}$

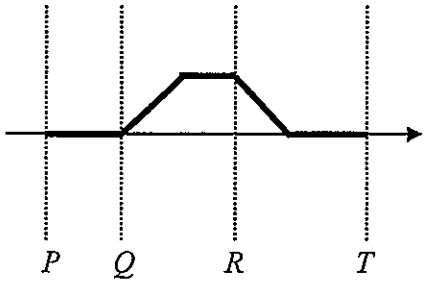
$= \frac{1.67 \times 10^{-27} \times 1.38 \times 10^6}{2 \times 10^{-2} \times 1.6 \times 10^{-19}}$

$= 0.7$ m

Question 26(a)

Criteria	Marks
• Draws correct graph	2
• Draws graph with FOUR correct sections	1

Sample answer:

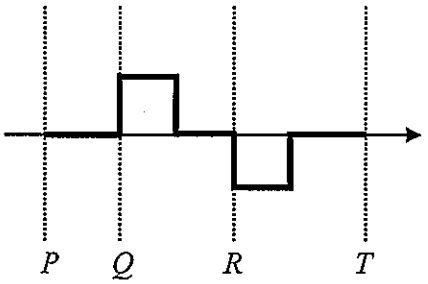


Graph can be inverted

Question 26(b)

Criteria	Marks
• Draws correct graph	2
• Draws graph with FOUR correct sections	1

Sample answer:



Graph can be inverted

Question 26(c)

Criteria	Marks
• States correct direction	1

Sample answer:

Anticlockwise

Question 27

Criteria	Marks
• Demonstrates a clear understanding of the torque on each side of the coil, how it changes in size and current direction and results in continuous rotation due to commutator	5
• Provides details of the force on each side of the coil, how it changes in size and current direction and results in continuous rotation due to commutator	4
• Provides some details of the forces causing rotation	2–3
• Provides some relevant information	1

Sample answer:

There is a horizontal magnetic field from the north pole to the south pole interacting with the conducting loop when the current flows through it.

The force on sides EH and FG is always zero because the conductor is parallel to the magnetic field and the current does not cut magnetic field.

The force on side EF is upwards and downwards on side GH in the position shown on the diagram. The result is a turning torque about the axis of the coil, the dotted line. The torque reduces as the coil turns and when the plane of coil is vertical and side EF is at the top, the torque is zero because the forces on EF and GH are vertical. The momentum of the coil carries it past this point and at this instant the commutator reverses the current direction in the coil. The result is that the force on side EF will now be in a downward direction so that the coil continues to turn in the same direction rather than oscillate.

Question 28

Criteria	Marks
• Shows a clear understanding of the production of spectral lines and their wavelength and calculates the wavelength correctly • Explains the difference between "proof" and supporting evidence and provides a reason why more evidence is needed	7
• Shows a clear understanding of the production of spectral lines and their wavelength and calculates the wavelength correctly • States a reason why more evidence is needed	6
• Shows a good understanding of the production of spectral lines and their wavelength and calculates the wavelength correctly • States evidence which supports student's statement	4–5
• Shows some understanding of the production of spectral lines and attempts to calculate the wavelength	2–3
• Provides some relevant information	1

Sample answer:

Spectral are produced when an electron in an excited state moves from a higher energy level to a lower energy level emitting a photon of which the wavelength depends on the energy difference.

Energy change for the transition shown = 5.74 – 3.54 eV = 2.2 eV

$= 2.2 \times 1.6 \times 10^{-19} = 3.52 \times 10^{-19}$ J

$$\Delta E = hf = \frac{hc}{\lambda},$$

$$3.52 \times 10^{-19} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$$

$$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{3.52 \times 10^{-19}}$$

$$\lambda = 5.647 \times 10^{-7} \text{ m} = 565 \text{ nm}$$

This is the wavelength for the far-left line in the spectrum which provides evidence supporting the student's statement. The role of science is to provide evidence supporting theories but can never "prove" a theory or statement in the same way as mathematicians prove relationships. However, one line does not identify the element as different elements may have one or two identical spectral lines.

Further analysis would need to be done to provide more evidence to indicate the existence of element X in this mixture such as showing that one or more other lines match electron jumps for element X.

Question 29(a)

Criteria	Marks
• Identifies amplitude and destructive interference	2
• Identifies amplitude OR destructive interference	1

Sample answer:

At point P, the wave from X is a trough, from Y is a crest. As the waves will cancel, it is a position of destructive interference with amplitude zero.

Question 29(b)

Criteria	Marks
• Shows a clear understanding of how the work of Young and Planck changed the previous models for the nature of light and matter, resulting in the acceptance of dual nature of light and matter	4
• Outlines the work of Young and Planck changed the previous models for the nature of light and matter, resulting in the acceptance of dual nature of light and matter	3
• Outlines relevant work by Young and Planck	2
• Outlines relevant work by Young OR Planck	1

Sample answer:

Initially physicists considered that light was made up of particles as suggested by Newton. Young produced interference patterns using a light source shining through 2 close slits. Interference and diffraction patterns are a wave property and therefore support the wave model of light. Planck explained the "ultraviolet catastrophe" graph with his hypothesis that light had a particle nature, having photons with a precise amount of energy given by $E = hf$.

Matter was considered to have a particle nature until it was shown that electrons interfere producing diffraction patterns. This experimental evidence cannot be explained by electrons having only a particle nature as in some situations they exhibit a wave nature. Both light and particles of matter therefore came to be considered as having a dual wave-particle nature.

Question 30(a)

Criteria	Marks
• Describes extending graph to determine the Y axis intercept value	1

Sample answer:

By extending the line of best fit of the graph below the X-axis, the Y-intercept could be determined to find the kinetic energy value in eV. This is the work function for the metal used and could be used to decide which metal was used.

Question 30(b)

Criteria	Marks
• Identifies the effect of frequency on whether the photoelectric occurs, the kinetic energy of the electrons and the rate of emission	3
• Identifies TWO of the following: the effect of frequency on whether the photoelectric occurs, on the kinetic energy of the electrons OR on the rate of emission	2
• Identifies ONE of the following: the effect of frequency on whether the photoelectric occurs, on the kinetic energy of the electrons OR on the rate of emission	1

Sample answer:

The photoelectric effect occurs when a photon of frequency equal to or greater than the threshold frequency hits an electron on a metal surface. At threshold frequency, the photon has the minimum energy (work function) needed to enable the electron to escape.

Photons with greater frequency provide the kinetic energy of the ejected photons, the amount equal to the excess energy.

Increasing the frequency does not increase the rate of electrons emission, that is, the photoelectric current.

Question 31(a)

Criteria	Marks
• Explains based on time dilation that each student will see the other student as younger	2
• States that each student will see the other student as younger	1

Sample answer:

The Theory of Special Relativity states that there is no absolute time. Instead, the measurement of time is relative to the frame of reference in which it is measured. In this case, each student is moving relative to the other. The time measured by each student on her own clock is greater than the time she observes on the clock of the other student, moving relative to her. From the perspective of either student, the other will be younger.

Question 31(b)

Criteria	Marks
• Explains the increase in mass and momentum as velocity increases and the limit of the speed of light	2
• Relates difference to the increase in mass	1

Sample answer:

Difference between relativistic and Newtonian momentum values occur because as a particle's speed approaches the speed of light, its mass increases, and its momentum increases accordingly. No object is able to reach the speed of light because of this increase. This increase in momentum is not accounted for by the classical formula, which assumes that mass remains constant regardless of speed.

Question 32(a)

Criteria	Marks
• Explains how the difference in mass results in different fusion rates and imbalance of forces sooner for stars at the top	3
• Provides a reason why the difference in mass results in different fusion rates	2
• Identifies rate of fusion OR mass	1

Sample answer:

Due to their greater mass, the core of the larger main sequence stars at top left reach a higher temperature due to their greater gravitational force inwards and hence have higher fusion rates. This results in faster depletion of the hydrogen fuel and eventually there is no longer a balance between between the gravity holding it together and the outwards pressure from fusion processes taking place. Consequent changes in the star means it leaves the main sequence sooner than the slow fusing stars at bottom of main sequence.

Question 32(b)

Criteria	Marks
• Identifies energy source for main sequence and source in shell and core for red giant	2
• Identifies fusion as energy source for both	1

Sample answer:

Main sequence stars fuse hydrogen to produce helium as their main source of energy while red giants' main source is helium fusing core which is surrounded by shells of other fusion reactions.

Question 33

Criteria	Marks
• Provides clear details of Thomson's experiment and how the experimental evidence of the electron changed the model of the atom	4–6
• Provides limited details of Thomson's experiment and its significance	2–3
• Provides ONE relevant piece of information	1

Sample answer:

In 1897, very little was known about the structure of matter and the nature of electricity. No subatomic particle (protons, neutrons or electrons) were known but were hypothesised to exist and constitute matter. Thomson's experiment with cathode rays, which were easily produced in a high voltage discharge tube, confirmed the existence of negatively charged subatomic particles and changed the model of the atom.

Scientists had argued over the nature of cathode rays. The problem was that the rays deflected in magnetic fields as if made up of negative charges but could not be deflected in electric fields. Thomson hypothesised that the rays ionised the gas in the tubes and extracted nearly all of the gas from a tube and showed that now the cathode rays did bend in an electric field after all.

Thomson went on to design an experiment involving the deflection of cathode rays by an electric field and the cancellation of that deflection by an applied magnetic field. This enabled him to find a value for the charge to mass ratio of the cathode ray particles. He proposed that cathode rays were the same as the "electrons" which Stoney had shown to be involved in electro-chemical processes and he used Stoney "electron" charge to find the mass of the cathode ray particles.

Thomson went on to propose the first model of the atom which became known as the "plum pudding" model in which negative electrons were embedded in a uniform positive sphere.

Thomson's work provided evidence for the first subatomic particle and was awarded the Nobel prize in physics for his discovery.

Question 34(a)

Criteria	Marks
• Provides details of terms making clear how they are related	3
• Indicates some understanding of the terms and their relationship	2
• Identifies Einstein's equation as connecting the terms	1

Sample answer:

When subatomic particles combine to form nuclei, energy is released resulting in the completed nucleus having a lesser mass than the sum of the masses of the individual particles that make it up. This is known as the mass defect.

The energy released is equal to the amount of energy required to separate the subatomic particles in the nucleus into individual particles and is called the binding energy.

Binding energy and mass defect are connected by Einstein's mass/energy equivalence, $E = mc^2$.

Question 34(b)

Criteria	Marks
• Calculates the average binding energy correctly	4
• Calculates the energy for whole nucleus in joules OR calculates the average binding energy with ONE error	3
• Calculates the energy for whole nucleus in joules with ONE error	2
• Calculates the mass of the nucleus components	1

Sample answer:

The mass of the 2 protons and 2 neutron $= 2 \times (1.673 \times 10^{-27} + 1.675 \times 10^{-27})$ kg $= 6.696 \times 10^{-27}$ kg

Mass of nucleus $= 4.0015\ \mu = 4.0015 \times 1.661 \times 10^{-27} = 6.646 \times 10^{-27}$ kg

Mass defect $= 0.05 \times 10^{-27}$ kg

$E = mc^2 = 0.05 \times 10^{-27} \times (3 \times 10^8)^2$
$= 4.5 \times 10^{-12}$ joules

Binding energy per nucleon $= 1.1 \times 10^{-12}$ joules

Question 35

Criteria	Marks
• Provides an outline of how accelerators function and details of experimental results which have provided evidence for the Standard Theory of Matter	4–5
• Identifies the role of accelerators in relation to the Standard Theory of Matter	2–3
• Provides ONE relevant piece of information	1

Sample answer:

Particle accelerators, such as linear accelerators or cyclotrons, are used to accelerate charged particles to very high energies. The speeds are so high that their mass increases due to relativistic effects. They are then collided with other particles to form new products which have extremely short lifespans and are not observable under normal conditions. These new products are then detected and analysed by computers, measuring variables such as energy, charge and mass. These measurements have led to the discovery of particles smaller than protons, neutrons and electrons which were once considered to be the smallest, and therefore, the fundamental particles.

Accelerators have enabled physicists to probe deeply into the structure of matter, leading to the development and corroboration of the Standard Model of Matter. Accelerators will continue to be used to test predictions based on the Standard Model and in the search for fundamental particles. Recently, evidence was found for the Higgs boson which had been theoretically predicted. In 2012, scientists confirmed its existence through the ATLAS and CMS experiments at the Large Hadron Collider (LHC) at CERN in Switzerland and physicists at CERN continue to investigate its properties.

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Question	Marks	Content module		Syllabus Outcomes (PH)	Targeted performance bands
Section I					
1	1	5	Motion in a Gravitational Field	11/12-4, 12-12	3-4
2	1	5	Motion in a Gravitational Field	11/12-6, 12-12	4-5
3	1	5	Circular Motion	11/12-6, 12-12	3-4
4	1	5	Motion in a Gravitational Field, Circular Motion	12-12	2-3
5	1	6	Motion in a Gravitational Field	11/12-4, 12-12	3-4
6	1	6	Charged Particles, Conductors and Electric and Magnetic Fields	11/12-4, 12-13	2-3
7	1	6	The Motor Effect	11/12-6, 12-13	2-3
8	1	6	The Motor Effect	11/12-4, 12-13	5-6
9	1	6	Electromagnetic Induction	12-13	2-3
10	1	6	Charged Particles, Conductors and Electric and Magnetic Fields	11/12-6, 12-13	4-5
11	1	7	Light: the Wave model	12-14	2-3
12	1	7	Light: the Wave model	12-14	2-3
13	1	7	Light: the Quantum Model	12-14	4-5
14	1	7	Light and Special Relativity	12-14	3-4
15	1	7	Light and Special Relativity	11/12-4, 12-14	5-6
16	1	8	Quantum Mechanical Nature of the Atom	12-15	3-4
17	1	7	Electromagnetic Spectrum	12-15	2-3
18	1	8	Structure of the Atom	12-15	2-3
19	1	8	Origin of the Elements	12-15	3-4
20	1	8	Deep Inside the Atom	12-15	2-3

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Question	Marks	Content module		Syllabus Outcomes (PH)	Targeted performance bands
Section II					
21	4	5	Motion in a Gravitational Field	11/12-6, 12-12	3-4
22(a)	1	5	Motion in a Gravitational Field	11/12-5, 12-12	3-5
22(b)	2	5	Motion in a Gravitational Field	11/12-4, 12-12	3-4
23	8	7	Electromagnetic Spectrum	11/12-7, 12-14	3-5
24(a)	3	5	Projectile Motion	11/12-4, 12-12	4-5
24(b)	4	5	Projectile Motion	11/12-5, 12-12	3-4
25	4	6	Charged Particles, Conductors and Electric and Magnetic Fields	11/12-5, 12-13	4-5
26(a)	2	6	Electromagnetic Induction	12-13	4-5
26(b)	2	6	Electromagnetic Induction	12-13	4-5
26(c)	1	6	Electromagnetic Induction	12-13	3-4
27	5	6	Applications of the Motor Effect	11/12-7, 12-13	2-3
28	7	8	Quantum Mechanical Nature of the Atom	11/12-6, 12-15	4-6
29(a)	2	7	Light: Wave Model	12-14	2-3
29(b)	4	7	Light: Wave Model	12-14	3-4
30(a)	1	7	Light: Quantum Model	11/12-5, 12-13	3-4
30(b)	3	7	Light: Quantum Model	12-13	3-5
31(a)	2	7	Light and Special Relativity	11/12-6, 12-14	5-6
31(b)	2	7	Light and Special Relativity	11/12-6, 12-14	4-5
32(a)	3	7	Origin of the Elements	12-15	3-4
32(b)	2	7	Origin of the Elements	12-15	3-4
33	6	8	Structure of the Atom	11/12-7, 12-15	3-5
34(a)	3	8	Properties of the Nucleus	12-15	4-5
34(b)	4	8	Properties of the Nucleus	11/12-5, 11/12-15	3-5
35	5	8	Deep Inside the Atom	11/12-7, 12-15	3-6