



HSC Physics

Student Workbook

Student name: _____



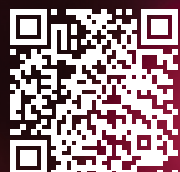


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- B Communication
- B Screen Media (Arts and Production)
- B Education (Primary)
- B Education (Secondary)
- B Arts
- B Arts (Interpreting and Translation)
- B Laws
- B Performing Arts (Acting)
- B Music
- B Design (Visual Communication)
- B Music
- B International Studies

YOU LOVE STUDIES OF RELIGION? *WHY NOT STUDY:*

- B Arts
- B Social Science
- B Education (Primary)
- B Education (Secondary)

YOU LOVE HISTORY? *WHY NOT STUDY:*

- B Arts
- B International Studies
- B Social Science
- B Education (Primary)
- B Education (Secondary)
- B Tourism and Event Management
- B Planning (Pathway to M Urban Management and Planning)

YOU LOVE VISUAL ARTS? *WHY NOT STUDY:*

- B Architectural Design
- B of Design
- B of Design and Technology
- B of Industrial Design (Honours)

YOU LOVE BUSINESS STUDIES? *WHY NOT STUDY:*

- B Business
- B Accounting
- B Education (Primary)
- B Education (Secondary)
- B Tourism and Event Management
- B Construction Management (Honours)

YOU LOVE LEGAL STUDIES? *WHY NOT STUDY:*

- B Criminology
- B Criminal and Community Justice
- B Cyber Security and Behaviour
- B Policing
- B Laws
- B Social Science
- B Humanitarian and Development Studies
- B Education (Primary)
- B Education (Secondary)
- B Construction Management (Honours)
- B Social Work
- B Youth Work

YOU LOVE COMMUNITY AND FAMILY STUDIES STUDIES? *WHY NOT STUDY:*

- B Arts
- B Criminology
- B Nursing
- B Midwifery
- B Psychology (Honours)
- B Psychological and Social Sciences
- B Social Science
- B Youth Work
- B Social Work
- B Humanitarian and Development Studies
- B Education (Early Childhood)
- B Education (Primary)
- B Education (Secondary)

YOU LOVE PHYSICS? *WHY NOT STUDY:*

- B Science
- B Education (Primary)
- B Education (Secondary)
- B Engineering
- B Architectural Design
- B Industrial Design (Honours)
- B Design and Technology

YOU LOVE CHEMISTRY? *WHY NOT STUDY:*

- B Science
- B Medical Science
- B Education (Primary)
- B Education (Secondary)

YOU LOVE HEALTH AND MOVEMENT SCIENCE? *WHY NOT STUDY:*

- B Health Science
- B Health, Physical Education and Sport
- B Exercise Physiology
- B Exercise Science
- B Sport and Performance Science
- B Occupational Therapy
- B Paramedicine
- B Physiotherapy
- B Podiatric Medicine
- B Speech Pathology
- B Traditional Chinese Medicine
- B Nursing
- B Midwifery
- B Education (Primary)

YOU LOVE MATHEMATICS? *WHY NOT STUDY:*

- B Computer Science
- B Data Science
- B Information and Communication Technology
- B Information Systems
- B Mathematics
- B Engineering
- B Education (Primary)
- B Education (Secondary)
- B Planning (Pathway to M Urban Management and Planning)
- B Accounting

YOU LOVE BIOLOGY? *WHY NOT STUDY:*

- B Health Science
- B Health, Physical Education and Sport
- B Occupational Therapy
- B Paramedicine
- B Physiotherapy
- B Podiatric Medicine
- B Speech Pathology
- B Sport and Performance Science
- B Traditional Chinese Medicine
- B Science
- B Medical Science
- B Nursing
- B Midwifery
- B Education (Primary)
- B Education (Secondary)
- B Clinical Science/Doctor of Medicine

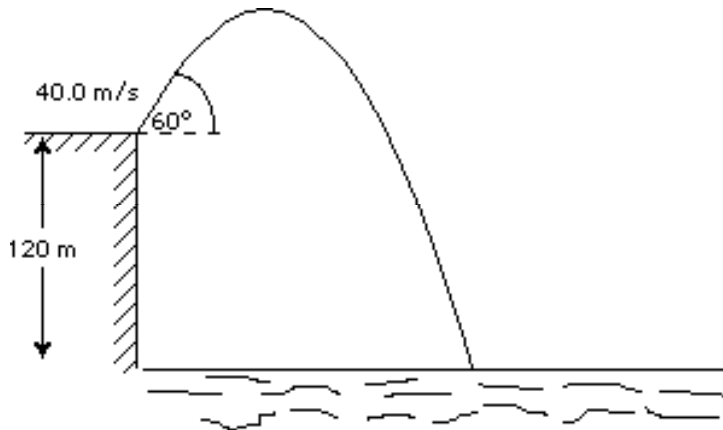
At Western, we have a wealth of support services to help you navigate your university journey:

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- Members of the ADF – Student Veteran Program
 - Elite athletes and performers support
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Module 5 - Advanced Mechanics

As shown in the diagram below, an object is projected off the top of a 120 m high ocean cliff, with a velocity of 40.0 m s^{-1} , at an angle of 60° above the horizontal.



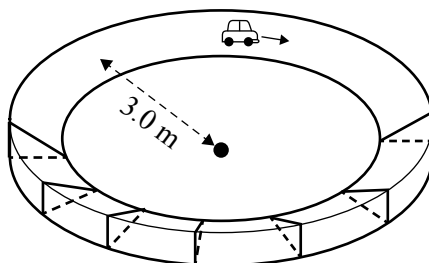
- What will be the maximum height reached above sea level?
- How long will the object be in the air?
- How far from the base of the cliff will the object land?
- What will be its velocity as it enters the sea?

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Question 2

A model car of mass 2.0 kg is placed on a banked circular track. The car follows a path of radius 3.0 m . The motor maintains it at a constant speed of 2.0 m s^{-1} .

The angle of bank is such that there are no sideways frictional forces between the wheels and the track.



- Draw a diagram showing all the forces acting on the car using solid lines and label each force. Show the resultant force as a dotted line, labelled F_R .
- Calculate the required angle of bank of the track, in degrees, to maintain the 2.0 kg car at 3.0 m s^{-1} on the 3.0 m circular path with no sideways friction between the wheels and the track. Show your working.

[illegible]

Question 3

Discuss the importance of Newton's Law of Universal Gravitation in understanding and calculating the motion of satellites.

This image shows a single page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Question 4

Ganymede is the largest of the moons of Jupiter, orbiting at a distance of 1.07 million km from the centre of Jupiter, in an orbit with a period of 7 days and 3 hours. It has a mass of 1.48×10^{23} kg and a diameter of 5268 km.

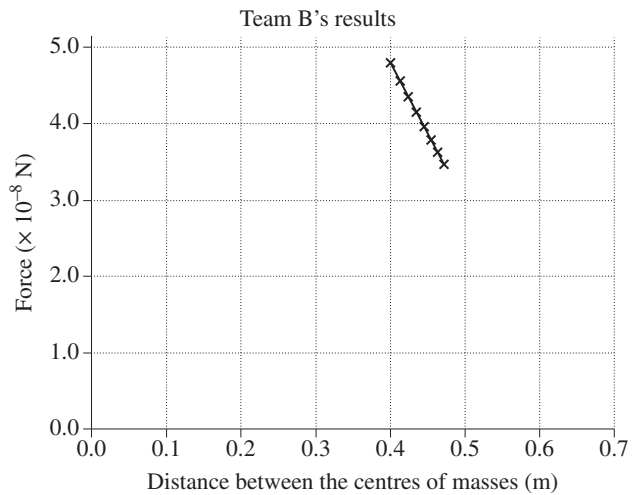
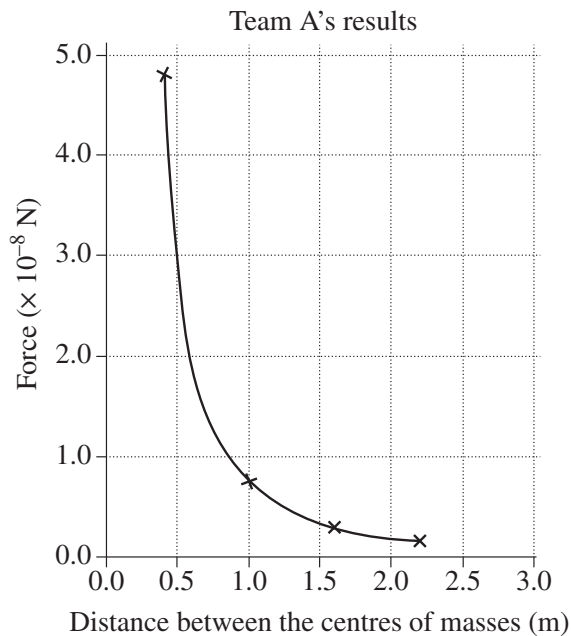
- What is the orbital velocity of Ganymede?
- Make use of the data provided to determine the mass of Jupiter.
- What would be the surface gravity on Ganymede?

[illegible]

Question 5

Two teams carried out independent experiments with the purpose of investigating Newton's Law of Universal Gravitation. Each team used the same procedure to accurately measure the gravitational force acting between two spherical masses over a range of distances.

The following graphs show the data collected by each team.



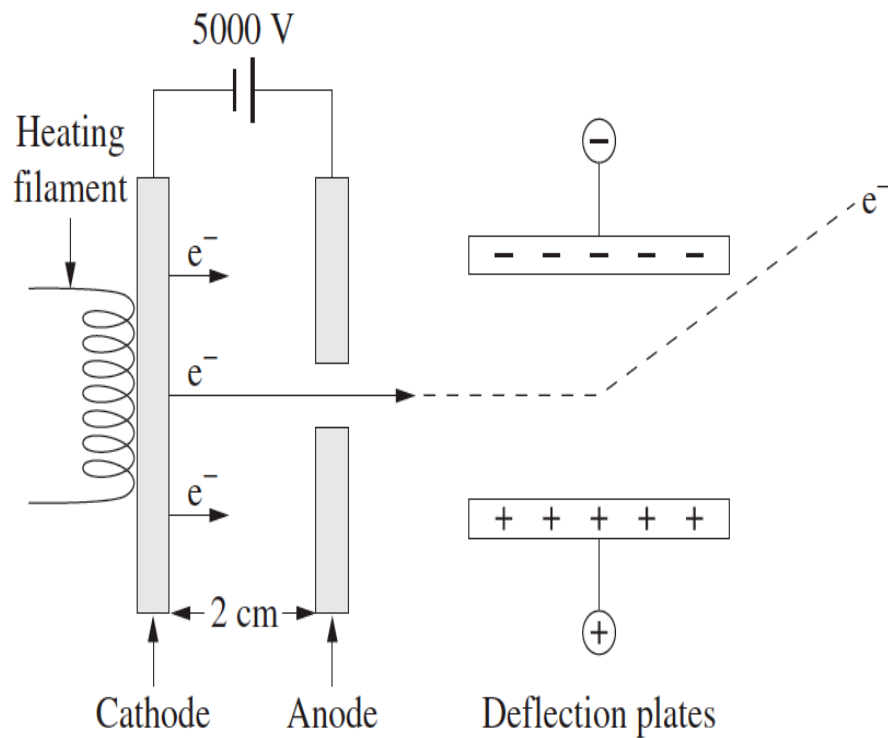
- Compare qualitatively the relationship between force and distance in the graphs.
- Assess the appropriateness of Team A's data and Team B's data in achieving the purpose of the experiments.

This image shows a full page of primary-ruled paper. It contains ten identical sets of horizontal lines arranged vertically. Each set includes three lines: a solid top line, a dashed midline, and a solid bottom line, providing a guide for letter height and placement. The entire page is white with no other markings or text.

Module 6 - Electromagnetism

Question 6

A part of a cathode ray oscilloscope was represented on a website as shown.



Electrons leave the cathode and are accelerated towards the anode.

Explain why the representation of the path of the electron between the deflection plates is inaccurate.

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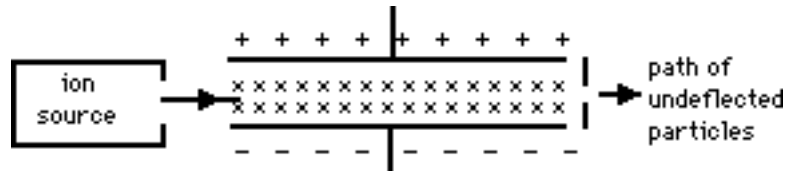
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Question 7

A velocity gate for charged particles can be made by allowing a stream of charged particles to pass through an area where an electric field is crossed (i.e. perpendicular) to a magnetic field, as shown.



- a) Show that the only particles that come through the crossed fields undeflected have a velocity given by: -

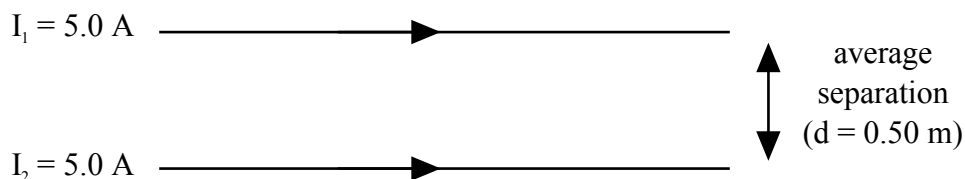
$$v = \frac{E}{B}$$

- b) The magnetic field is provided by a 2.0×10^{-3} T magnet. The plate separation is 5.0 cm. What voltage must be supplied to provide undeflected ions of velocity 2.5×10^7 m s⁻¹?
- c) What modifications (if any) would need to be made to the velocity gate to accommodate negative particles? Explain your answer.

This image shows a full page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page, typical of notebook or legal stationery. There are no margins, text, or other markings on the page.

Question 8

A physics student wanted to investigate the forces of attraction (F) between two parallel current-carrying conductors carrying currents I_1 and I_2 (also known as Ampere's Law) as shown by the diagram and equation below.



$$\text{Ampere's Law} - \frac{F}{l} = \frac{\mu_o}{2\pi} \frac{I_1 I_2}{r}$$

μ_o = magnetic permeability constant

l = common length of conductors

The student noticed that as the length (l) of the parallel conductors was increased the force of attraction (F) between the conductors also increased. Their data is shown in the table below.

<i>Length (m)</i>	<i>Force between conductors ($\times 10^{-6}$ N)</i>
1.00	9.0
1.20	10.8
1.40	12.5
1.60	14.2
1.80	16.2

- Plot the force and length values from the table and draw the line of best fit.
- Determine the slope of the line of best fit.
- Use the slope calculated in (b) above and the Ampere's Law equation to determine the experimental value of the magnetic permeability constant μ_o .

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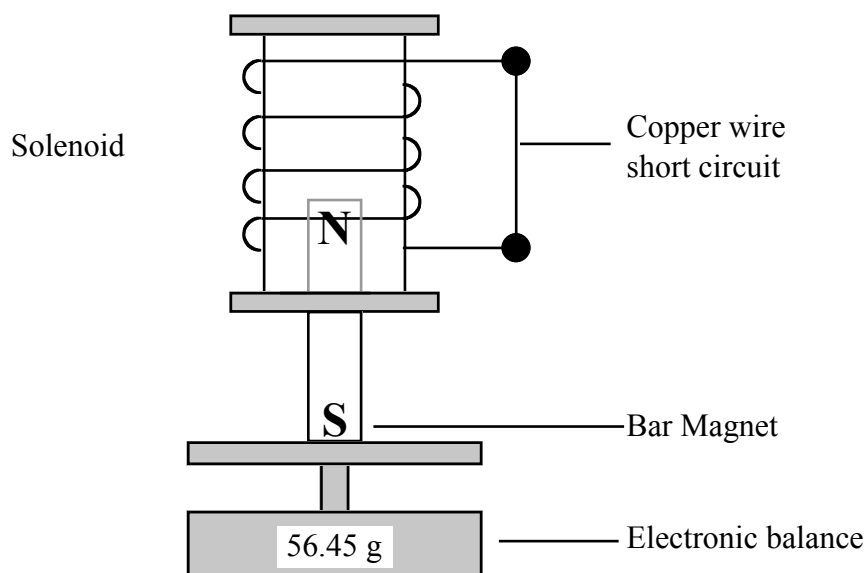
Question 9

- Draw a labelled diagram of a step down transformer showing all the essential features.
- Explain how two features of the transformer you have labelled decrease energy loss.

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Question 10

A bar magnet is placed on a sensitive electronic balance as shown in the diagram. A hollow solenoid is held stationary, such that the magnet is partly within the solenoid. The solenoid is then lifted straight up without touching the magnet. The reading on the balance is observed to change briefly.



- Why does a current flow in the solenoid?
- Explain the reason for changes in the reading of the electronic balance as the solenoid is removed.

[illegible]

Question 11

The photographs show the readings on a multimeter correctly attached to a DC electric motor while it is connected to an 4.0 V DC power supply. In one of the photos, the DC motor is being allowed to turn without any load being attached to it. In the other photo, the axle of the motor is being prevented from turning while it is still attached to the power supply.

Photo X



Photo Y



- Which of the photos shows the readings on the multimeter when there is no load being applied to the motor? Justify your answer.
- Calculate the resistance of the coils of the motor.
- Explain the difference in the readings shown on the multimeters in the photographs.
- Explain how this situation is related to the law of conservation of energy.

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Module 7 - The Nature of Light

Question 12

James Maxwell presented a paper outlining the nature of light.

- Describe the four pieces of evidence that Maxwell used in his work.
- How did he use these to unify electricity and magnetism?
- How was he able to predict the velocity of light?
- What was important about Maxwell's theory of light in relation to other forms of electromagnetic waves?

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Question 13

- Describe two historical methods used to determine the speed of light.
- Describe two contemporary methods used to determine the speed of light.
- How is the speed of light currently defined?

This image shows a full page of a worksheet designed for handwriting practice. It features 20 evenly spaced, horizontal dashed lines across the entire width of the page. The background is plain white, and there are no margins or additional markings present.

Question 14

The hydrogen_{beta} line in the spectrum of hydrogen occurs at a wavelength of 4.86×10^{-7} m. The light from a star in our galaxy was analysed and that particular line actually appeared at 4.83×10^{-7} m.

- Provide a reason why the hydrogen_{beta} line in the star's spectrum is not where it should be.
- Assuming Earth is stationary; determine the speed of the other star relative to Earth.

How can the light from a star give us information about its: -

- c) Rotational velocity
- d) Composition
- e) Density

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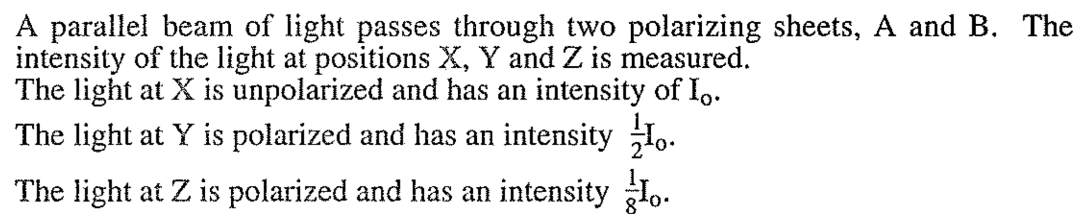
Question 15

Slits 0.100 mm apart are illuminated by light of wavelength 540 nm. An interference pattern is produced on a screen 130 cm away.

- What is the distance between the bright fringes?
- What is the angle made between the central bright fringe, the double slits and the 5th bright fringe to the right of the central maximum?
- A diffraction grating with 800 lines per millimetre is illuminated by light of 633 nm. How many maxima will be visible on a screen? Explain your answer.

[illegible]

Consider the following arrangement used in an experiment to investigate polarized light.



- (i) On the basis of the wave model of light, explain the terms *unpolarized* and *polarized*.
- (ii) Explain why the intensity of the light at position Y is less than that at position X.
- (iii) What is the angle between the polarizing directions of sheets A and B? Show your working.

This image shows a full page of white paper with horizontal dashed lines, typical of primary school handwriting practice paper. The lines are evenly spaced and run across the entire width of the page. There are no margins, text, or other markings present.

Question 17

Applying the law of conservation of energy, explain why $E_k = hf - \Phi$

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Question 18

Explain how the analysis of quantitative observations contributed to the development of the concept that certain matter and energy are quantised.

[illegible]

Module 8 - From the Universe to the Atom

Question 19

Provide a timeline that describes transformations of energy into matter during the first million years after the big bang.

[illegible]

Question 20

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- This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

“Top Ten” Physics Experiments

Cathode Ray tubes

Balmer – Hydrogen Spectrum

Thomson – Electrons

Millikan – Charge on Electron

Rutherford – Nucleus

Bohr – Electron shells

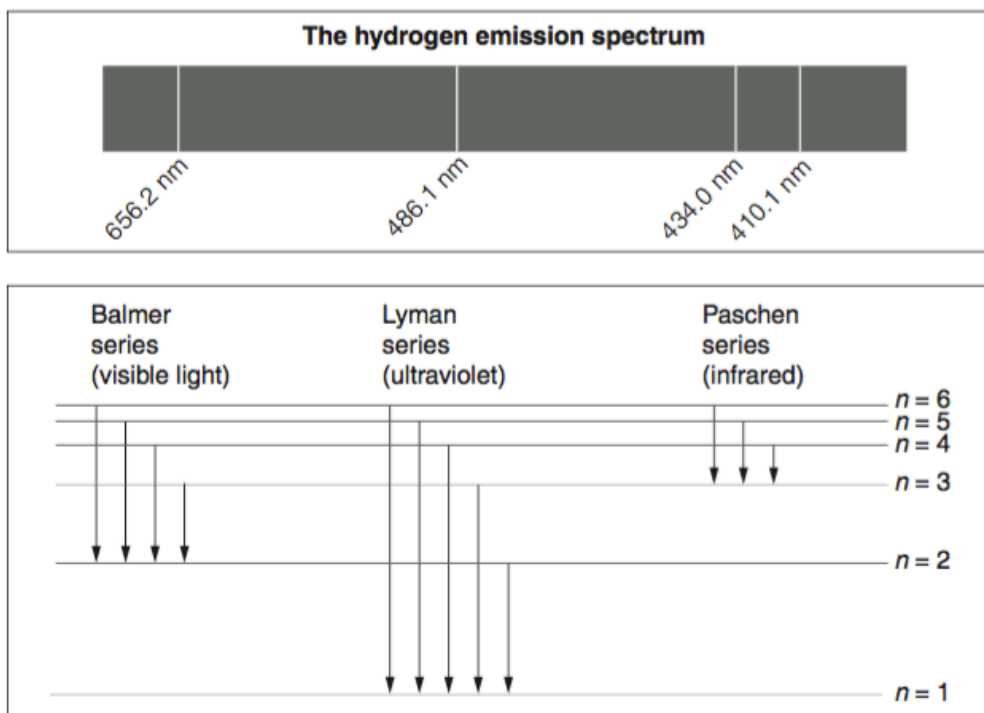
De Broglie – Electrons as waves

Schrödinger – Shapes of orbitals (and cat!)

Chadwick - Neutrons

Question 21

The diagrams show features of the hydrogen emission spectrum.

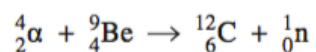


With reference to Bohr's postulates, explain how the line at 434.0 nm in the hydrogen emission spectrum is produced. Support your answer with calculations.

[illegible]

Question 22

The following is a nuclear reaction that produces a neutron.



The table shows the masses of the particles in the reaction.

<i>Particle</i>	<i>Mass (u)</i>
${}^4_2\alpha$	4.0012
${}^9_4\text{Be}$	9.0122
${}^{12}_6\text{C}$	12.0000
${}^1_0\text{n}$	1.0087

Using the data from the table, calculate the energy released in this reaction. State your answer in joules.

[illegible]

Question 23

Using the standard model, analyse the roles of both forces and particles in the current understanding of the atom.

This image shows a single page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Sample Answers

Question 1

- a) Vertically $u = 40\sin 60 \text{ m s}^{-1}$, $a = -9.8 \text{ m s}^{-2}$, $v = 0 \text{ m s}^{-1}$, $s = ?$

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

$$\therefore s = \frac{v^2 - u^2}{2a} = \frac{(0 \text{ m s}^{-1})^2 - (40.0\sin 60 \text{ m s}^{-1})^2}{2 \times -9.8 \text{ m s}^{-2}} = 61 \text{ m}$$

So, height above sea level = $120 \text{ m} + 61 \text{ m} = 180 \text{ m}$

- b) Vertically when object hits surface of sea

$$u = 40\sin 60 \text{ m s}^{-1}, a = -9.8 \text{ m s}^{-2}, s = -120 \text{ m}, t = ?$$

$$\therefore -120 = 40.0\sin 60t - 4.9t^2$$

$$\text{i.e. } -4.9t^2 + 40.0\sin 60t + 120 = 0$$

$$\therefore t = \frac{-40.0\sin 60 \pm \sqrt{(40.0\sin 60)^2 - 4 \times -4.9 \times 120}}{-9.8}$$

$t = 9.6 \text{ s}$ (other answer is -2.6 s).

- c) Horizontally $V_{av} = 40.0\cos 60 \text{ m s}^{-1}$, $t = 9.6 \text{ s}$, $s = ?$

$$V_{av} = \frac{s}{t} \quad \therefore s = V_{av} \times t = 40.0\cos 60 \text{ m s}^{-1} \times 9.6 \text{ s} = 190 \text{ m}$$

- d) Vertically $u = 40.0\sin 60 \text{ m s}^{-1}$, $a = -9.8 \text{ m s}^{-2}$, $s = -120 \text{ m}$, $v = ?$

$$v^2 = u^2 + 2as \quad \therefore v = \pm\sqrt{u^2 + 2as} = \pm\sqrt{(40.0\sin 60)^2 + 2 \times -9.8 \times -120} = \pm 60 \text{ m s}^{-1}$$

Must be -60 m s^{-1} , as heading vertically down when enters sea.

$$\text{Horizontally } V_{av} = 40.0\cos 60 \text{ m s}^{-1}$$

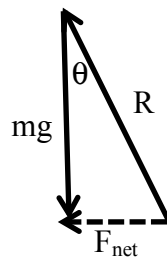
Velocity on entering sea

$$V = \sqrt{(-60)^2 + (40.0\cos 60)^2} = 63 \text{ m s}^{-1}$$

$$\tan \theta = \frac{60}{40.0\cos 60} \quad \therefore \theta = 72^\circ \quad \text{Object enters sea at } 63 \text{ m s}^{-1} \text{ at } 72^\circ \text{ below horizontal.}$$

Question 2

a)



b) For no friction, all F_{net} is resultant of normal reaction force and gravity.

F_{net} is the centripetal force moving car in circular path. $F_{\text{net}} = \frac{mv^2}{r}$

$$\tan \theta = \frac{F_{\text{net}}}{mg} = \frac{\frac{mv^2}{r}}{mg} = \frac{v^2}{rg} = \frac{(3.0 \text{ m s}^{-1})^2}{3.0 \text{ m} \times 9.8 \text{ m s}^{-2}} = 0.31 \quad \therefore \theta = 17^\circ$$

Question 3

For a satellite of mass m , exhibiting (almost) uniform circular motion, $F_c = \frac{mv^2}{r}$.

For the satellite, this force is provided by the gravitational field of the planet of mass M .

$$\therefore \frac{mv^2}{r} = \frac{GmM}{r^2} \quad \text{From this result, the orbital velocity can be calculated. } v = \sqrt{\frac{GM}{r}}$$

Also, since $v = \frac{2\pi r}{T}$, this value can be substituted into the equivalence between centripetal and gravitational force.

$$\therefore \frac{m \left(\frac{2\pi r}{T} \right)^2}{r} = \frac{GmM}{r^2}. \text{ This can be rearranged to give } \frac{r^3}{T^2} = \frac{GM}{4\pi^2} \text{ which is Kepler's Law.}$$

Hence, Newton's law of universal gravitation can be used to provide valuable information about the motion of satellites, including the orbital velocity, period and radius of their orbits.

Note: - this is the answer to a 4 mark question. If more marks given, could elaborate on answer to include escape velocity, gravitational potential energy, etc.

Question 4

- a) $v = \frac{2\pi r}{T} = \frac{2\pi \times 1.07 \times 10^9 \text{ m}}{171 \times 3600 \text{ s}} = 10900 \text{ m s}^{-1}$
- b) $v = \sqrt{\frac{GM}{r}} \quad \therefore M = \frac{v^2 r}{G} = \frac{(10921 \text{ m s}^{-1})^2 \times 1.07 \times 10^9 \text{ m}}{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}} = 1.91 \times 10^{27} \text{ kg}$
- c) $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 1.48 \times 10^{23} \text{ kg}}{(2.634 \times 10^6 \text{ m})^2} = 1.42 \text{ m s}^{-2}$

Question 5

- (a) Both graphs show that as distance increases, the force decreases. However, in Team A's graph, the force between the masses decreases at a decreasing rate, whereas in Team B's graph, the force decreases at a constant rate.
- (b) Team A's data set has a good range but too few measurements for a valid relationship to be deduced.
Team B's data set has sufficient measurements but over an insufficient range of distances for a valid relationship to be deduced.

Question 6

The path of the electron beam is inaccurate for two reasons. Electrons are negatively charged and so should experience a force of attraction toward the positive plate, NOT the negative plate as shown in the diagram. In addition, the force on the electron will be constantly vertically downward. This will cause the electron to follow a parabolic path toward the positive plate and not the two straight line segments shown

Question 7

- a) To pass through the crossed fields undeflected, the net force acting on the charged particles must be zero. Hence, the force due to the electric field must be equal in magnitude but opposite in direction to the force due to the magnetic field.

$$\text{I.e. } \Sigma F = ma = 0 = F_{\text{electric}} - F_{\text{magnetic}}$$

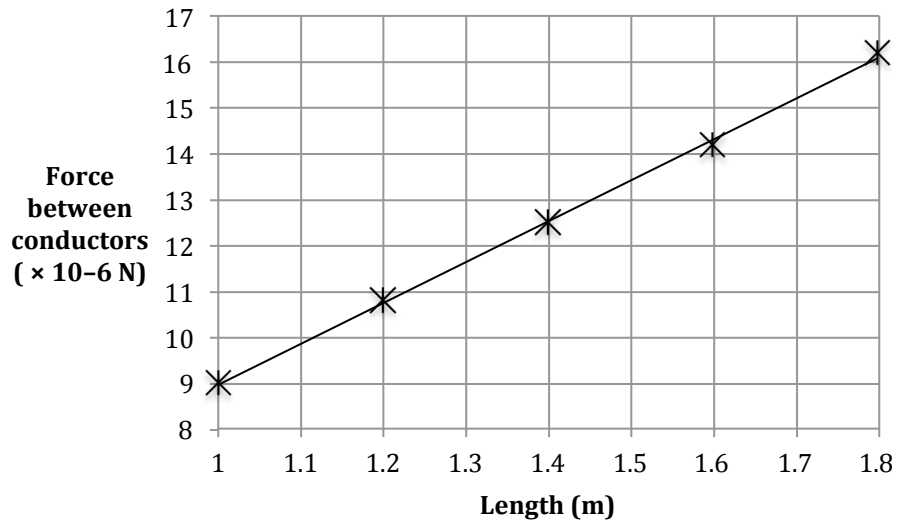
$$\therefore F_{\text{electric}} = F_{\text{magnetic}} \quad \therefore qE = qvB \quad \therefore v = \frac{E}{B}$$

- b) Since $v = \frac{E}{B} = \frac{V}{Bd}$ $\therefore V = Bdv = 2.0 \times 10^{-3} \times 0.050 \times 2.5 \times 10^7 = 2500 \text{ V}$

- c) The velocity of undeflected particles does not depend on either the magnitude OR the sign of the charge. Hence, no modification would need to be made.

Question 8

a)



- b) From graph, LOBF appears to go through two of the data points. Will use them to determine gradient. Graph could also be extrapolated to go through (0,0).

$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{(12.5 \times 10^{-6} - 9.0 \times 10^{-6}) \text{ N}}{(1.40 - 1.00) \text{ m}} = 8.8 \times 10^{-6} \text{ N m}^{-1}$$

- c) From Ampere's law, $\therefore F = \left(\frac{\mu_0 I_1 I_2}{2\pi r} \right) l$ Hence, graph plotted above is of the form

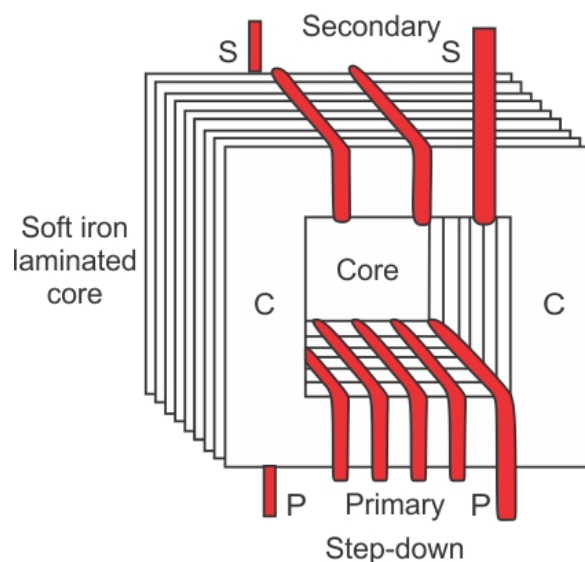
$$F = ml. \text{ Gradient of graph is } \frac{\mu_0 I_1 I_2}{2\pi r} = 8.8 \times 10^{-6} \text{ N m}^{-1}$$

$$\therefore \mu_0 = \frac{2\pi r \times 8.8 \times 10^{-6} \text{ N m}^{-1}}{I_1 I_2} = \frac{2\pi \times 0.50 \text{ m} \times 8.8 \times 10^{-6} \text{ N m}^{-1}}{5.0 \text{ A} \times 5.0 \text{ A}} = 1.1 \times 10^{-6} \text{ N A}^{-2}$$

$$\text{Actual value is } 4\pi \times 10^{-7} \text{ N A}^{-2} = 1.3 \times 10^{-6} \text{ N A}^{-2}$$

Question 9

a)



- b) To try to achieve complete flux linkage between the primary and secondary coil so minimal energy is lost, the coils are placed in close proximity to each other and a soft iron core is used for maximum flux linkage. However, using a solid iron core would mean that eddy currents of considerable magnitude would be induced in it as it is a conductor in a changing magnetic field. To limit the production of induced eddy currents in the iron core, it is constructed from many very thin laminations that are electrically insulated from each other. The very thin nature of each soft iron lamination prevents large eddy currents from forming but still allows the magnetic effect of the soft iron core to maximise flux linkage between the coils.

Question 10

- a) As the solenoid is lifted, it is moving relative to the magnetic field of the bar magnet and so its coils are cutting through lines of flux. An emf will be induced across the solenoid (Faraday's Law). Since the ends of the solenoid are connected by the copper wire short circuit, a current will flow in the solenoid.
- b) The direction of the current induced in the solenoid will be such that a magnetic field will be produced that attempts to oppose the motion producing the emf initially. I.e., a south pole will be induced at the lower end of the solenoid. This will apply a force upward on the bar magnet, reducing the reading on the balance as the net force is reduced. If the solenoid is totally removed, no upward magnetic force will be acting on the bar magnet and so the balance will return to the reading of 56.45 g.

Question 11

- a) Photo X shows the current drawn by the motor when no load is placed on it. As the coil of the motor turns in the magnetic field it is inducing a back emf across the turns of the motor coil, reducing the net voltage across the coils. Hence, for the fixed resistance of the coil, there is less overall current running through it.
- b) Using the data from photo Y, $V = IR \quad \therefore I = \frac{V}{R} = \frac{4.0 \text{ V}}{4.17 \text{ V A}^{-1}} = 0.96 \text{ A}$
- c) When the coil is prevented from turning, no back emf is induced and so the full 4.0 V of the supply emf is across the resistance of the coil, increasing the current drawn, so a higher reading is shown than when there is no load on the motor.
- d) If the emf induced in the coil had been in the same direction as the supply emf, then the net voltage across the coil would have been higher than 4.17 V. Hence, a larger current than 0.96 A would have flowed. This would increase the torque of the motor, causing it to spin faster. This would have induced a larger emf again, increasing the current, etc. So, the motor would gain more and more mechanical energy without any further input of electrical energy. This violates the principle of conservation of energy, which states that energy cannot be created or destroyed, but can be converted from one form into another.

Question 12

- a) *Gauss's Law of electricity* The amount of electric flux through a Gaussian surface depends on the charge inside the Gaussian surface.

Gauss's Law of magnetism The net magnetic flux through a Gaussian surface is zero.

Faraday's Law of induction Showed the relationship between a changing magnetic field and the production of electric fields.

Ampere's Circuital Law The magnetic field around a conductor is related to the magnitude of the current flowing in the conductor.

- b) Maxwell developed four equations based on the work of the physicists above that mathematically described their work. In his work he was able to show that the speed of light depended on the permittivity of free space and the permeability of free space (constants that are associated with electric and magnetic fields).

$$c^2 = \frac{1}{\mu_0 \epsilon_0} \quad \therefore c = \sqrt{\frac{1}{\mu_0 \epsilon_0}} = \sqrt{\frac{1}{4\pi \times 10^{-7} \times 8.854 \times 10^{-12}}} = 2.998 \times 10^8 \text{ m s}^{-1}$$

- d) Maxwell's equations did not limit the frequencies of the radiation to just those of the visible light spectrum. This implied that theoretically, EMW could exist beyond the frequencies of visible light, leading the way to subsequent discoveries of other types of EMW.

Question 13

- a) Many to choose from - make sure that your answer has as much detail as you can put in. Below are some brief (not full) descriptions of some of the methods used. You should know at least two of them in significant detail, including reasons why they may not have been an accurate method and approximate value for speed of light obtained.

Galileo 1638 - uncovering lights to measure time interval for light to travel to a distant observer and back.

Romer - observations of Jupiter's moon Io moving into and out of eclipse. Time difference due to light crossing Earth's orbit meant observation of eclipses happening at different to predicted time allowed speed of light to be estimated.

Fizeau 1849 - toothed cog rotating rapidly, blocking path of light.

Focault 1862 - rotating mirror (also allowed speed of light in other substances to be measured).

- b) Need to be able to give a detailed description of: -

Resonant Cavity method (knowing exact frequency of waves that set up a standing wave pattern in a box of very accurately measured length) - distance between nodes can be measured, hence wavelength known. Allows speed of light to be determined.

Interferometry Splitting a beam of known frequency into two perpendicular paths, then adjusting path lengths to determine path difference using interference of recombined beams allows wavelength to be accurately measured, allowing speed of light to be calculated.

- c) The speed of light is defined in terms of the metre. A metre is defined to be the distance that light travels in $\frac{1}{299792458}$ s.

$$\text{Hence, the speed of light is defined as } c = \frac{s}{t} = \frac{1 \text{ m}}{\frac{1}{299792458} \text{ s}} = 299792458 \text{ m s}^{-1}$$

NESA rounds this to $3.00 \times 10^8 \text{ m s}^{-1}$ (3 sig figs) on the data sheet.

Question 14

- a) The H_β line is appearing at a shorter wavelength (higher frequency) than it ordinarily would. This means that it has been blue-shifted (toward the blue end of the spectrum) and is most likely caused by the star moving toward Earth.

b) $v = f\lambda \quad \therefore f = \frac{v}{\lambda} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{4.86 \times 10^{-7} \text{ m}} = 6.17 \times 10^{14} \text{ Hz}$

$$f' = \frac{v}{\lambda} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{4.83 \times 10^{-7} \text{ m}} = 6.21 \times 10^{14} \text{ Hz} \quad f' = f \left(\frac{v_{\text{wave}} + v_{\text{observer}}}{v_{\text{wave}} - v_{\text{source}}} \right)$$

$$\therefore 6.21 \times 10^{14} = 6.17 \times 10^{14} \left(\frac{c + 0}{c - v_{\text{source}}} \right) \quad \therefore \frac{6.21}{6.17} = \frac{c}{c - v}$$

$$\therefore v = c - \frac{6.17}{6.21}c = 1.93 \times 10^6 \text{ m s}^{-1} \text{ toward Earth}$$

- c) As a star rotates, light being emitted from the edges of the star (as viewed from Earth) is either red-shifted (from the receding side) or blue-shifted (from the approaching side). This causes spectral lines in the spectrum to become broader. Analysis of the amount of broadening can provide the rotational speed of the star.
- d) As light from the star passes through the atmosphere of the star, elements in the atmosphere absorb at their characteristic wavelengths. Analysis of the absorption spectrum received from the star will indicate the elements present in the atmosphere of the star, and hence the composition of the star. The intensity of absorption will be proportional to the amount of each element present and so the relative abundance of elements in the star can also be determined.
- e) Lower density stars allow light to travel further before being absorbed by atoms/ions in the star. Hence, absorption spectral lines of less dense stars tend to be sharper than absorption lines in denser stars.

Question 15

a) $d = 1.00 \times 10^{-4} \text{ m}$, $L = 1.30 \text{ m}$, $\lambda = 540 \times 10^{-9} \text{ m}$, $X = ?$

$$m\lambda = d \frac{X}{L} \quad \therefore X = \frac{m\lambda L}{d} = \frac{1 \times 540 \times 10^{-9} \text{ m} \times 1.30 \text{ m}}{1.00 \times 10^{-4} \text{ m}} = 7.02 \times 10^{-3} \text{ m} \quad (7.02 \text{ mm})$$

b) $m\lambda = d \sin \theta \quad \therefore \sin \theta = \frac{m\lambda}{d} = \frac{5 \times 540 \times 10^{-9} \text{ m}}{1.00 \times 10^{-4} \text{ m}} = 0.0270 \quad \therefore \theta = 1.55^\circ$

- c) Maxima that are diffracted by more than 90° will not be visible. Hence, will find what order maximum will produce diffraction of 90° .

$$m\lambda = d \sin \theta \quad \therefore m = \frac{d \sin \theta}{\lambda} = \frac{1.00 \times 10^{-3} \text{ m}}{633 \times 10^{-9} \text{ m}} \times \sin 90^\circ = 1.97$$

Hence, only the central maximum ($m = 0$) and the first order maxima ($m = \pm 1$) will be visible. Just missed on seeing the second order maxima. A total of 3 maxima are visible.

Question 16

- (i) Unpolarised light has the electric fields of the light vibrating in all possible planes.
Polarised light means that the all the electric fields of the light are vibrating in the same plane.
- (ii) When the unpolarised light passes through the polarising sheet only the component of the electric fields that are parallel to the characteristic direction of the sheet will be transmitted, while the component perpendicular to the characteristic direction will not be transmitted. Hence, the intensity at Y will be half the intensity at X.
- (iii) $I = I_0 \cos^2 \theta$ (Malus' Law)

Now $I_Y = \frac{1}{2} I_0$, and $I_Z = \frac{1}{8} I_0$

$$\frac{1}{8} I_0 = \frac{1}{2} I_0 \cos^2 \theta$$

$$\cos^2 \theta = \frac{1}{4} \quad \text{so } \theta = 60^\circ$$

I.e. the angle between sheets A and B is 60°

Question 17

The law of conservation of energy states that energy cannot be created or destroyed. It is transferred or transformed. The initial energy of a photon of light is hf . If this photon hits a metal surface, the energy is passed onto an electron, which can be released from the metal surface. For the electron to be released, it will possess kinetic energy (E_k) and some energy to remove the electron from the metal surface (the work function of Φ). Therefore, $hf = E_k + \Phi$ which is $E_k = hf - \Phi$.

Question 18

Experiments such as the ones testing the photoelectric effect and Millikan's measurement of the fundamental unit of charge have demonstrated that certain quantities measured in physics are quantised. That is, they only appear as exact multiples of some fundamental value, or quantum.

Millikan found that the value of the charge on an oil drop was an integer multiple of 1.6×10^{-19} C, and so he concluded that this was the charge on a single electron. In this situation, quantisation was expected since the electron had been determined to be a particle. However, this result provided critical experimental evidence. This, combined with the Thomson experiment, which determined the charge to mass ratio, allowed for the mass of an electron to be determined. Thus the quantum of mass of an electron was shown through quantitative observations.

The discovery of quantisation of light, and hence energy in the form of electromagnetic radiation, as shown in the photoelectric effect experiments, was much more surprising. The understanding that light was a wave was well supported by experimental evidence, and so it was not expected that the energy would be divided into discrete packets. However, when experiments showed that there was a minimum frequency of light that would produce a photocurrent and that the amount or intensity of light did not affect the ability of electrons to be removed from a metal surface, it was explained by one electron receiving one photon or quantum of energy specific to the frequency of that light ($E = hf$). If a photon did not have enough energy, an electron could not be removed. This could only be adequately explained by a quantum model. In this case, experimental evidence generated a change in physicists' concept of energy, requiring a broader understanding of quantisation in physical processes.

Answers could include:

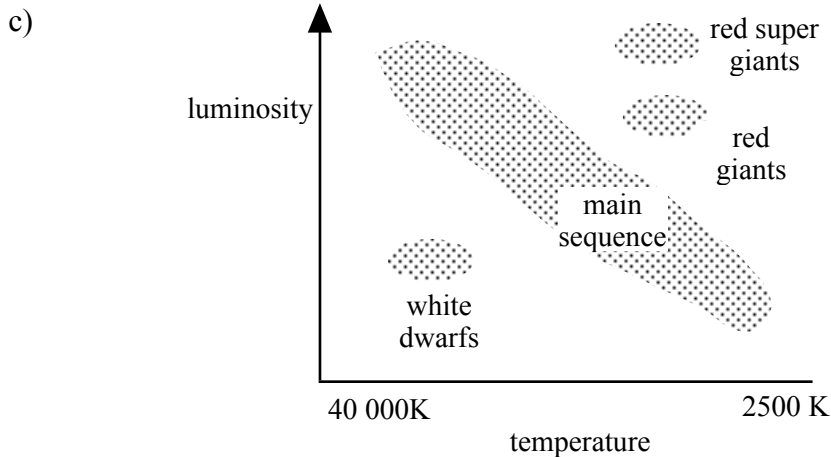
- spectroscopy and the existence of fixed energy levels in the atom
- cathode ray experiments showing the particle nature of the electron
- radioactivity experiments
- scintillation experiments
- blackbody radiation experiments.

Question 19

Age of Universe	Temperature (K)	What's Happening?
0	?	• ?
10^{-43} s	10^{32}	- Beginning of space and time - Universe smaller than a proton - Energy only present
10^{-34} s	10^{27}	- Universe size of pea (Huge inflation in size) - Much of the energy had been converted to fundamental particles such as quarks and electrons ($E=mc^2$)
10^{-15} s	10^{15}	- Four fundamental forces of the universe (gravitational, electromagnetic, SNF, WNF) become decoupled from the Grand Unified Theory (GUT) force. - Matter in universe composed of quark gas or plasma.
10^{-6} s	10^{13}	- Temperature low enough for quarks and antiquarks to combine to form protons and antiprotons. - Slightly high proportion of protons over antiprotons creates a universe with matter instead of antimatter. Matter/antimatter annihilation releases much energy into expanding universe. (1 000 000 001 protons to 1 000 000 000 antiprotons)
10^{-4} s		- neutrons formed by beta(+) decay of protons - Universe consists of protons, neutrons, electrons, neutrinos and a lot of energy, that can't travel very far without hitting matter.
10^{-2} s		Universe now size of solar system
1 s	10^{10}	- Universe 1 - 10 light years across (expands faster than the speed of light during the "superinflationary stage") - Density 10 kg cm^{-3} 82% protons. 18% neutrons (ratio slowly increased as universe ages)
3 s	5.9×10^9	electron - positron annihilation occurs, leaving slight excess of electrons
3.2 min	3×10^9	Fusion between protons and neutrons begins, forming nuclei of deuterium, tritium, helium and lithium
13 min		- Fusion stops - Universe is dark, as matter density is too high for radiation to travel far. and no stars exist yet
380 000 years	3000 K	electrons captured by atoms, allowing radiation to pass through, universe becomes transparent.

Question 20

- a) The HR diagram is a graph of a star's luminosity (on the vertical axis) against its temperature (or colour, or spectral type) on the horizontal axis.
- b) The axes are not linear. The vertical axis has equal spacings corresponding by an increase in luminosity of a factor of 10. The horizontal axis starts at the right hand side, at about 2500 K, and extends to the left, at about 40 000K. Each equal spacing on the horizontal axes represents an approximate doubling of temperature.



- d) For main sequence stars, the more massive the star, the more energy it produces, and so the hotter it is, and so the more luminous. Hence, for the main sequence, small, cool stars are at the lower right, while large, hot stars are at the upper left.

However, a group of stars was discovered that were red in colour, indicating a relatively low surface temperature. However, these stars were very luminous, indicating they were giving out a lot of energy. The only way this could happen was if the stars were very big. These are the red giants and supergiants.

Another group of stars were white, indicating high surface temperatures, but they were not very luminous. Hence, they must be quite small. These are called white dwarfs.

Question 21

Bohr's postulates state that an electron orbits in fixed energy levels. Only when an electron jumps from a higher energy level to a lower energy level, it emits an exact amount of energy in the form of a photon. The specific wavelength of the photon can be determined according to the Rydberg equation. The blue light is part of the visible Balmer series and therefore $n_f = 2$.

The wavelength in this case is 434.0 nm. According to the equation, this corresponds to a jump from the 5th energy level to the 2nd energy level.

For Balmer series $n_f = 2$

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

$$n_i^2 = \frac{1}{\left(\frac{1}{4} - \frac{1}{1.097 \times 10^7 \times 434 \times 10^9} \right)}$$

$$n_i = 5$$

Answers could include:

Taking clues from the diagram of the Balmer series, student could put $n_f = 2$ and $n_i = 5$ into the equation to obtain $\lambda = 434.0$ nm.

Question 22

$$\text{Initial mass} = 4.0012 + 9.0122 = 13.0134u$$

$$\text{Final mass} = 12.000 + 1.0087 = 13.0087u$$

$$\text{Mass difference} = 13.0087 - 13.0134 = -0.0047u$$

$$\text{Mass in kg} = 0.0047 \times 1.661 \times 10^{-27} = 7.8067 \times 10^{-30} \text{ kg}$$

$$E = mc^2 = 7.8067 \times 10^{-30} \times (3.00 \times 10^8)^2 = 7.0 \times 10^{-13} \text{ J}$$

Question 23

In the standard model, fundamental particles – quarks and leptons – interact through four fundamental forces. The constituents of protons and neutrons are three quarks. The strong force holds nucleons together in the nucleus, overcoming the electrostatic repulsion between protons. An electron is a lepton, which has no constituents. The force of gravity attracts protons and neutrons within the nucleus but this force is negligible.

The electrostatic force results in a mutual repulsion of protons and an attraction for the electrons toward the nucleus. Electrons orbit the nucleus. The strong nuclear force counteracts the electrostatic force, but only within a limited range of subatomic distances. The weak force is involved in the process of radioactive decay.

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