2022

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 2–11)
20 marks
- Attempt Questions 1–20
- Allow about 35 minutes for this part

Section II (Pages 12–30)
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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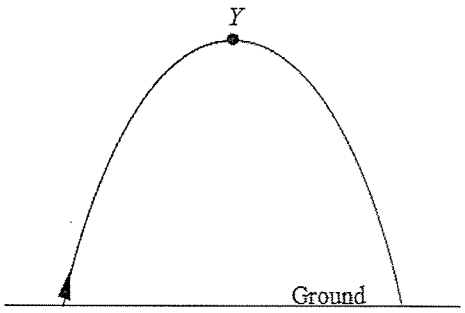
19				
20				

STUDENT NUMBER/NAME.....

1 Which statement about an object undergoing projectile motion is correct?



A. Its kinetic energy at point Y will be zero.

B. Its potential energy at point Y is a minimum.

C. Its kinetic energy will be the same at launch as it is at impact.

D. Its kinetic energy on launch will be the same as the potential energy at point Y.

2 Which is a correct expression for the total energy of an orbiting satellite?

A. $E_{\text{total}} = \frac{E_K}{2}$

B. $E_{\text{total}} = -\frac{E_K}{2}$

C. $E_{\text{total}} = \frac{U}{2}$

D. $E_{\text{total}} = -\frac{U}{2}$

3 Two satellites are in the same Low Earth Orbit. Satellite X has four times the mass of satellite Y.

What is the ratio of their orbital speeds?

A. $X : Y = 1 : 1$

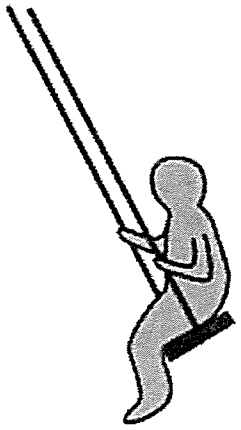
B. $X : Y = 1 : 4$

C. $X : Y = 4 : 1$

D. $X : Y = 2 : 1$

STUDENT NUMBER/NAME.....

4 Students discuss the best way to increase speed when on a swing in a children's playground.



Which statement is correct and supported by physics principles?

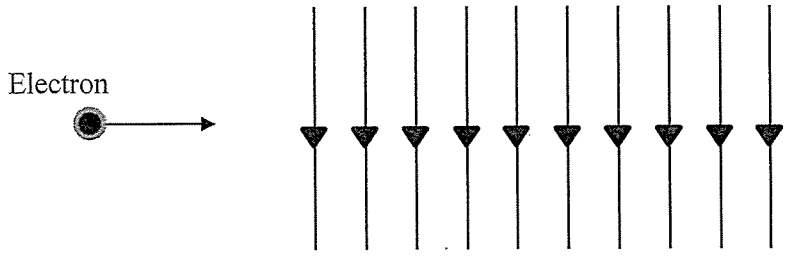
A. Straighten your legs at top of swing to increase speed, as the leg movement adds to available kinetic energy.

B. At top of swing, straighten your legs and pull on the support ropes, because both actions raise your centre of mass, adding potential energy.

C. Pull on the support ropes at top of swing to provide a torque around the pivot point where the rope is attached.

D. At top of swing, straighten your legs and pull on the support ropes, because both use force and therefore increase the centripetal acceleration.

5 The diagram shows an electron which moves with a constant velocity, entering an electric field at a right angle.



Which alternative describes the path of the electron in the electric field?

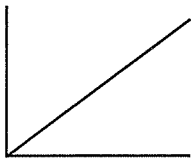
A. A parabolic path down the page

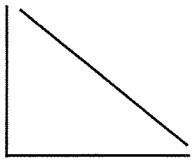
B. A circular path down the page

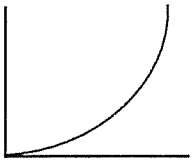
C. A parabolic path up the page

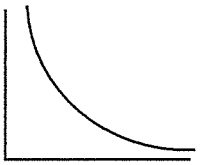
D. A circular path up the page

6 Which graph could show the relationship between the force between parallel current-carrying conductors and the distance between them?

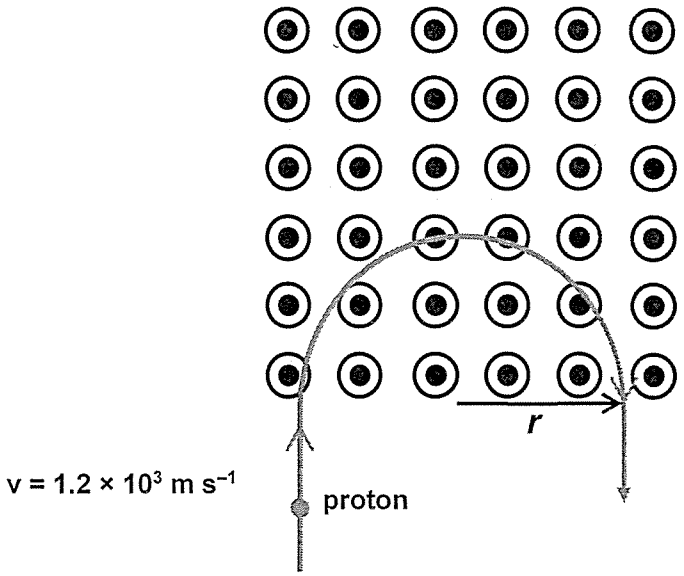
A. 

B. 

C. 

D. 

7 A proton with a velocity of 1.2×10^3 m s^{-1} is fired into a uniform magnetic field of 3.0×10^{-2} *T*, directed out of the page, as shown in the diagram below. It moves in a vacuum in a semi-circle of radius *r*.



Which choice best gives the speed of the proton as it exits the magnetic field?

A. 0.8×10^3 m s^{-1}

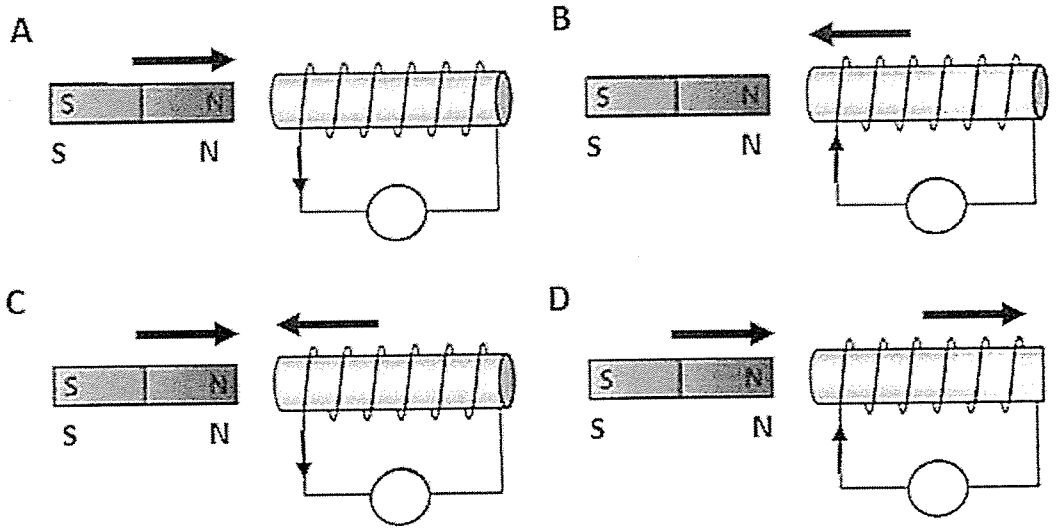
B. 1.2×10^3 m s^{-1}

C. 1.8×10^3 m s^{-1}

D. 2.4×10^3 m s^{-1}

8 The arrows in the diagrams below represent the motion direction of the magnet or the coil. The speeds are identical in each diagram.

Which alternative shows the correct direction of the induced current I in the coil?



9 Which wave behaviour provided evidence for the transverse nature of light waves?

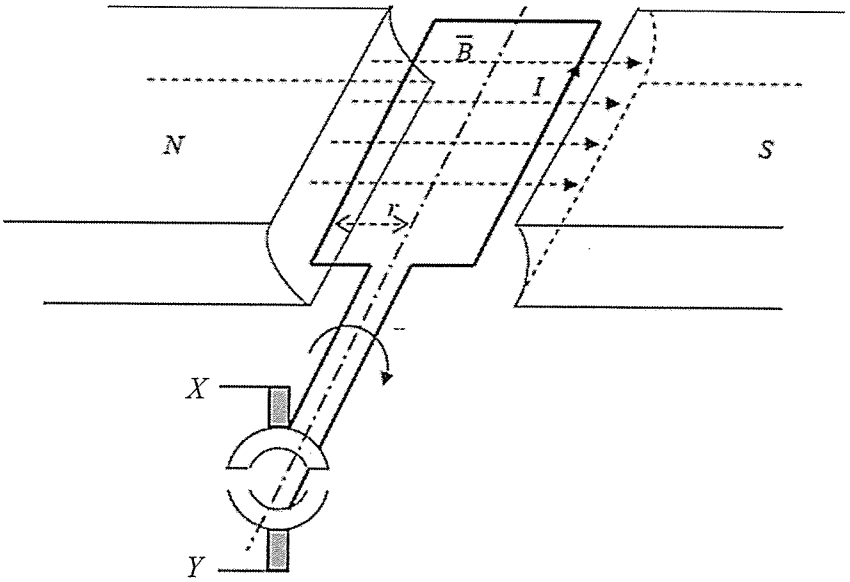
A. Polarisation
B. Diffraction
C. Interference
D. Refraction

10 Which is the best description of an electromagnetic wave?

A. Perpendicular oscillating electric and magnetic fields
B. Accelerating electric and magnetic fields
C. Perpendicular constant electric and magnetic fields
D. Radiating parallel electric and magnetic fields

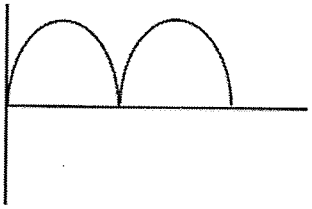
STUDENT NUMBER/NAME.....

11 A student set up a model generator according to the diagram below and attached a galvanometer across the points X and Y.

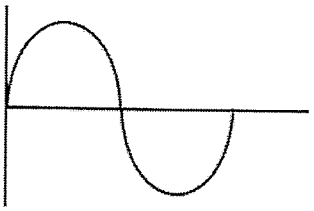


Which graph best shows how the current through the meter changes as the coil is rotated 360° from the position shown?

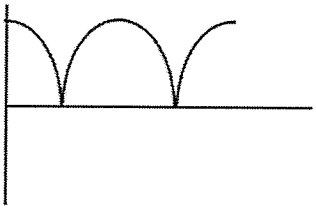
A.



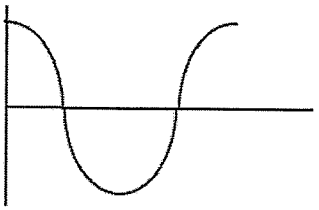
B.



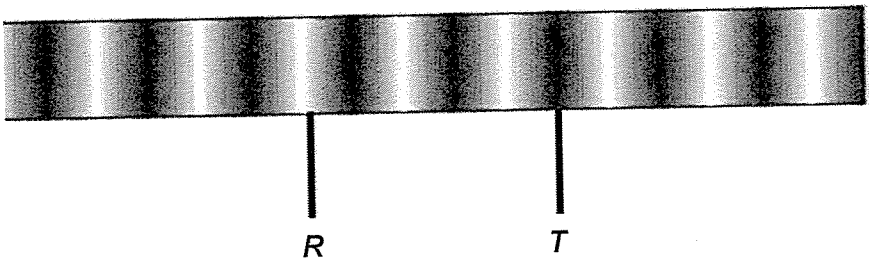
C.



D.



12 The diagram shows the regular light and dark interference pattern produced by a laser beam through two close slits 0.10 mm apart on a screen 1.6 m away from the slits. The distance between maximum at R and minimum at T on the interference pattern is 18 mm.



According to this information in the diagram, what is the wavelength of the incident light used in this experiment?

A. $1.1. \times 10^{-8}$ m

B. 2.2×10^{-7} m

C. 4.5×10^{-7} m

D. 4.5×10^{-4} m

13 Which statement about the spectra of incandescent and laser lights is correct?

A. Incandescent light has a continuous spectrum, laser light has a spectrum specific to its narrow frequency range.

B. Laser light has a continuous spectrum, incandescent light has a spectrum concentrated in the yellow region.

C. Laser light has a very wide spectrum concentrated in the infra-red, incandescent has a very narrow spectrum.

D. Both laser light and incandescent light have a very narrow spectrum.

14 Which is a correct about special relativity?

A. The time dilation predicted by the special relativity equation has never been measured by physicists.

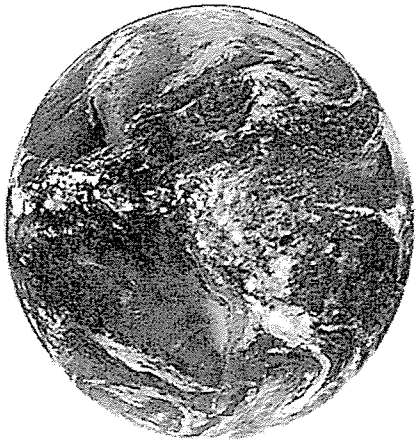
B. Special relativity equations only apply to space travel.

C. The maximum speed "c" of both light and particles predicted by special relativity has been measured.

D. Special relativity is supported by both experiments and astronomical observations.

STUDENT NUMBER/NAME.....

15 A rocket is heading directly towards the surface of the Earth at a constant speed of 0.75c. Physicists on Earth calculate the time that the rocket will take to reach the surface of Earth as 850 microseconds.



How long does the pilot in the rocket calculate it will take him to reach the surface of Earth?

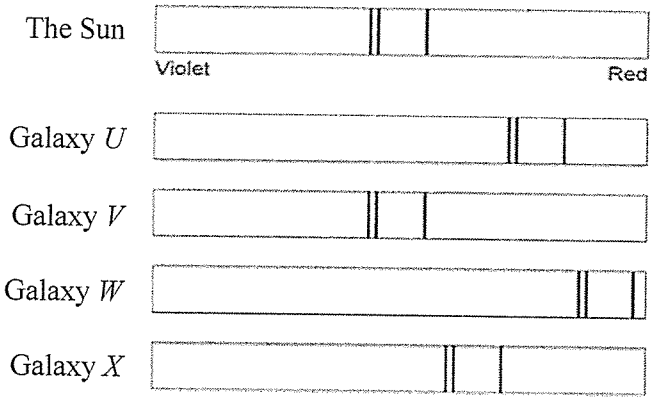
A. 562 microseconds

B. 638 microseconds

C. 1133 microseconds

D. 1235 microseconds

16 The diagram shows three identically spaced lines on light spectra from our Sun and four galaxies.



On this information, which galaxy is closest to us?

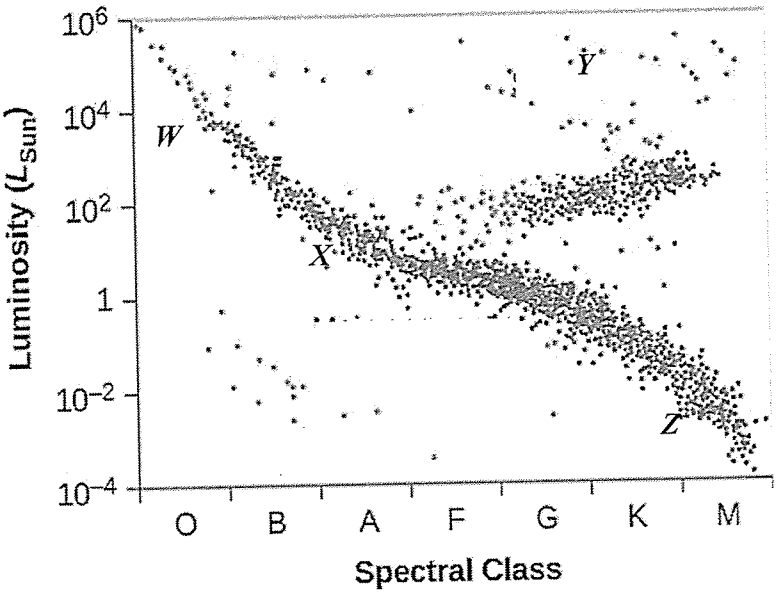
A. *U*

B. *V*

C. *W*

D. *X*

17 The Hertzsprung-Russell diagram for the nearby stars has four stars, marked *W*, *X*, *Y* and *Z*.



Which alternative about these four stars is correct?

A. Star *W* is the hottest, largest and most massive of the four.

B. Star *X* is a relatively small, yellow star, similar to our Sun.

C. Star *Y* is the largest and hottest of the four.

D. Star *Z* is the smallest and has the longest remaining lifespan.

18 Which statement about binding energy is INCORRECT?

A. Binding energy is equal to the product of the square of the speed of light and the mass defect in a nucleus.

B. The most stable nuclei have the smallest binding energy.

C. Binding energy is the energy needed to break a nucleus into its component nucleons.

D. Binding energy is the energy released when nucleons join to form a nucleus.

STUDENT NUMBER/NAME.....

19 Polonium-210 is a radioactive isotope that decays by emitting an alpha radiation.

Which is the correct decay equation for polonium-210?

A. $^{210}_{84}\text{Po} \longrightarrow ^{214}_{82}X + ^{4}_{2}\text{He}$

B. $^{210}_{84}\text{Po} \longrightarrow ^{214}_{86}X + ^{4}_{2}\text{He}$

C. $^{210}_{84}\text{Po} \longrightarrow ^{206}_{82}X + ^{4}_{2}\text{He}$

D. $^{210}_{84}\text{Po} \longrightarrow ^{206}_{86}X + ^{4}_{2}\text{He}$

20 What is the general name given to the particles formed when two or more quarks combine?

A. Baryons

B. Hadrons

C. Leptons

D. Mesons

STUDENT NUMBER/NAME.....

Section II

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

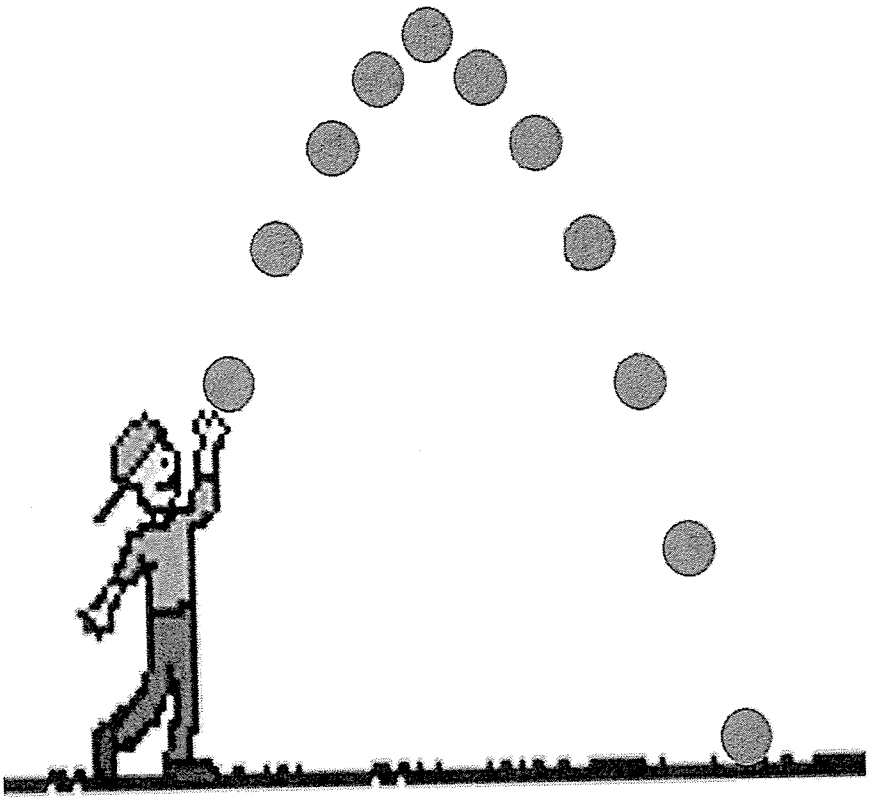
Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

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)

The diagram shows a strobe photo of a ball projected into the air. The camera took 7 images per second of the ball.



Question 21 continues on the next page

STUDENT NUMBER/NAME.....

Question 21 (continued) **Marks**

(a) What was the maximum height of the ball above the ground? **2**

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(b) Determine the range of the projectile. **2**

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End of Question 21

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Question 22 (5 marks) **Marks**

Account for the release of energy in both the process of fusion and fission. Identify examples in your answer. **5**

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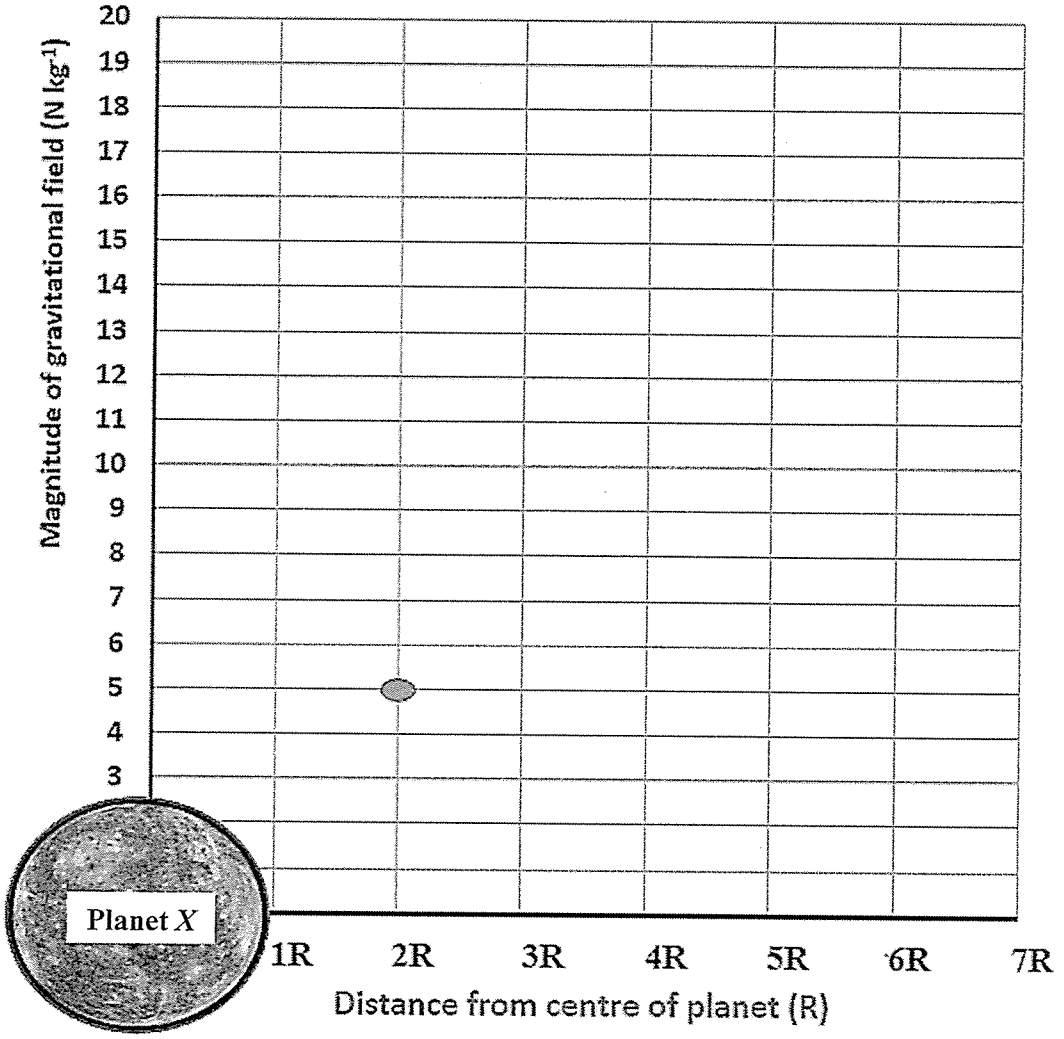
Question 23 (3 marks) **Marks**

The value of the gravitational field at distance 2R from the surface of planet X is 5 N kg^{-1}. This is plotted on the graph below. **3**

Determine the magnitude of the gravitational field at distances of R, 4R and 6R and complete the graph.



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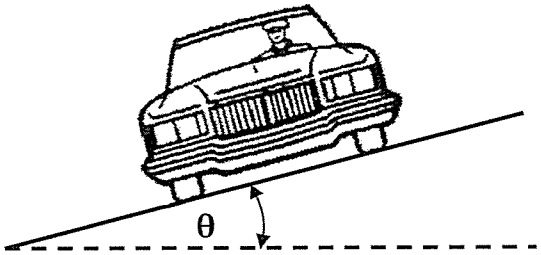
Question 24 (4 marks) **Marks**

A road has a circular curve with a radius of 90 m and is properly banked at angle θ for a car travelling at 60 kph on its smooth surface. **4**



Determine the angle at which the curve is banked using vector resolution.

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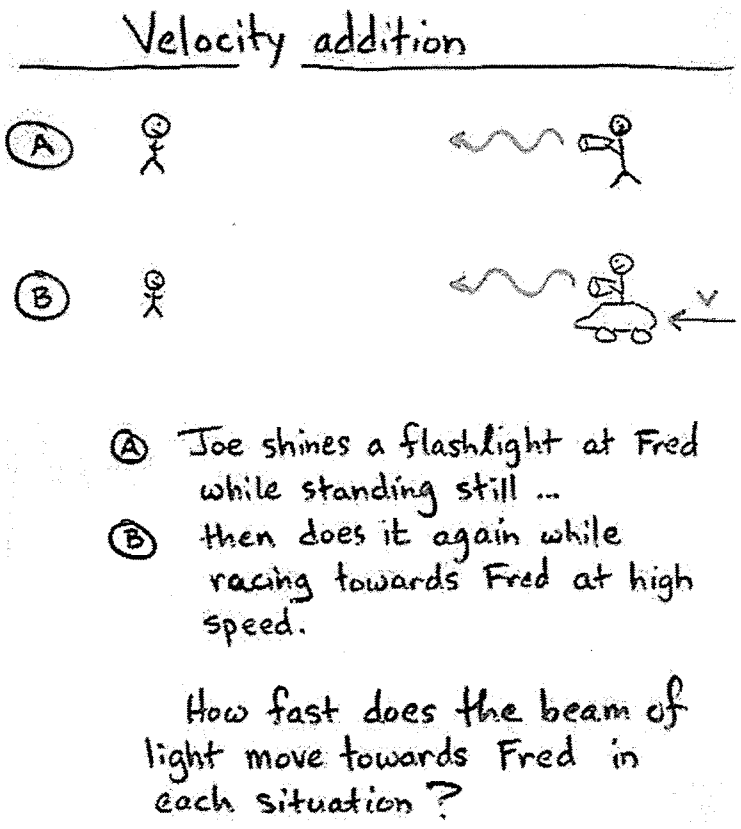
Question 25 (5 marks) **Marks**

Consider the drawing below. **5**



Explain the relevance of the Michelson-Morley experiment or other evidence to the question in the diagram and the relevance to ONE of Einstein's contributions to Physics.

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STUDENT NUMBER/NAME.....

Question 26 (6 marks) **Marks**

The table shows data for three of the moons of Jupiter, the largest planet in our solar system with a diameter of approximately 143 000 km.

Moon of Jupiter	Orbital radius (km)	Orbital period ($\times 10^5$ s)	(Orbital radius)^3 ($\times 10^{26}$ m^3)	(Orbital period)^2 ($\times 10^{10}$ s^2)
Io	493 500	1.53	1.2	2.34
Europa	742 500	3.1	4.1	9.61
Ganymede	1 141 500	6.2	14.9	38.4

(a) On the axes provided, graph relevant data to verify Kepler's Law of Periods. Include a line of best fit. **3**

(b) Explain how the graph provides evidence for Kepler's law of Periods. **1**

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(c) Using your graph, determine the mass of Jupiter. **2**

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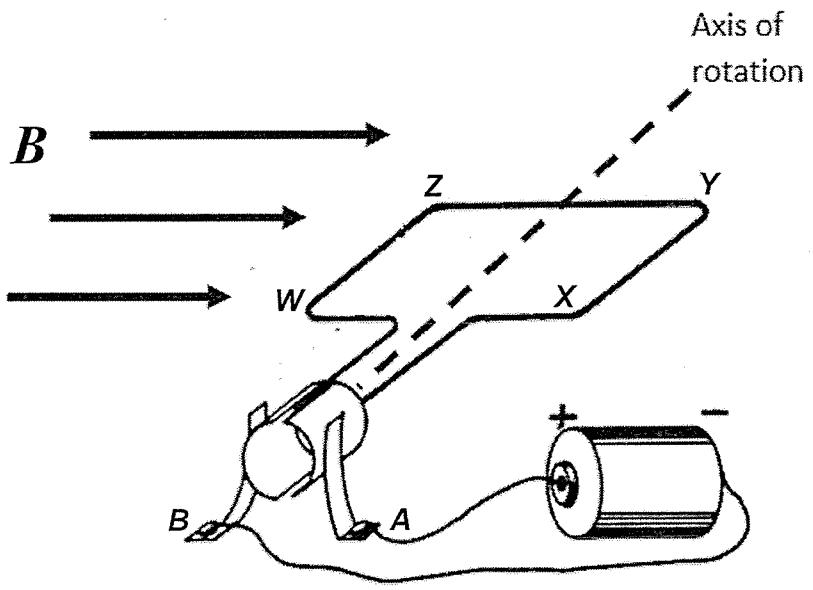
Question 27 (6 marks) **Marks**

The diagram below shows a simple electric motor. The square coil *WXYZ* has sides of 4.0 cm and lies completely in the horizontal uniform magnetic field *B* of strength 2.0 *T*. The magnetic field is perpendicular to the sides *WZ* and *XY*. The coil has 20 turns and rotates about the axis shown. The current drawn from the battery is 2.5 A.



(a) For the position of the coil in the diagram, determine the torque on the side *WZ*. **3**

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(b) Explain the continuous movement of the coil in relation to the changing torque acting on the coil. **3**

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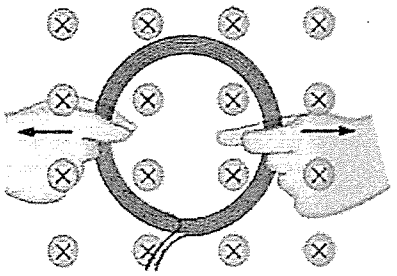
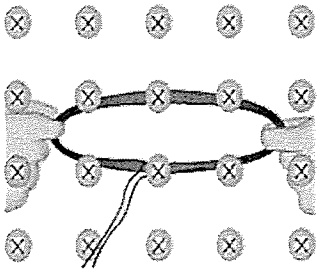
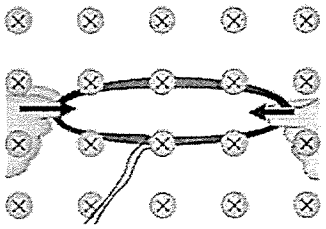
Question 28 (5 marks) **Marks**

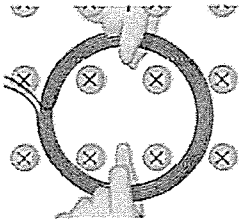
The diagram shows a flexible coil of wire with multiple turns in a magnetic field directed into the page. The ends of the wire making up the coil are connected to a galvanometer. A student pulls the sides of the coil which distorts it horizontally, as shown in the diagram on the right below.

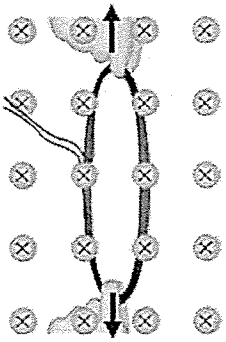




The coil is then pushed back to the original circular shape before being pulled and distorted vertically.







Explain what would be observed on the galvanometer as the shape of the coil is changed. In your answer, identify the direction of the current in the coil during any current flow. **5**

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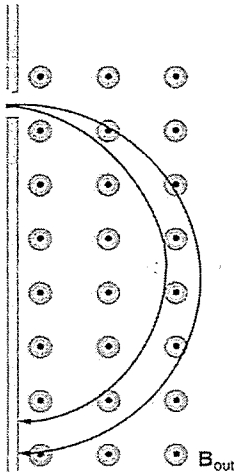
Question 29 (4 marks) **Marks**

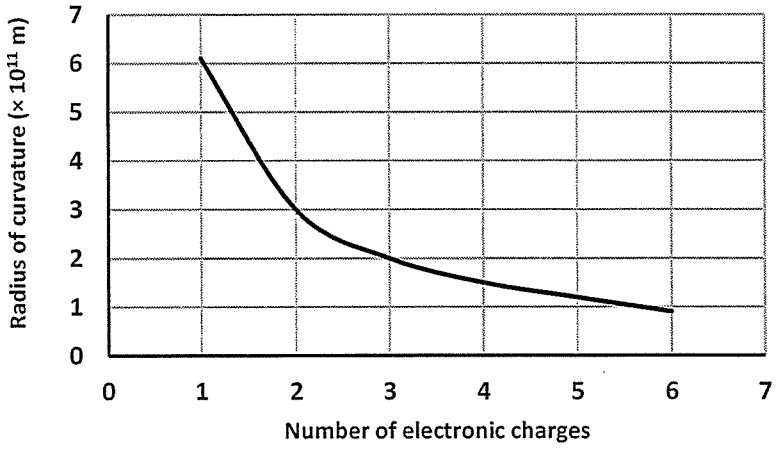
Using a mass spectrometer, some students did an experiment to determine the relationship between the charge on a particle and its radius of curvature in a magnetic field. The diagram shows the path of only two of the six charged particles observed. **4**



Their results are shown in the table.

Charge on particle (Number of electronic charges)	*Radius of curvature of path ($\times 10^{-11}$ m)*
1	6.1
2	2.9
3	2.1
4	1.5
5	1.2
6	0.9

The students plotted their results, shown on the graph below, and concluded that the radius of curvature of a charge in a magnetic field, is inversely proportional to the magnitude of the charge.



Question 29 continues on the next page

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Question 29 (continued) **Marks**

Evaluate their conclusion and identify any problems with their method.

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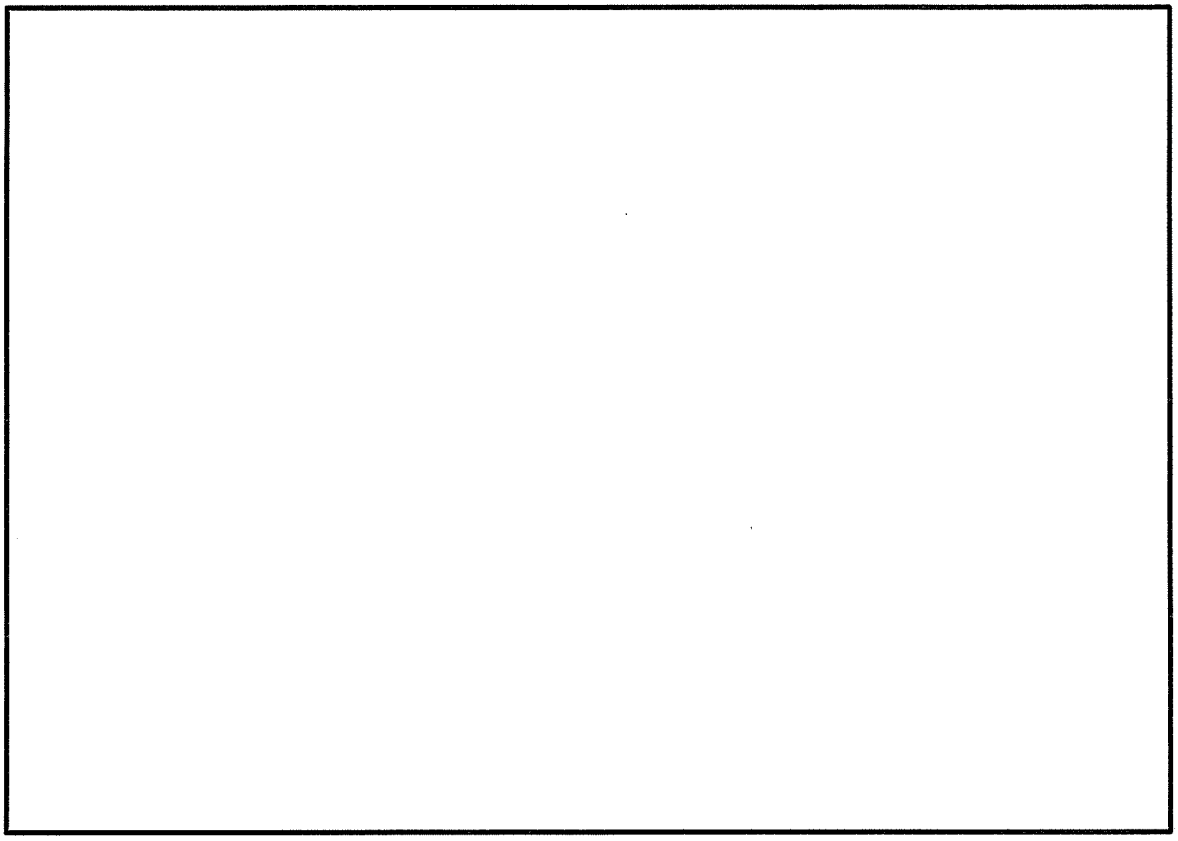
End of Question 29

STUDENT NUMBER/NAME.....

Question 30 (4 marks) **Marks**

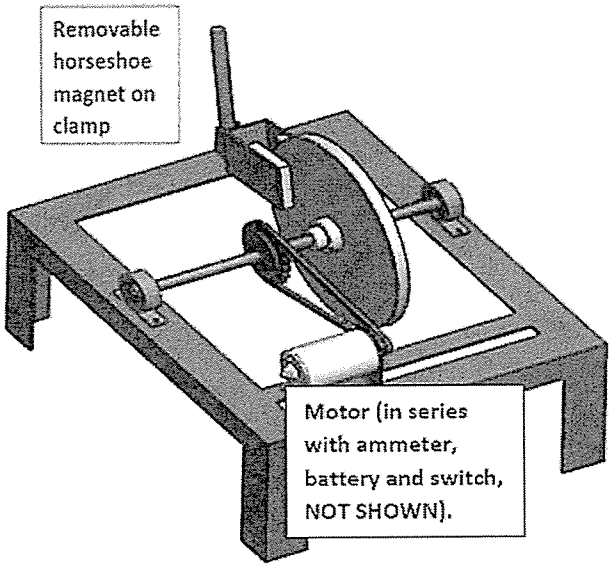
Draw a labelled diagram to show the propagation of waves according to Huygen's model of light. **4**



STUDENT NUMBER/NAME.....

Question 31 (7 marks) **Marks**

A student sets up an aluminium disc which is able to rotate in the vertical plane. The axle of the disc has a pulley wheel turned by a motor in series with an ammeter, battery and switch. A clamp with a horseshoe magnet can be attached so that a horizontal magnetic field passes through one part of the disc. 7



The student observes the current and the speed of disc rotation, before and after the magnet is attached with its magnetic field passing through the disc. When the magnet is in place, the current through the ammeter is more and the speed of rotation of the disc is less.

By applying Lenz's Law, explain each observation.

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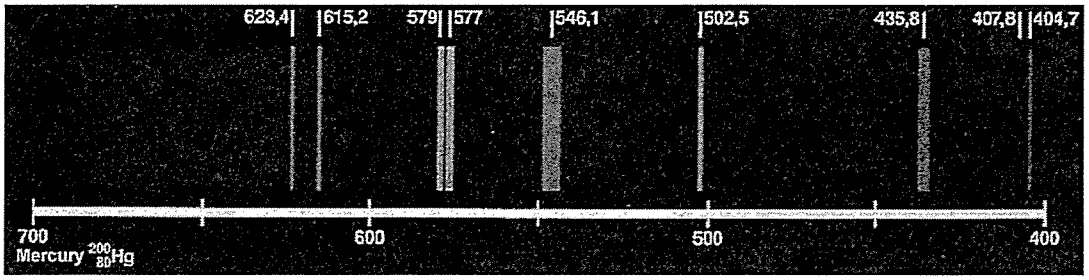
Question 32 (9 marks) **Marks**

The diagram shows a mercury vapour emission spectrum with the wavelength of each line labelled in nanometres.



(a) Explain how such a mercury spectrum is produced. **4**

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(b) Determine which line of the spectrum has photons with the least energy and calculate the energy of these photons in eV. **3**

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Question 32 continues on the next page

STUDENT NUMBER/NAME.....

Question 32 (continued) **Marks**

(c) A student suggested that if the voltage across the mercury vapour lamp was increased, providing more energy to the system, the spectral lines would all shift to higher frequencies to reflect this increased energy. **2**

Evaluate this hypothesis.

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End of Question 32

STUDENT NUMBER/NAME.....

Question 33 (4 marks) **Marks**

Recent high speed particle collision experiments in the Large Hadron Collider accelerator have produced results that causes scientists to hypothesise that quarks may be composed of smaller particles. **4**

How would this discovery affect the Standard Model of Matter and our understanding of the idea of fundamental particles?

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STUDENT NUMBER/NAME.....

Question 34 (7 marks) **Marks**

In an experiment, students used a light source that emitted a wide range of frequencies. They used filters so that only specific frequencies could fall onto a photoelectric plate. Most of the filters produced frequencies which did not cause emission. 7

Julie says that if the intensities of these frequencies were increased, emission will occur. They experimented with this variable and found that emission still did not occur.

Explain the student's observations and how they provide evidence for the nature of light.

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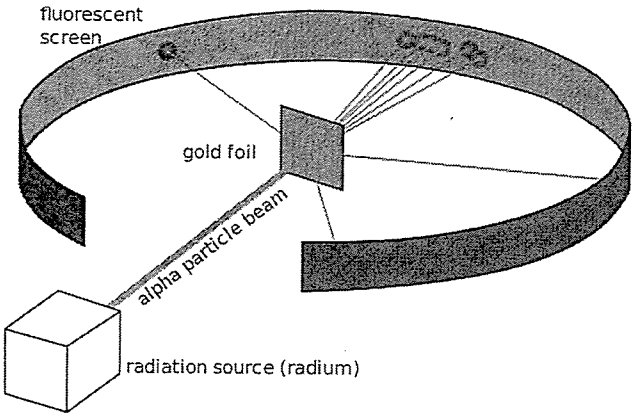
STUDENT NUMBER/NAME.....

Question 35 (7 marks) **Marks**

The diagram represents an important experiment done by a group of scientists in 1907. 7



Outline the background to the experiment, its results and the proposed model of the atom based on the experimental results.

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End of paper

STUDENT NUMBER/NAME.....

Extra writing space

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)	1.097×10^7 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

FORMULAE SHEET

Motion, forces and gravity

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

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

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

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

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

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

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

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

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

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

$$v = u + at$$

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

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

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

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

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

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

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

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

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

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

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

$$Q = mc\Delta T$$

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

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

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

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

$$I_1r_1^2 = I_2r_2^2$$

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

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.

NSW INDEPENDENT TRIAL EXAMS – 2022
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
C	C	A	B	C	D	B	B	A	A	C	C	A	D	A	D	D	B	C	B

Section II

Question 21(a)

Criteria	Marks
• Correctly calculates the maximum height	2
• Calculates maximum height with one error	1

Sample answer:
Time to fall from highest point where vertical velocity is zero = 6 × 1/7 s
$s = ut + \frac{1}{2}at^2$
$= 0 + 4.9 \times (6 \times 1/7)^2$
Maximum height = 3.6 m

Question 21(b)

Criteria	Marks
• Correctly calculates the range using part(a) answer	2
• Calculates range with one measurement error	1

Sample answer:
Distance from ground to bottom of ball at highest point = 9.8 cm
Range of ball = 7.2 cm
9.8 cm represents 3.6 m
Therefore, 1 cm represents 3.6/9.8
Hence, range is 7.2 × 3.6/9.8 = 2.6 m

Question 22

Criteria	Marks
• Describes clearly the process of fission and fusion • Provides an example for each • Explains the source of the energy released	4–5
• Outlines the process of fission and fusion with examples or with identification of energy source	2–3
• Indicates difference between fission and fusion	1

Sample answer: In both fission and fusion reactions, the products have more binding energy than the reactants. Binding energy per nucleon is greatest for element 56, iron after which it decreases to uranium. In fusion, small elements join to form larger nuclei, increasing binding energy. This occurs in the Sun where hydrogen atoms become helium. In fission, large nuclei break apart to form smaller "daughter" nuclei, also with more binding energy. Uranium isotopes bombarded with neutrons break up, producing the energy used in atom bombs and nuclear reactors.

The binding energy change is equivalent to the mass decrease of the products compared to the reactants multiplied by c^2 as $E = mc^2$. This is the energy released in the reactions.

Question 23

Criteria	Marks
• Calculates magnitude of gravitational field at THREE of the distances and draws a smooth curve	3
• Calculates magnitude of gravitational field at THREE of the distances and draws a line OR • Calculates magnitude of gravitational field at TWO of the distances and draws a smooth curve	2
• Calculates magnitude of gravitational field at TWO of the distances OR • Draws a smooth curve	1

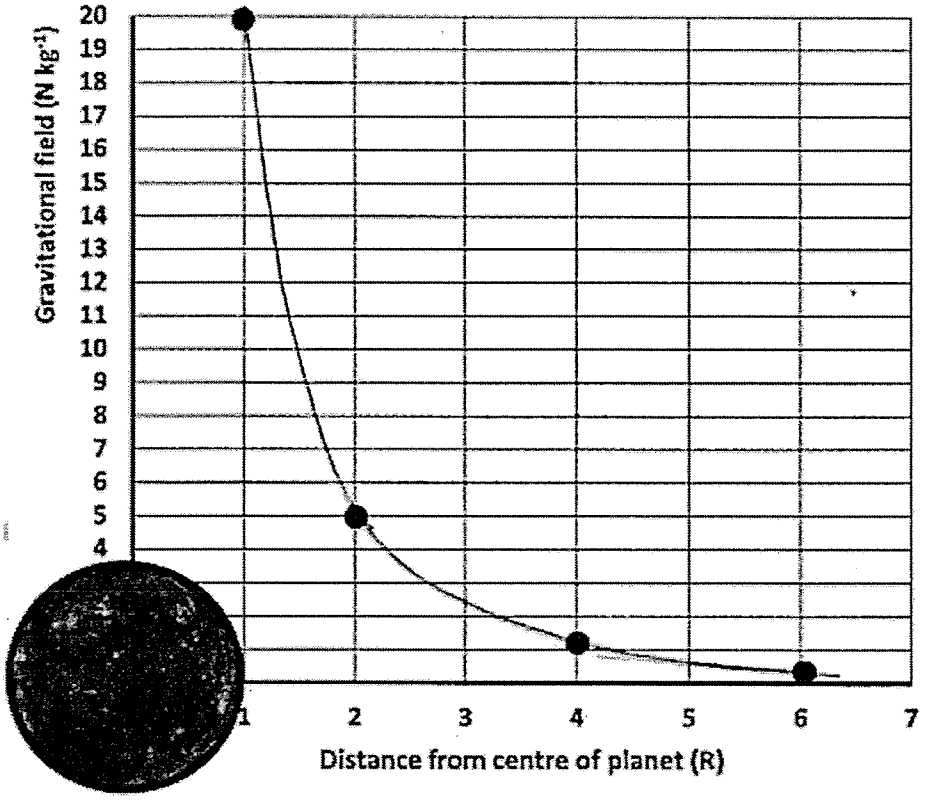
Sample answer:

Gravitational field = $-GM/R^2$ and is inversely proportional to the square of the distance from the centre of planet.

If the distance is halved, from 2R to 1R, gravitational field is $4 \times 5 = 20$ N kg^{-1}

If the distance is doubled, from 2R to 4R, gravitational field is $5/4 = 1.25$ N kg^{-1}

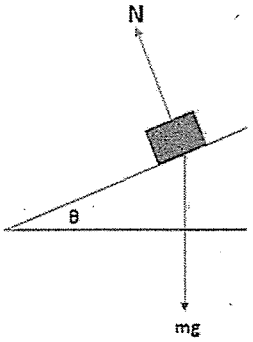
If the distance is tripled, from 2R to 6R, gravitational field is $5/9 = 0.55$ N kg^{-1}



Question 24

Criteria	Marks
• Calculates angle Θ using correct horizontal and perpendicular resolution of vectors	4
• Calculates angle Θ using vector triangle diagram	3
• Provides statements resolving horizontally and vertically with ONE error	2
• Identifies horizontal centripetal force and normal reaction perpendicular to surface	1

Sample answer:



Resolving normal reaction horizontally, $N \sin \Theta = mv^2/r$
Resolving normal reaction vertically, $N \cos \Theta = mg$

$\tan \Theta = v^2/rg$
$= (60 \times 10^3)^2 / (60 \times 60)^2 \times 90 \times 9.8$
$= 17.5°$

Question 25

Criteria	Marks
• Provides discussion relevant to question in diagram • Outlines aim of Michelson-Morley experiment or other evidence relevant to Einstein's two postulates of Special Relativity	4–5
• Provides TWO of the following: discussion relevant to question in diagram, outlines aim of Michelson-Morley experiment or other evidence, relevance to Einstein's two postulates of Special Relativity	2–3
• Provides ONE of the following: discussion relevant to question in diagram, outlines aim of Michelson-Morley experiment or other evidence, relevance to Einstein's two postulates of Special Relativity	1

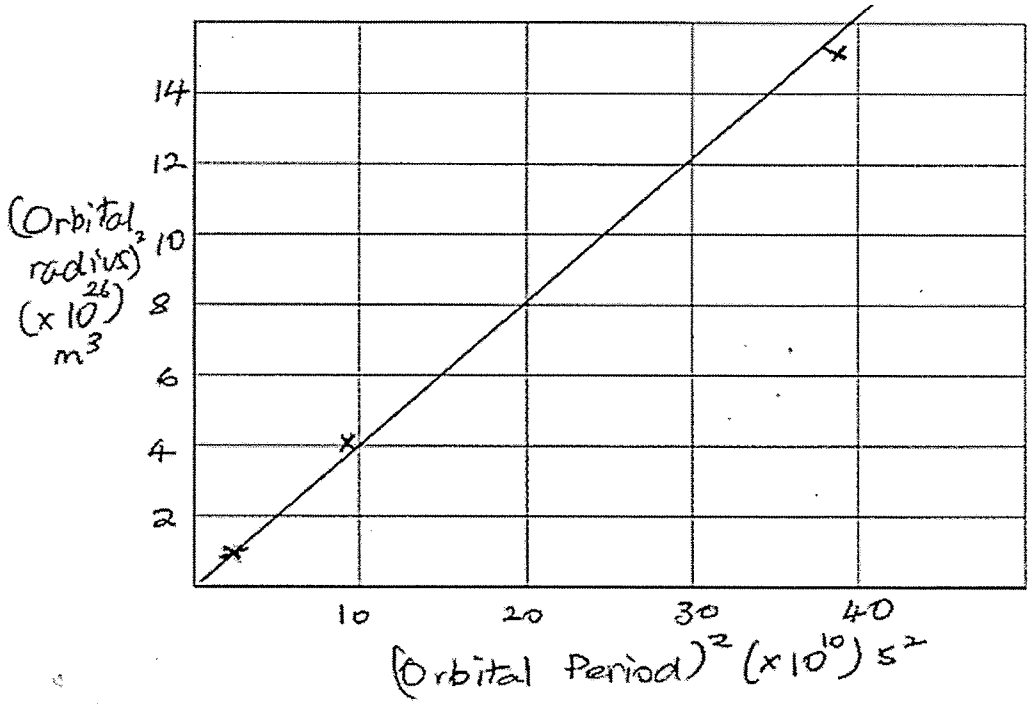
Sample answer: Everyday experience could lead to the answer that beam B moves faster that beam A. This is the case for objects projected from moving vehicles but we now know that this is not the case for light. Light and sound are both waves. Sound was known to be carried by air which moved with the Earth while light, known to travel much faster, was thought to be carried by the aether through which the Earth moved. Michelson and Morley's experiment aimed to prove the existence of aether. According to that theory, light should move through the aether at different speeds, depending on its relative movement through the aether. The experiment failed to obtain evidence using interference effects to provide evidence of the difference in speed. It was considered a failure.

Einstein was aware of the results of similar previous experiments and also the work of Maxwell on electromagnetic waves and abandoned the concept of the aether. He stated that the speed of light in a vacuum is an absolute constant and that the laws of physics are the same in all inertial frames of reference. These two postulates are the basis of Special Relativity which predicts that Fred measures the light moving towards him at the same speed in each situation above.

Question 26(a)

Criteria	Marks
• Provides a ruled straight line graph of radius cubed against period squared with suitably labelled axes	3
• Provides graph without correct labels or graph not ruled	2
• Provides graph without correct labels and graph not ruled	1

Sample answer:



Question 26(b)

Criteria	Marks
• Relates constant gradient to Kepler's law	1

Sample answer: From the Kepler's law equation, $\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$ = constant = gradient for the graph.

Since the graph has a constant gradient, it shows that Kepler's Law of Periods holds for these three moons of Jupiter.

Question 26(c)

Criteria	Marks
• Calculates mass of Jupiter correctly using point on their graph	2
• Correctly derives equation for mass based on gradient	1

Sample answer: $\frac{GM}{4\pi^2}$ = gradient

Mass of Jupiter = $\frac{4\pi^2}{G}$ × gradient

$= (4 \times 3.1415^2/6.67 \times 10^{-11}) \times (8 \times 10^{26}/20 \times 10^{10}) = 2.4 \times 10^{27}$ kg

Question 27(a)

Criteria	Marks
• Provides correct answer with units and direction	3
• Provides correct answer without units or without direction	2
• Provides incorrect answer with units and direction	1

Sample answer:

Force on WZ = nBIl = $20 \times 2.0 \times 2.5 \times 4 \times 10^{-2} = 4.0$ N

Current direction through side WZ is towards W. Using Right Hand Push Rule, the force on WZ is upwards.

Torque = F × distance from axis = $4.0 \times 2 \times 10^{-2} = 8.0 \times 10^{-2}$ Nm vertically upwards

Question 27(b)

Criteria	Marks
• Shows a clear understanding of the operation of the motor	3
• Provides some details of zero torque, momentum effect, change of current in coil sides	2
• Provides some details of TWO of the following: zero torque, momentum effect, change of current in coil sides	1

Sample answer: As the coil rotates, the torque on sides WZ and XY reduce to zero, as the perpendicular distance of the force direction to the axis of rotation reduces to zero. The momentum of the coil moves it past the vertical position. In the vertical position, the commutator setup (AB) changes the direction of the current in the coil, and hence, the direction of the torque acting on WZ and XY is changed every 180°, resulting in continuous rotation.

Question 28

Criteria	Marks
• Shows a good understanding of the reason for induced current and current direction during changes of coil shape, with correct current directions for THREE changes	5
• Shows a good understanding of the reason for induced current and for current direction during changes in coil shape, with correct current for TWO changes of coil shape OR • Provides the reason for induced current and for current direction, and correct current direction for THREE changes of coil shape	4
• Provides the reason for induced current and for current direction, and correct current direction for TWO changes of coil shape	3
• Provides the reason for induced current and for current direction, and correct current direction for ONE changes of coil shape	2
• Provides the reason for induced current and for current direction OR • Provides correct current direction for ONE change of coil shape	1

Sample answer: Because there is relative movement between a conductor (the coil) and the magnetic field, (or because the flux through the coil decreases), a current will be induced in the coil. The area of the coil reduces to zero as the sides come together.

The direction of the induced current will be such that the decrease in flux through the coil is opposed. Therefore, a clockwise current flows in the coil to restore flux through the coil.

Returning the coil to its original shape increases the flux though it, and therefore, results in the induction of an anticlockwise current to oppose this increase.

Distorting the coil vertically also induces a clockwise current because the distortion reduces the flux through the coil in the same way as distorting it horizontally did.

Question 29

Criteria	Marks
• Provides reasons for invalid conclusion based on lack of identified controlled variable and derived relationship between radius and charge based on a curve	3–4
• Provides reasons for invalid conclusion based on lack of controlled variables	2
• Provides shape of graph as reason for invalid relationship	1

Sample answer: Conclusion is invalid. A conclusion cannot be made because the graph is not a straight line. Their conclusion can only be based on a straight line graph plotting the inverse of charge or radius against the other variable. Also, the experiment description does not have the necessary controlled variables stated. The mass and velocity of the charged particle will affect the radius of curvature, as well as the charge.

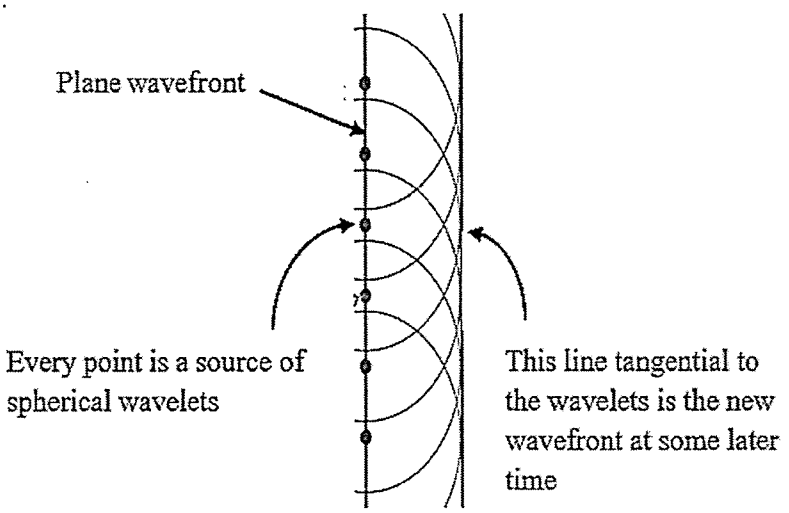
Centripetal force, $mv^2/r = Bqv$ Therefore, $r = (mv/B) \times 1/q$

This shows that radius is inversely proportional to charge, only if mass and velocity are constant, as well as magnetic field.

Question 30

Criteria	Marks
• Draws a diagram with ruled wavefront tangential to spherical wavelets from a plane wavefront and with THREE of the labels shown below	4
• Draws a diagram with wavefront tangential to spherical wavelets and with TWO of the labels shown below	3
• Draws a diagram with wavefront formed by spherical wavelets and with ONE of the labels shown below	2
• Draws a diagram of a wavefront with spherical wavelets	1

Sample answer:



Question 31

Criteria	Marks
• Clearly explains the cause of a back emf in motor and the eddy currents in the disc based on Lenz's law and why the eddy currents change the ammeter reading	6–7
• Outlines the cause of a back emf in motor and the eddy currents in the disc based on Lenz's law and why the eddy currents change the ammeter reading	4–5
• Outlines the cause of a back emf in motor and identifies eddy currents OR • Outlines why the eddy currents are set up and identifies the occurrence of a back emf in the motor	2–3
• Identifies eddy currents in the disc OR • Identifies back emf in motor	1

Sample answer: When a motor is switched on, the motion of the motor's rotating coil in its magnetic field will induce a back emf in the coil according to Faraday's law of induction. The direction of this emf must be such that it opposes the motion of the coil (Lenz's Law) and therefore, does not contravene the law of conservation of energy. The net voltage decreases, and therefore, the current flow decreases. The magnitude of the back emf is proportional to the rotational speed of the motor coil.

When the horseshoe magnet surrounds part of the aluminium disc, eddy currents are set up in the disc because the disc is a conductor moving in a magnetic field. By Lenz's Law, the direction of the currents will be such as to oppose the magnetic field and oppose the motion of the disc. This is known as the braking effect, reducing the rotational speed of the disc and the motor coil. Consequently, the back emf is also less, resulting in the greater current.

Question 32(a)

Criteria	Marks
• Shows a good understanding of electron movement between specific energy levels in mercury atoms, the emission of the energy difference as a quanta with wavelength determined by Planck's equation	4
• Provides some details of electron movement between specific energy levels in mercury atoms, the emission of the energy difference as a quanta with wavelength determined by Planck's equation	3
• Identifies emission of energy by electrons and outlines the movement between energy levels	2
• Identifies emission of energy by electrons	1

Sample answer: A high voltage is applied across a low pressure mercury gas in a glass tube, called a discharge tube. Electrons around the mercury nuclei absorb energy, i.e., are "excited" and move to higher energy "orbits" around the nucleus. Excited electrons in higher energy levels in the mercury atoms in the vapour, emit specific quanta of energy when they fall back to lower energy orbits. The energy emitted depends on which two orbits are involved in the jump, with the energy emitted being the energy difference of the orbits. The energy difference is emitted as a quantum where the energy is equal to hf, according to Planck's formula. Because the orbital values are limited, a line spectrum is formed (rather than a continuous spectrum).

Question 32(b)

Criteria	Marks
• Identifies the longest wavelength and calculates the correct energy in eV	3
• Identifies the longest wavelength and calculates the correct energy in Joules	2
• Identifies the shortest wavelength and calculates the correct energy in eV	1

Sample answer: Energy of a photon is proportional to its frequency. The longest wavelength light, (623.4 nm) has the least energy photons.

$E = hc/\lambda = (6.626 \times 10^{-34} \times 3 \times 10^{8})/(623.4 \times 10^{-9}) = 3.19 \times 10^{-19}$ Joules

$E = 3.19 \times 10^{-19}/1.602 \times 10^{-19} = 1.99$ eV

Question 32(c)

Criteria	Marks
• Identifies hypothesis as invalid and provides reason for extra lines	2
• Identifies hypothesis as invalid and provides reason	1

Sample answer: The hypothesis is invalid because the energy levels involved in electron transitions producing the above lines are not changed and these transitions would still occur. The higher supplied energy would allow the electrons to move into higher level orbits, higher energy levels resulting in extra lines with higher frequencies as these electrons move back to lower levels.

Question 33

Criteria	Marks
• Describes the nature of science, how scientific models develop and change based on new evidence	3–4
• States that theories and models change based on new evidence	1–2

Sample answer: All Science is a developing study, with its models verified by experimental evidence, but not considered as final and unchangeable. As technology improves, then our understanding of the world, and hence of matter, will grow. The current Standard Model is a tool that represents our current level of understanding, after many years of work by scientists, but like all scientific knowledge, may change based on the results of further experiments.

The discovery of particles smaller than quarks would not affect the concept of fundamental particles – they will still be defined as those which are not made up of smaller particles. However, quarks, one of the current fundamental particles will no longer be able to be considered as fundamental. Over the last few centuries, the particles identified as fundamental particles of matter, have changed a number of times.

Question 34

Criteria	Marks
• Provides a well-reasoned explanation of how photons explain the result and how a simple wave nature for light does not • Identifies dual nature of light	6–7
• Outlines how photons explain the result and how a simple wave nature for light does not	4–5
• Outlines how photons explain the result	2–3
• Provides a relevant statement	1

Sample answer: This result can only be explained if light waves are made up of particles, packets of wave energy called photons. The term "intensity", when applied to electromagnetic radiations, therefore, refers to the number of photons in a beam – it does not refer to an increase in the energy of each photon, that is, increasing intensity means more photons, but each has the same energy.

For the photoelectric emission of electrons, the electrons must receive an amount of energy known as the work function of the material, to enable the electron to be emitted. One photon has to have greater energy than the work function for emission to occur. This would explain why increasing the intensity did not result in emission, which Julie predicted.

If the light photons were waves, then the electrons of the emitter would be subjected to a continuous supply of energy and eventually, if the intensity is increased, enough would be absorbed to cause emission at any frequency.

The fact that this does not happen means that these observations provide evidence for the particle nature of the light. Experiments show that light does exhibit wave behaviour and is described as having a dual nature.

Question 35

Criteria	Marks
• Outlines clearly the background to the experiment including Thomson's model • Provides details of results and Rutherford's model of the atom • Explains how the model relates to the results	6–7
• Outlines the background to the experiment, provides some details of results and model of the atom and explains how the model relates to the results	4–5
• Provides TWO of the following: the background to the experiment, the results, the new model of the atom	2–3
• Provides ONE of the following: the background to the experiment, the results, the new model of the atom	1

Sample answer: This experiment, eventually known as the Rutherford alpha particle scattering experiment, was done by two of Rutherford's postgraduate students – Geiger and Marsden. It had been shown that alpha particles were deflected when passing through very thin gold foil, and it was not understood how this occurred based on Thomson's the plum pudding model of the atom, a random arrangement of positive and negative charge. Rutherford expected that the alpha particles would pass through the gold foil with very small deflections from their path. Most of the alpha particles were observed to pass straight through the foil or to be scattered only one or two degrees by the foil. The surprising result was that a few alpha particles were observed to be scattered at larger angles and a very few were reflected almost straight back.

Rutherford proposed that the force causing the large deflections and repulsion of the positively charged alpha particles, could only be caused by a positively charged small object with concentrated mass in the centre of the gold atoms. He also proposed that this centre, called the nucleus, was surrounded by a much larger region of mainly empty space and circling electrons, too small to cause the occasional deflections of alpha particles. Rutherford's new model of the atom was able to explain the experimental results of the alpha particle scattering experiments.

NSW INDEPENDENT TRIAL EXAMS – 2022
PHYSICS – TRIAL HSC EXAMINATION
MAPPING GRID

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

NSW INDEPENDENT TRIAL EXAMS – 2022
PHYSICS – TRIAL HSC EXAMINATION
MAPPING GRID

Section II					
21(a)	2	5	Projectile Motion	12-6 12-12	2-3
21(b)	2	5	Projectile Motion	12-5, 12-6, 12-12	4-5
22	5	8	Deep Inside the Atom	12-7, 12-15	3-6
23	3	5	Motion in a Gravitational Field	12-3, 12-4, 12-12	3-5
24	4	5	Circular Motion	12-6, 12-12	3-5
25	5	7	Light and Special Relativity	12-7, 12-14	3-6
26(a)	3	5	Motion in a Gravitational Field	12-4, 12-12	2-4
26(b)	1	5	Motion in a Gravitational Field	12-7, 12-12	3-2
26(c)	2	5	Motion in a Gravitational Field	12-6, 12-12	4-5
27(a)	3	6	The Motor Effect Applications of the Motor Effect	12-6, 12-13	3-4
27(b)	3	6	Applications of the Motor Effect	12-7,12-13	3-5
28	5	6	Electromagnetic Induction	12-6, 12-7, 12-13	3-5
29	4	6	Charged Particles, Conductors and Electric and Magnetic Fields	12-5, 12-13	3-5
30	4	7	Light: Wave Model	12-7, 12-14	2-4
31	7	6	Electromagnetic Induction Applications of the Motor Effect	12-6, 12-7, 12-13	3-6
32(a)	4	7	Quantum Mechanical Nature of the Atom	12-7, 12-15	2-4
32(b)	3	7	Quantum Mechanical Nature of the Atom	12-6, 12-15	3-5
32(c)	2	7	Quantum Mechanical Nature of the Atom	12-7, 12-15	3-5
33	4	8	Deep inside the Atom	12-7, 12-15	4-5
34	7	7	Light: Quantum Model	12-6, 12-7, 12-14	3-6
35	7	8	Structure of the Atom	12-7, 12-15	2-4