2026 **ANDRE TUTORING SAMPLE PAPER**

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Calculators approved by NESA may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2–7)

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

Section II – 80 marks (pages 9–36)

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

Section I

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

Use the multiple-choice answer sheet for Questions 1–10.

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1 According to the Standard Model of particle physics, what is the fundamental composition of an antiproton structure?

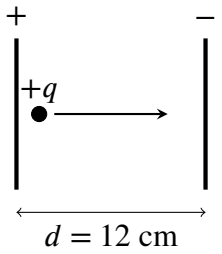
A. Two up quarks and one down quark.

B. Two down quarks and one up quark.

C. Two antiup quarks and one antidown quark.

D. Two antidown quarks and one antiup quark.

2 An isolated test charge of $+3.0\times10^{-6}$ C is positioned at rest inside a uniform vertical electric field established between two parallel plates spaced 12 cm apart.



If the electric field strength is $E = 4.0\times10^{3}$ V m^{-1}, what is the total work done by the field on this charge when it travels halfway across the gap?

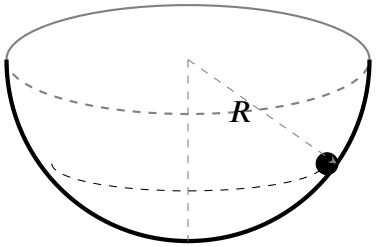
A. 7.2×10^{-4} J

B. 1.4×10^{-3} J

C. 2.8×10^{-3} J

D. 5.8×10^{-2} J

3 A small ball executes constant speed horizontal circular motion inside a smooth, frictionless hemispherical bowl of radius $R = 0.80$ m.



Which vector diagram correctly depicts the net force F_{net} and its contributing forces acting on the ball?

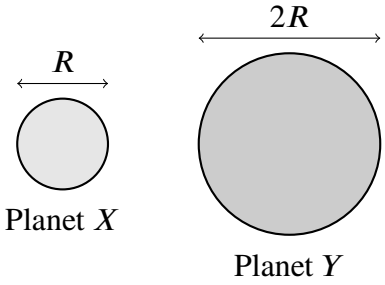
A. Normal force acts horizontally, weight acts down, F_{net} acts up the bowl surface.

B. Normal force acts perpendicular to the bowl surface, weight acts down, F_{net} acts horizontally toward the center.

C. Normal force acts up the bowl surface, weight acts down, F_{net} acts vertically up.

D. Normal force acts vertically up, weight acts down, F_{net} acts tangent to the circle path.

4 Two planets, X and Y, have identical masses, but the radius of planet Y is twice that of X.



What is the escape velocity from the surface of planet Y if the escape velocity from planet X is v_{esc}?

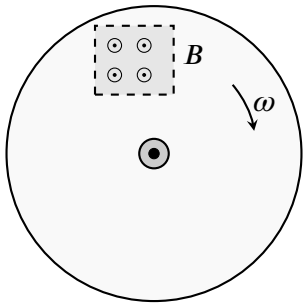
A. $\frac{1}{2}v_{\text{esc}}$

B. $\frac{1}{\sqrt{2}}v_{\text{esc}}$

C. $\sqrt{2}v_{\text{esc}}$

D. $2v_{\text{esc}}$

5 A large copper disk rotates clockwise at a high constant frequency. A uniform magnetic field directed out of the page passes through a small region near the upper edge of the disk, as shown below.



Copper Disk

As the disk rotates through this magnetic field region, what occurs inside the copper material?

A. Eddy currents form primarily at the entering and exiting borders of the field region, creating an electromagnetic braking torque that slows the disk down.

B. Eddy currents form uniformly only at the center of the field region, creating an electromagnetic braking torque that slows the disk down.

C. Eddy currents form primarily at the entering and exiting borders of the field region, creating a driving magnetic force that speeds the disk up.

D. Eddy currents form uniformly only at the center of the field region, creating a driving magnetic force that speeds the disk up.

6 Which historical experiment provided the first concrete evidence validating the matter-wave hypothesis formulated by Louis de Broglie?

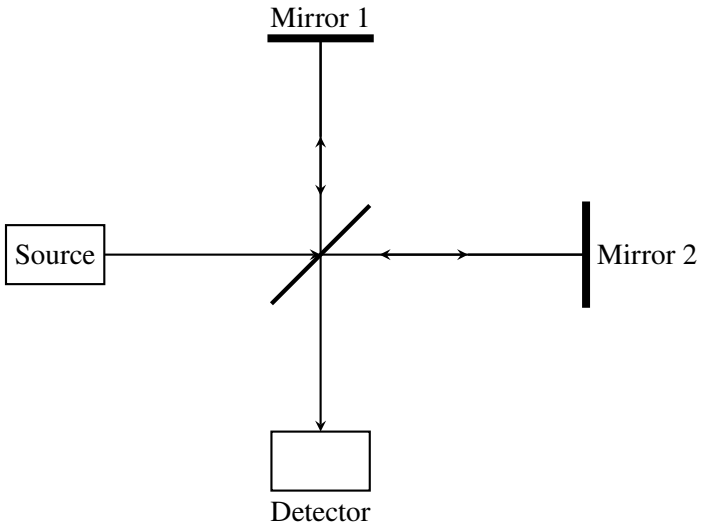
A. The observation of distinct alpha particle back-scattering by gold leaf foils.

B. The diffraction of an electron beam through a crystalline nickel target lattice.

C. The fine split of sodium chemical spectral profiles inside strong magnetic zones.

D. The precise measurement of blackbody energy distributions using a prism refractometer.

7 The diagram below shows a simplified schematic of the Michelson-Morley interferometer experiment. The entire apparatus was rotated smoothly to measure Earth's velocity relative to the hypothetical luminiferous aether.



Which of the following correctly pairs the actual interference pattern observation made during the rotation of the apparatus with its valid scientific conclusion?

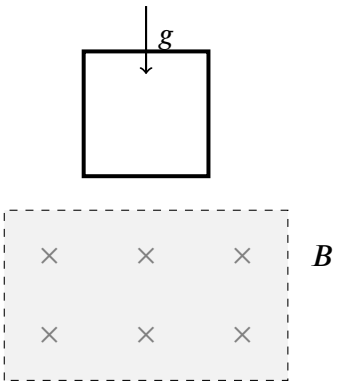
A. Periodic fringe shifts occurred, concluding that there is no experimental evidence for a luminiferous aether.

B. Periodic fringe shifts occurred, concluding that the speed of light depends on the observer's frame velocity.

C. No significant fringe shifts occurred, concluding that there is no experimental evidence for a luminiferous aether.

D. No significant fringe shifts occurred, concluding that the speed of light depends on the observer's frame velocity.

8 The diagram shows a square loop of side length $s = 0.10$ m falling freely under gravity into a region containing a uniform horizontal magnetic field $B = 0.50$ T directed into the page.



As the bottom wire edge initially crosses the top boundary line of the field at a velocity of $v = 4.0$ m s^{-1}, what is the magnitude of the induced electromotive force (EMF) in the loop?

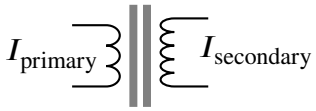
A. 0.02 V

B. 0.20 V

C. 2.00 V

D. 4.00 V

9 An ideal step-up transformer has $N_p = 200$ turns on its primary coil and $N_s = 800$ turns on its secondary coil. The primary side is connected across an AC power supply.



If the RMS current running through the primary circuit is measured to be $I_{\text{rms}} = 12.0$ A, what is the resulting RMS current delivering power through the secondary circuit load?

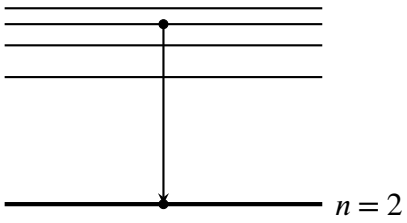
A. 3.0 A

B. 4.0 A

C. 48.0 A

D. $48.0\sqrt{2}$ A

10 An electron in an excited hydrogen atom de-excites by transitioning directly down to the $n = 2$ energy level. This atomic event emits a single photon with a measured frequency of $f = 7.31 \times 10^{14}$ Hz.



From which orbital level (n) did this transition originate?

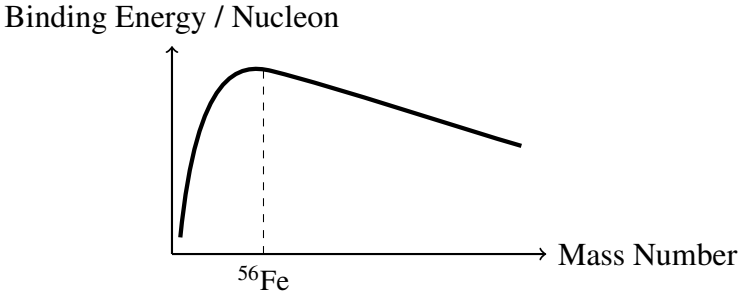
A. $n = 4$

B. $n = 5$

C. $n = 6$

D. $n = 7$

11 The graph below tracks the average binding energy per nucleon plotted against the total mass number for stable atomic isotopes.



Based on this curve configuration, which statement describing nuclear stability trends is correct?

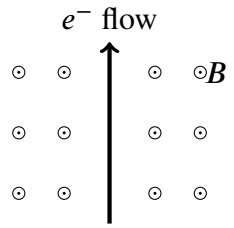
A. Light nuclei readily release net energy when undergoing nuclear fission.

B. Heavy nuclei readily release net energy when undergoing nuclear fusion.

C. Nuclei near Iron-56 possess the highest binding energy per nucleon and are exceptionally stable.

D. The binding energy per nucleon drops exponentially to zero for all isotopes with odd atomic weights.

12 A straight, uniform wire segment of length $L = 0.40$ m is immersed inside a horizontal uniform magnetic field $B = 0.15$ T pointing directly out of the page. The wire has a steady electron flow moving vertically upwards.



If the current passing through the wire is 5.0 A, what is the magnitude and vector direction of the magnetic force acting on this wire segment?

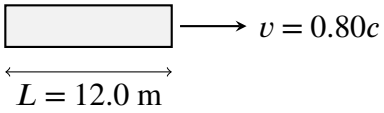
A. 0.03 N directed horizontally to the left.

B. 0.03 N directed horizontally to the right.

C. 0.30 N directed horizontally to the left.

D. 0.30 N directed horizontally to the right.

13 A high-speed relativistic probe travels horizontally past a stationary space station at a constant velocity $v = 0.80c$. An observer on the space station measures the total length of the moving probe along its direction of motion to be exactly 12.0 m.



What is the length of the probe when measured by an onboard astronaut at rest relative to the vehicle?

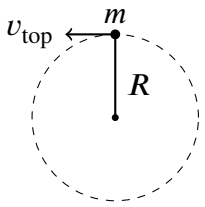
A. 7.2 m

B. 9.6 m

C. 15.0 m

D. 20.0 m

14 A mass m is swung in a vertical circle of radius R attached to a light, inextensible string. The speed of the mass varies due to gravity.



What is the minimum kinetic energy the mass must possess at the exact top of its trajectory to prevent the string from going slack?

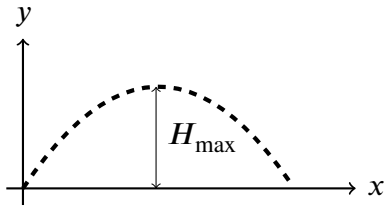
A. 0

B. $\frac{1}{2}mgR$

C. mgR

D. $\frac{5}{2}mgR$

15 A projectile is launched from ground level over a flat horizontal field. It follows a parabolic trajectory and strikes the ground exactly 6.0 s later. Air resistance is negligible.



What is the maximum vertical height (H_{max}) attained by the projectile during its flight?

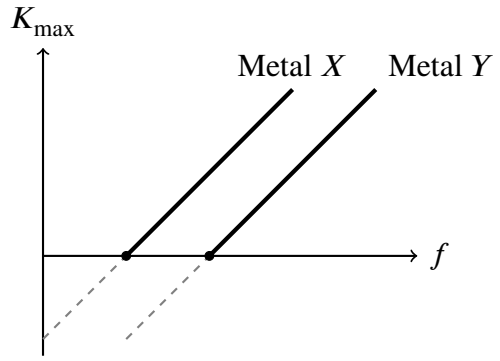
A. 44.1 m

B. 88.2 m

C. 176.4 m

D. 352.8 m

16 The graph below shows the maximum kinetic energy (K_{max}) of photoelectrons as a function of incident light frequency (f) for two different metallic elements, Metal X and Metal Y.



Based on the experimental data plotted, which of the following statements is completely correct?

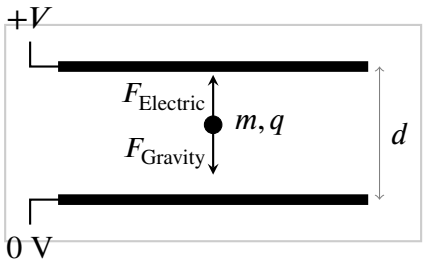
A. The slope of the line for Metal X is greater than Metal Y because it has a smaller work function.

B. Both curves possess identical slopes equal to Planck's constant h, and Metal Y requires a higher threshold photon energy to initiate emission.

C. Metal X will emit photoelectrons with a greater maximum kinetic energy than Metal Y for any arbitrary frequency of incident light.

D. The work function (ϕ) of Metal X is larger than the work function of Metal Y.

17 Millikan oil drop apparatus is shown below. An atomised mist of oil droplets enters a chamber containing two parallel plates spaced a distance d apart under an adjustable electric potential difference V.



What was the primary scientific conclusion inferred from these experimental results of this experiment?

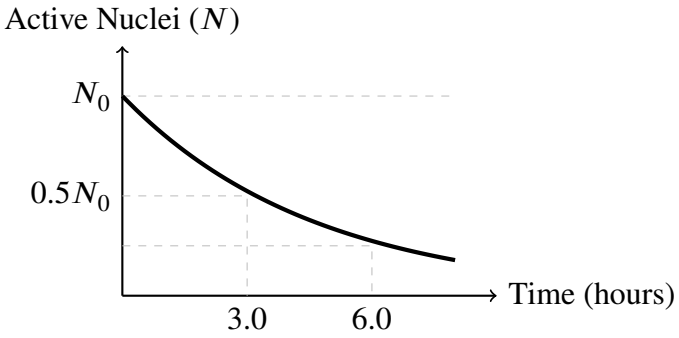
A. Electric charge is continuous and can scale to infinitely small fractional variations.

B. Electric charge is quantized, existing only as integer multiples of a fundamental elementary charge unit.

C. The mass of an oil droplet determines the polarity of the static charge it accumulates.

D. The electric field between parallel plates varies exponentially based on the mass density of the medium.

18 A radioactive isotope sample undergoes alpha decay. An engineer tracks the remaining undecayed core quantity over time, producing the experimental curve shown below.



How many hours will it take for the total active nuclei population to fall to exactly $\frac{1}{7}$ of its initial value (N_0)?

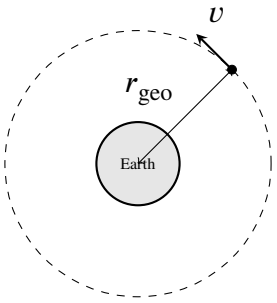
A. 5.3 hours

B. 8.4 hours

C. 9.0 hours

D. 10.5 hours

19 A communications satellite is launched into a high-altitude circular geostationary orbit of radius $r_{\text{geo}} = 4.22 \times 10^7$ m directly above Earth's equator.



To ensure that the satellite remains hovering permanently over a fixed geographical coordinate on Earth's surface, what must be its constant orbital tangential velocity (v)?

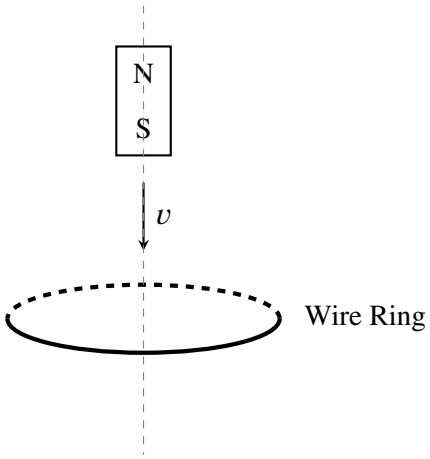
A. 3.1 km s^{-1}

B. 7.9 km s^{-1}

C. 11.2 km s^{-1}

D. 30.7 km s^{-1}

20 A permanent bar magnet is dropped vertically downward, southern pole first, along the central axis of a stationary copper wire ring resting in a horizontal plane.



As viewed from directly above looking down on the ring, which option correctly describes the direction of the induced conventional current as the magnet approaches the ring, and the corresponding direction of the net magnetic force exerted on the ring?

A. Induced current flows clockwise; the net magnetic force on the ring is directed vertically downward.

B. Induced current flows clockwise; the net magnetic force on the ring is directed vertically upward.

C. Induced current flows counter-clockwise; the net magnetic force on the ring is directed vertically downward.

D. Induced current flows counter-clockwise; the net magnetic force on the ring is directed vertically upward.

Physics

Section II Answer Booklet

80 marks
Attempt Questions 21–36
Allow about 2 hours and 25 minutes for this section

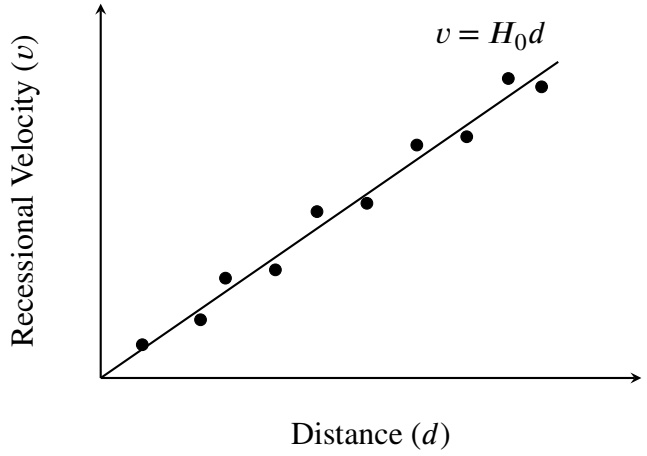
Instructions

- Write your Centre Number and Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Your responses should include relevant mathematical reasoning and/or calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (4 marks)

The Big Bang theory is the prevailing cosmological model that explains the origin and expansion of the universe. The diagram below illustrates the relationship discovered by Edwin Hubble between the radial velocity of distant galaxies and their distance from Earth.



Explain how two distinct pieces of scientific evidence support the Big Bang theory. **4**

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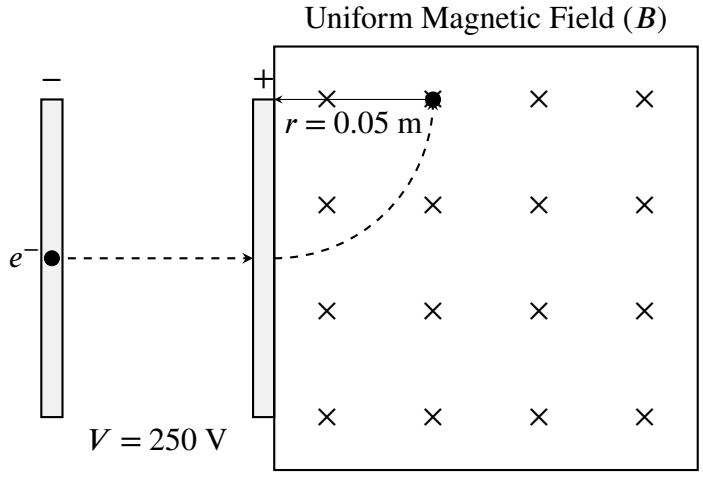
End of Question 21

Question 22 (6 marks)

An electron is accelerated from rest through a potential difference of 250 V before entering a region of uniform magnetic field strength B, where it undergoes uniform circular motion with a radius of 0.05 m.



(a) Show that the velocity of the electron upon entering the magnetic field is approximately 9.38×10^6 m s^{-1}. **2**

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(b) Determine the magnitude of the uniform magnetic field B. **2**

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Question 22 continues on next page

(c) An alpha particle, is accelerated through the same potential difference and enters the magnetic field. Compare how the radius of the alpha particle's path compares to that of the electron. **2**

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End of Question 22

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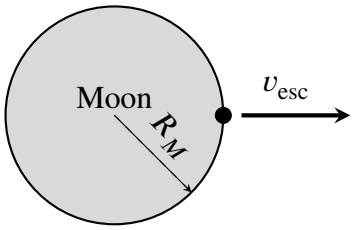
Question 23 (4 marks)

A scientific probe of mass 240 kg is resting on the surface of the Moon. Due to the Moon's gravitational field, the probe has a total gravitational potential energy of -6.75×10^8 J.



(a) Explain why the gravitational potential energy of an object in a gravitational field is defined to have a negative value. **2**

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(b) By considering the total mechanical energy required to escape to determine the escape velocity from the surface of the Moon. **2**

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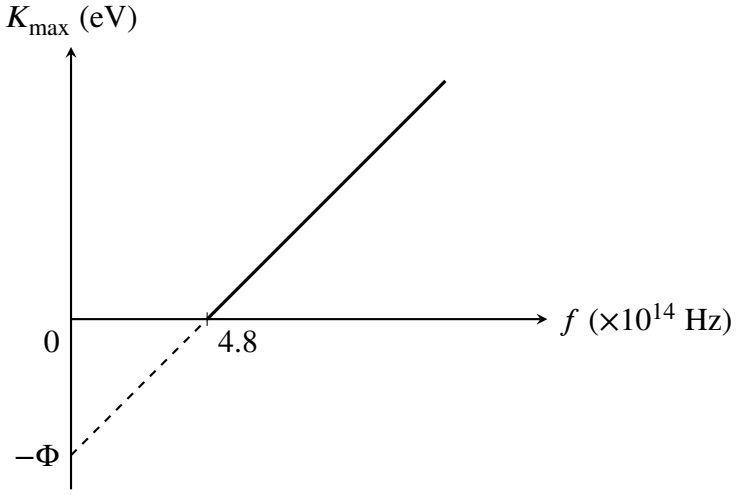
End of Question 23

Question 24 (5 marks)

To determine the work function of an unknown metal surface, a student conducts a photoelectric effect experiment. They record the maximum kinetic energy (K_{max}) of emitted photoelectrons as a function of the incident light frequency (f), producing the graph shown below.



(a) Calculate the work function Φ of the metal in joules (J). **2**

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(b) The student replaces the light source with one that has a higher intensity but emits photons of the same frequency. Explain the effect this change has on the stopping voltage and the photocurrent measured in the circuit. **3**

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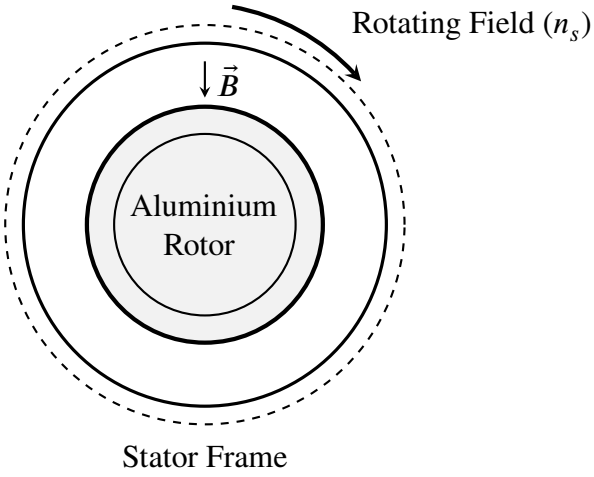
End of Question 24

Question 25 (5 marks)

A simplified cross-section of an AC induction motor shows an aluminium rotor cage placed inside a stator. The stator produces a constantly rotating magnetic field of uniform strength B that rotates clockwise.



Explain how the rotating magnetic field induces a torque within the aluminium rotor to make it spin, and evaluate why the rotor's operating speed can never in practice match the rotation speed of the magnetic field. **5**

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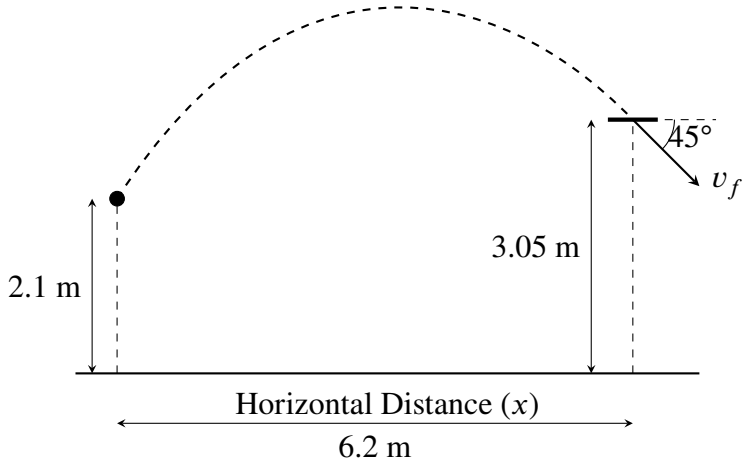
End of Question 25

Question 26 (6 marks)

A basketball player releases a ball from an initial height of 2.1 m above the ground. The ball travels through a parabolic trajectory and passes cleanly through the hoop, which is located at a height of 3.05 m and a horizontal distance of 6.2 m from the launch position.

High-speed camera telemetry reveals that the ball enters the hoop at an angle of 45° below the horizontal, with a final velocity of v_f, taking exactly 1.15 s from the moment of release to reach the basket.



(a) Determine the magnitude of the final velocity v_f as the basketball passes through the hoop. **2**

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(b) Calculate the initial velocity and launch angle above the horizontal at which the basketball was released by the player. **4**

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Question 27 (4 marks)

The Standard Model classifies matter into fundamental particles, including quarks and leptons. Quarks combine to form composite particles known as hadrons, which are held together by the strong nuclear force. The diagram below illustrates the valence quark composition of two different types of hadrons.

Hadron Group A Hadron Group B

Distinguish between the fundamental structures of a baryon and a meson, providing an example for each, and show that the hadrons A and B above have an integer charge. **4**

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End of Question 27

Question 28 (7 marks)

Scientific progress in physics often relies on the development and refinement of models to explain complex phenomena. Consider the following statement:

> ***"Models are our best current description of the universe around us, but no model is complete without limitations."***

Justify this statement with reference to the historical development of the model of light. **7**

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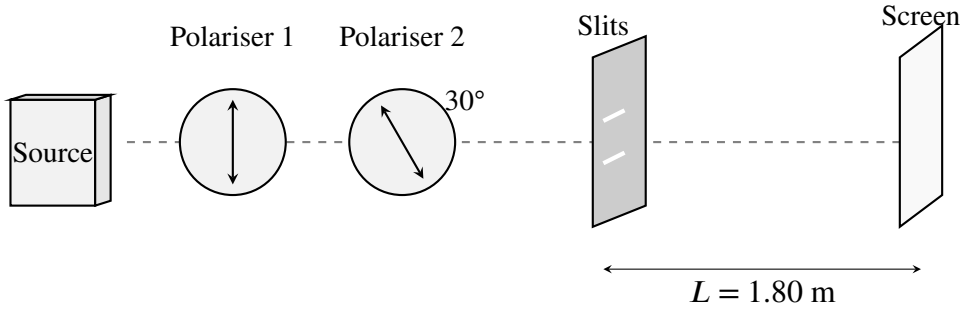
End of Question 28

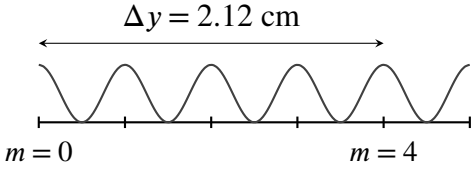
Question 29 (6 marks)

An unpolarised monochromatic light source with an output intensity of $I_0 = 12.0\ \text{W m}^{-2}$ passes through a vertical polariser and a second polariser oriented at $\theta = 30°$ to the vertical.

The resulting beam encounters a double-slit with slit separation of $d = 0.22$ mm placed a distance $L = 1.80$ m from a viewing screen, producing an interference pattern.



The distance from the central maximum to the center of the 4th bright fringe is $y = 2.12$ cm.



Calculate the intensity of the light reaching the double slit and the experimental wavelength (λ). If the manufacturer's specification states the true wavelength is $\lambda = 632.8$ nm, evaluate the percentage error and accuracy of the experiment. **6**

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End of Question 29

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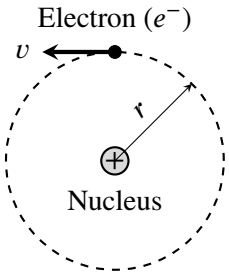
Question 30 (5 marks)

The Rutherford planetary model describes the atom as containing a, dense, positively charged nucleus orbited by negatively charged electrons. Consider a hydrogen atom where an electron moves in a circular orbit of radius $r = 5.3 \times 10^{-11}$ m around a single proton, travelling at a constant speed of $v = 2.18 \times 10^{6}$ m s^{-1}.



(a) Outline the experimental evidence that led Ernest Rutherford to propose a dense, positively charged nucleus at the centre of the atom. **2**

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(b) Calculate the centripetal acceleration of the orbiting electron in this model. **1**

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(c) Explain why this stable planetary model is the contradicts the classical theory of electromagnetism. **2**

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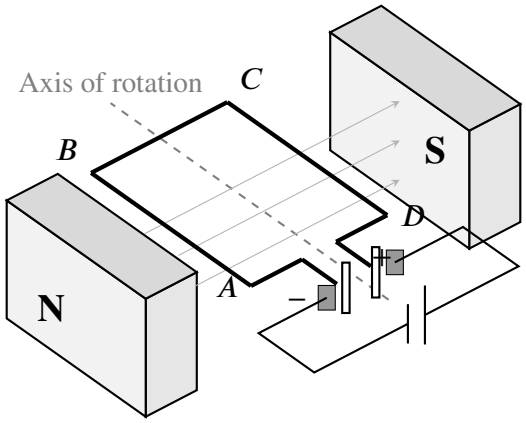
End of Question 30

Question 31 (6 marks)

A DC motor features a 50-turn rectangular armature coil $ABCD$ with length $L = 0.15$ m (sides AB, CD) and width $w = 0.08$ m (side BC). The coil is situated in a uniform magnetic field of $B = 0.45$ T.



(a) Determine the required current I passing through the circuit if the total repulsive force per unit length experienced between the parallel 50-turn bundles AB and CD is calculated to be 1.05×10^{-3} N m^{-1}. **2**

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(b) Calculate the maximum total torque experienced by the armature coil due to the external magnetic field B during operation. **2**

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Question 31 continues on next page

(c) After completing the first 360° rotation, the current to the motor is doubled. On the axes provided below, sketch a graph showing the force due to the external magnetic field acting on side AB over a total rotation of 720°. **2**

End of Question 31

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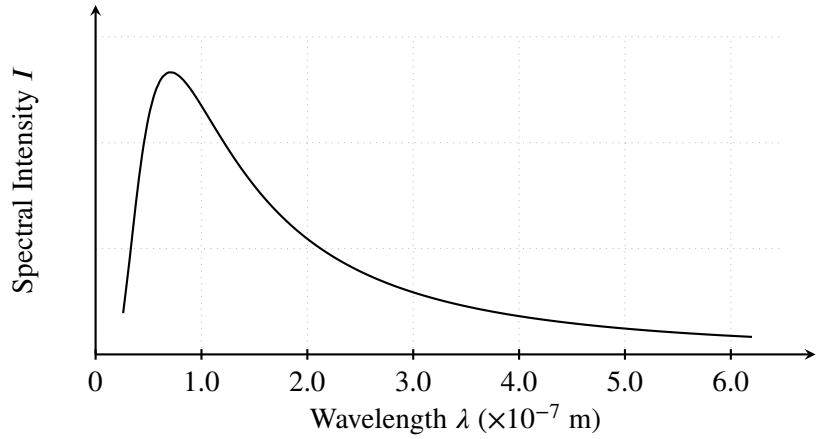
Question 32 (6 marks)

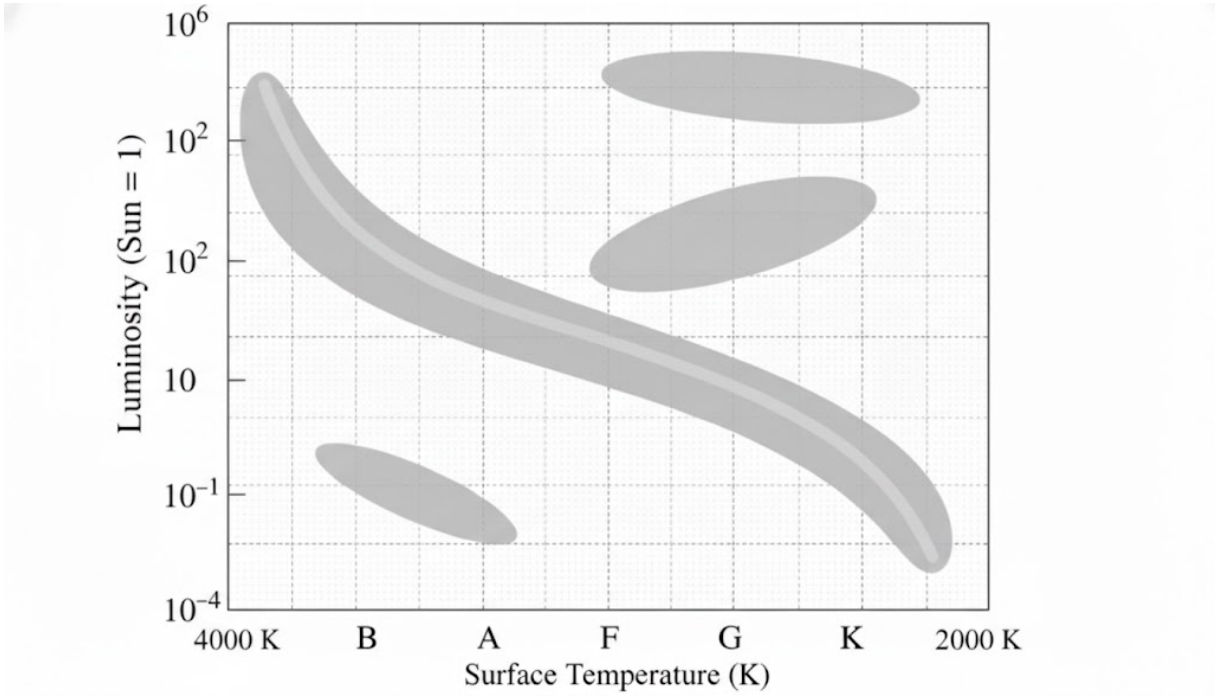
Astronomers studying a distant, massive main-sequence star have determined its stellar spectra and that it fuses using CNO cycle shown below, which releases $E = 4.28 \times 10^{-12}$ J per reaction: **6**

$$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2e^{+} + 2\nu_e + 2\gamma$$

Stellar Blackbody Radiation Profile



Hertzsprung-Russell (H-R) Diagram



Determine the surface temperature of this star, and calculate the net mass defect (Δm) required per cycle of CNO.

Hence, justify the star's spectral class classification zone on the Hertzsprung-Russell diagram and what type of star it is.

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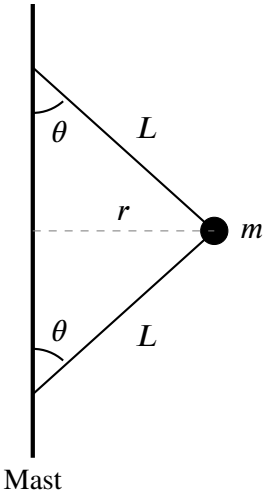
End of Question 32

Question 33 (5 marks)

A small apparatus consists of a vertical central mast that rotates under gravity. A mass m is attached to the mast by two separate, light, inextensible strings of equal length L. The upper string is fixed to the top of the mast, and the lower string is fixed to a point further down.

As the system rotates at a constant tangential speed v, both strings remain taut, each forming an identical angle θ relative to the vertical mast.



(a) Construct two distinct simultaneous equations resolving the vertical forces and horizontal forces acting on the mass m in terms of the upper string tension T_1, the lower string tension T_2, m, g, L, θ, and v. **2**

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Question 33 continues on next page

(b) Show by algebraic derivation that the tension in the lower string can be expressed strictly as: **3**

$$T_2 = \frac{m}{2}\left(\frac{v^2}{L\sin\theta} - \frac{g}{\cos\theta}\right)$$

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End of Question 33

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Question 34 (5 marks)

Muons are unstable subatomic particles created high in Earth's atmosphere by cosmic ray collisions. Despite having an extremely short mean lifetime of $\tau_0 = 2.2 \times 10^{-6}$ s in their rest frame, a significantly larger fraction of muons survive the journey to reach detectors at Earth's surface than classical physics predicts. **5**

Explain how this phenomenon provides experimental evidence for Einstein's Postulates of Special Relativity. In your response, contrast the quantitative reasoning from both the perspective of an observer on Earth's surface and an observer traveling in the rest frame of the muon.

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End of Question 34

Question 36 (6 marks)

The activity of a radioactive sample represents the rate at which its nuclei disintegrate. This is measured in Becquerels (Bq), where 1 Bq = 1 decay per second. The activity A at any time t depends on the number of remaining radioactive nuclei N and the decay constant λ, governed by the relationship:

$$A = \lambda N$$

A medical facility prepares a fresh, pure sample of Carbon-14 with an initial mass of exactly 1.20×10^{-6} grams. The half-life of Carbon-14 is known to be 5730 years.

(a) Calculate the initial activity A_0 of the fresh sample in Becquerels (Bq). **3**

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(b) Determine the total time, in years, required for the sample's activity to drop down to exactly 4.50×10^4 Bq. **3**

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