PEM

Student Number

2024 **TRIAL HIGHER SCHOOL CERTIFICATE 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 sheet and Periodic Table are provided

Total marks: 100

Section I – 20 marks (pages 2–10)

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

Section II – 80 marks (pages 11–25)

- Attempt Questions 21–34
- Allow about 2 hours and 25 minutes for this section

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

Use the multiple-choice answer sheet for Questions 1-20

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1 If Earth's radius were to suddenly double with no change in mass, the gravitational field strength at the surface would:

(A) quarter.

(B) double.

(C) quadruple.

(D) halve.

2 How does back EMF affect the operation of an electric motor?

(A) It decreases the efficiency of the motor.

(B) It increases the power output of the motor.

(C) It increases the current drawn from the power source.

(D) It reduces the current drawn from the power source when the motor speeds up.

3 What contribution did Maxwell’s equations make to physics?

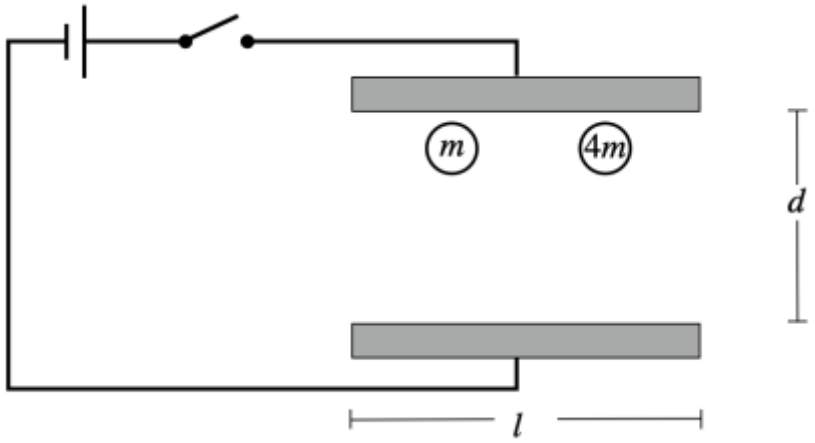
(A) It determined the velocity of light.

(B) It established the foundations for a dual wave-particle model of light.

(C) It distinguished electricity and magnetism as separate fields of study.

(D) It unified electricity and magnetism into a single theory of electromagnetism.

4 The diagram below shows two positive particles between parallel electric plates. The particles have an equal charge, but particle 2 has a mass four times as large as particle 1.



When the switch is turned on, which particle will have the greater energy upon reaching the negative plate?

(A) Particle 1.

(B) Particle 2.

(C) They will both have the same energy.

(D) The potential difference between the plates is required to answer the question.

5 Which particle was predicted by quantum mechanics to mediate the weak force and later discovered experimentally?

(A) Gluon

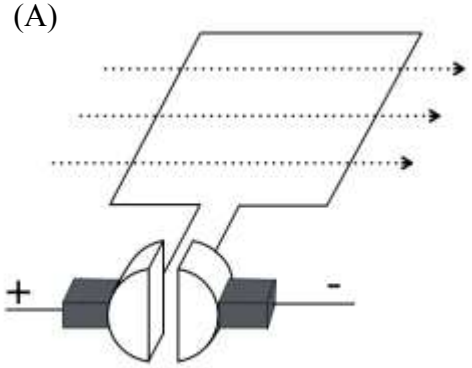
(B) Photon

(C) W and Z bosons

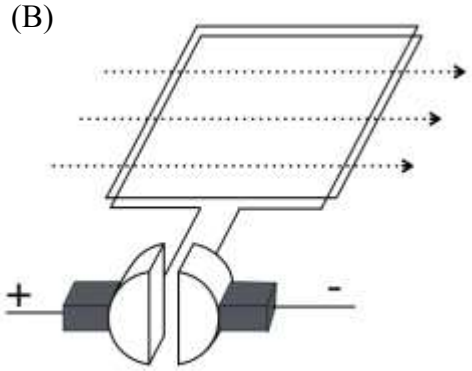
(D) Graviton

6 Which of the following scenarios shown will produce the greatest torque on the coil?

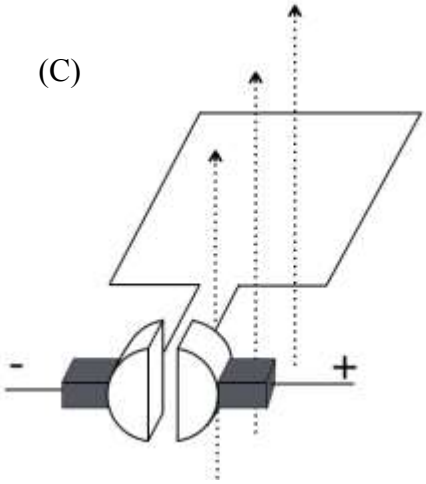
(A)



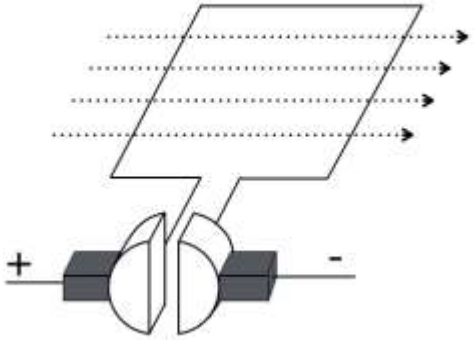
(B)



(C)



(D)



7 Which principle states that it is impossible to simultaneously know both the position and momentum of a particle with precise accuracy?

(A) Heisenberg's Uncertainty Principle

(B) Pauli's Exclusion Principle

(C) Coulomb's Law

(D) Hubble's Law

8 Calculate the energy of a photon emitted when an electron in a hydrogen atom transitions from the $n = 3$ level to the $n = 2$ level.

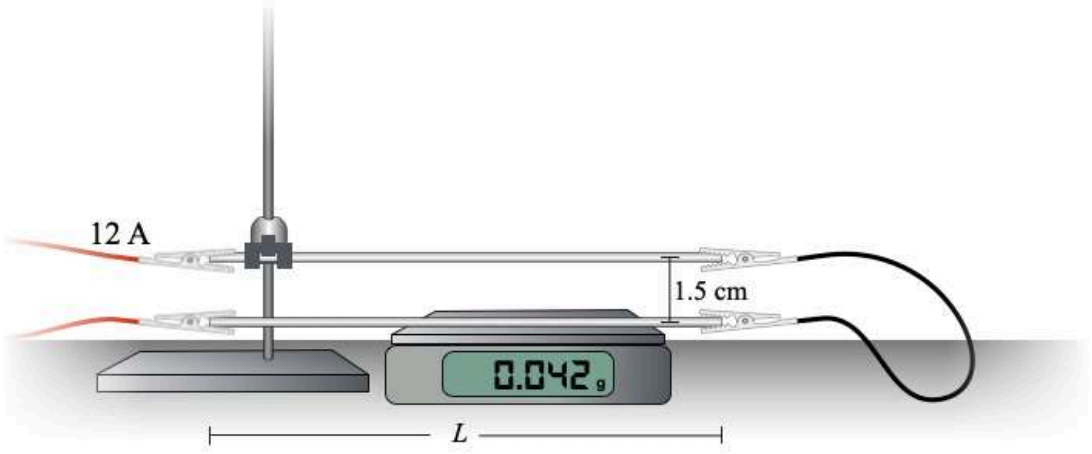
(A) 1.89 eV

(B) 2.55 eV

(C) 3.03 eV

(D) 3.40 eV

9 The apparatus shown below was setup to measure the force between two current carrying conductors. Before the current was turned on, the scale was zeroed.



Determine the length of the two current carrying conductors shown in the image above.

(A) 2.1 m

(B) 2.1×10^{-1} m

(C) 2.1×10^{-2} m

(D) 2.1×10^{-3} m

10 What does a large redshift indicate about a celestial object?

(A) It is moving towards us.

(B) It is moving away from us.

(C) It is stationary.

(D) It is decreasing in size.

11 A car of mass 1200 kg is driving in a horizontal circular track of radius 50 meters with a constant speed of 20 m s^{-1}. If the coefficient of friction between the car's tires and the track is 0.1, what is the work done by friction over one complete revolution?

(A) 0 J

(B) 75 360 J

(C) 150 720 J

(D) 226 080 J

12 How were the resulting patterns in Thomas Young's double-slit experiment explained?

(A) The patterns were explained as the result of particles of light colliding and cancelling out each other's momentum.

(B) The patterns were explained by the polarisation of light as it passed through the slits, aligning light waves in a specific orientation.

(C) The patterns were explained by the refraction of light, bending through the slits at different angles to form patterns on the screen.

(D) The patterns were explained by the diffraction and subsequent interference of light waves from the two slits, creating regions of constructive and destructive interference.

13 Spectral broadening is most effective to determine:

(A) The distance to distant galaxies, by measuring the redshift in their spectral lines.

(B) The temperature of a star, as the width of spectral lines can indicate the thermal motion of particles.

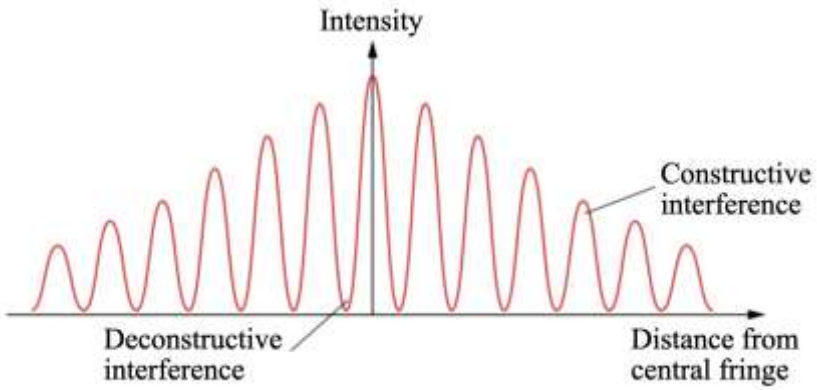
(C) The rotational velocity of a star, as broadening due to the Doppler effect reveals the speed of its rotating surface.

(D) The strength of a magnetic field within a star, based on Zeeman splitting observed in the broadening of lines.

14 Which of the following planets does not belong in the same solar system?

	Planet	Orbital Period (s)	Orbital Radius (km)	Mass (kg)
(A)	W	7.6×10^6	5.791×10^7	3.3×10^{23}
(B)	X	5.94×10^7	2.2794×10^8	6.42×10^{23}
(C)	W	9.296×10^8	1.4267×10^9	5.68×10^{26}
(D)	Z	2.651×10^9	4.4983×10^{10}	1.02×10^{26}

15 The image below shows how the intensity of the interference pattern in Thomas Young's double-slit experiment decreases with increasing distance from the central bright spot.



How can this changing intensity be explained?

(A) The decrease in intensity is due to the conservation of energy, as light energy is more dispersed further from the centre.

(B) The decrease in intensity is a result of the inverse square law, which states that intensity decreases proportionally to the square of the distance from the source.

(C) The decrease in intensity is caused by the increase in the path difference between the two waves from the slits, leading to less constructive interference at larger angles.

(D) The decrease in intensity can be partly explained by polarisation effects where light waves become more polarised as they travel further from the central maximum, reducing their ability to interfere constructively.

16 A ferris wheel car covers an arc distance of 62.8 meters in 2 minutes. If the radius of the ferris wheel is 10 meters, what is the angular velocity in degrees per second?

(A) $0.90^\circ\ s^{-1}$

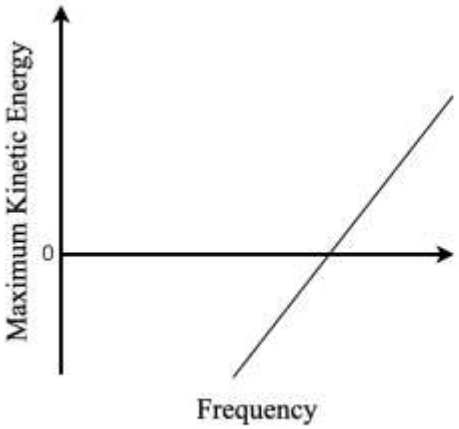
(B) $1.80^\circ\ s^{-1}$

(C) $3.00^\circ\ s^{-1}$

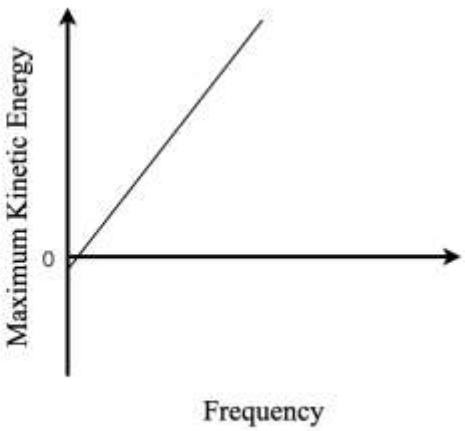
(D) $6.00^\circ\ s^{-1}$

17 The following graphs plots the maximum kinetic energy of the emitted photoelectrons against incident radiation frequency for four different metal surfaces.

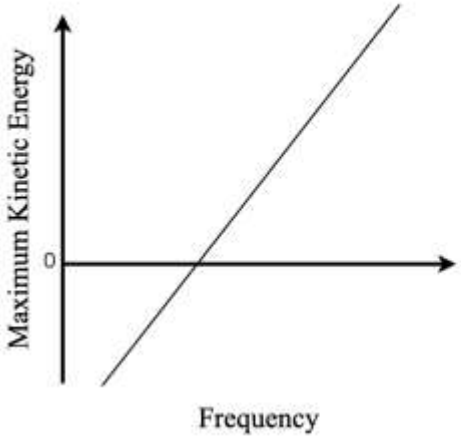
I.



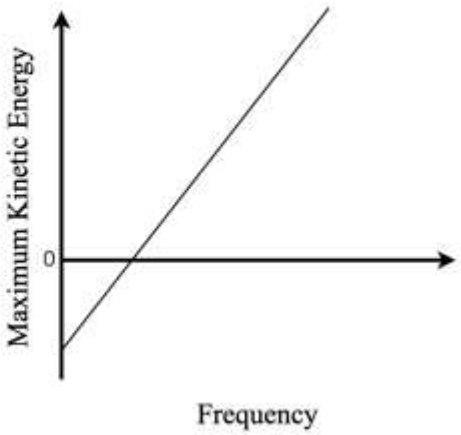
II.



III.



IV.



Which of the following statements about the metals is true?

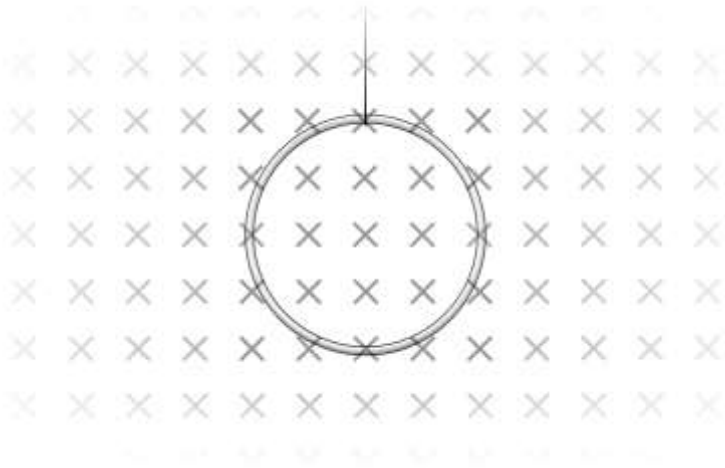
(A) Metal IV has a greater threshold frequency than metal III.

(B) For the same frequency, the photoelectrons emitted by II will have less kinetic energy than the photoelectrons emitted by I.

(C) Metal III has a greater work function than metal I.

(D) The threshold frequency of III would not cause photoemission for metal II.

18 A ring is hung by a fishing line so that is sits within a magnetic field as shown below.



Determine the change in flux when the ring rotates from its position by 120˚.

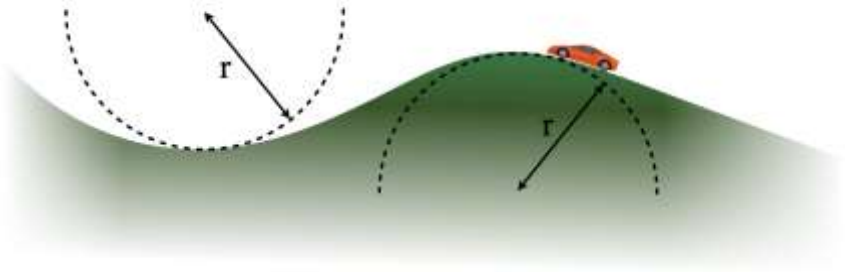
(A) $-\frac{3}{2}B \times A$

(B) $-\frac{1}{2}B \times A$

(C) $\frac{1}{2}B \times A$

(D) $\frac{2}{3}B \times A$

19 A car is driving on a hilly country road as shown below. In the section illustrated, the hill and trough have the same radius. At the peak of the hill, the normal force acting on the 80 kg driver from the seat is 400 N.



If the car maintains its speed throughout the section, what is the magnitude of the normal force experienced by the driver as the car passes through the bottom of the valley?

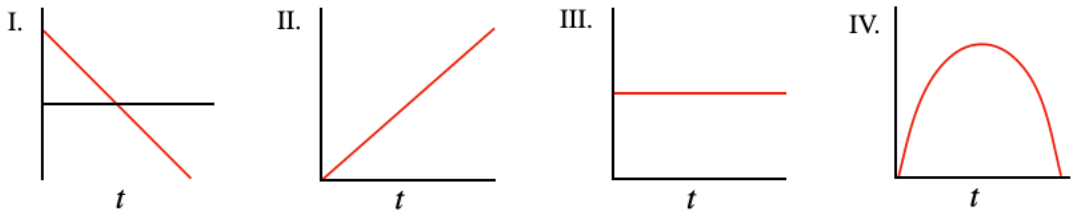
(A) 800 N

(B) 1200 N

(C) 1600 N

(D) 2000 N

20 Five incomplete time graphs are shown below for different variables of the motion of a projectile that lands at the same height that it was launched from.



Which of the flowing identifies the y axis of each graph with its correct quantity of motion.

	I.	II.	III.	IV.
(A)	Δv_y	Δx	a	v
(B)	v_y	Δx	v_x	Δy
(C)	Δy	v_x	a	Δx
(D)	Δv_y	v_x	Δx	Δy

Sections II – 80 marks
Attempt questions 21-34
Allow about 2 hour 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.

Question 21 (8 marks)

(a) Calculate the orbital velocity of a satellite in a circular orbit 400 km above the surface of Mars. Assume Mars' radius is 3 390 km and its mass is 6.42×10^{23} kg. **4**

(b) When the satellite's orbit increases from 400 km above the surface of Mars to 800 km from the surface, the satellite experiences a change in total mechanical energy equal to 2.7×10^{8} J. Calculate the satellite's mass. **4**

Question 22 (12 marks)

(a) Explain the main role of the iron core in a transformer in terms of flux linkage. **3**

(b) Justify the lamination of the iron core and explain why the laminations do not affect the role of the core. **5**

Question 22 continues on page 13

Question 22 (continued)

(c) A step-down transformer is used in a residential area to reduce the high voltage from power lines to a more usable level for homes. The primary coil of the transformer is connected to a power line with a voltage of 11 000 V and the secondary coil supplies power at 220 V. The transformer operates with a primary current of 0.5 A. Assume that the transformer is 95% efficient. **4**

Determine the current in the secondary coil.

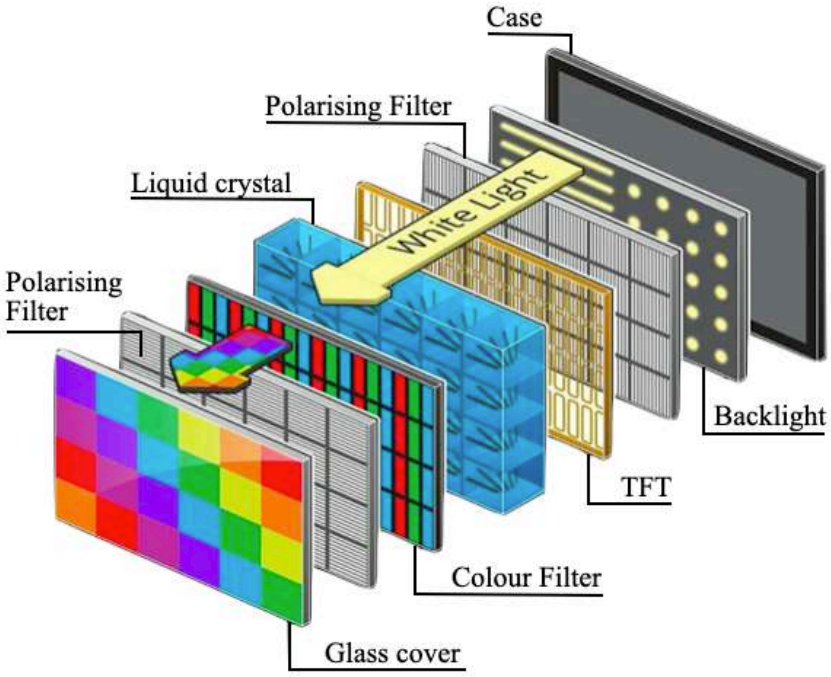
Question 23 (6 marks)

A model rocket, initially on the ground, was launched at an angle of 20.0˚ from the horizontal. After a 2.50 s motor burn, the model had a velocity of 82.0 m s^{-1} and then followed projectile motion for the remainder of its flight.

Determine the horizontal range of the rocket after landing. Assume its initial trajectory did not change during its motor burn.

Question 24 (4 marks)

Liquid crystal display (LCD) screens have a series of layers that manipulate light to produce the desired image, as shown below. Light is first polarised and then passed through very small liquid crystal cells. The liquid crystal cells will individually rotate the plane of polarisation according to a supplied voltage. This light then passes through a RED, GREEN or BLUE sub-pixel filter. This coloured light now passes through a final polarising filter that is perpendicular to the original polarising filter.



The sub-pixel intensities are combined to form a single pixel colour. Varying intensities can produce over 16 million colours.

Question 24 continues on page 16

Question 24 (continued)

Figure 1. below shows the RGB palette which illustrates the colours formed with varying intensities of RED and GREEN, when BLUE has a set value of 90.

Intensity values range from 0-255.

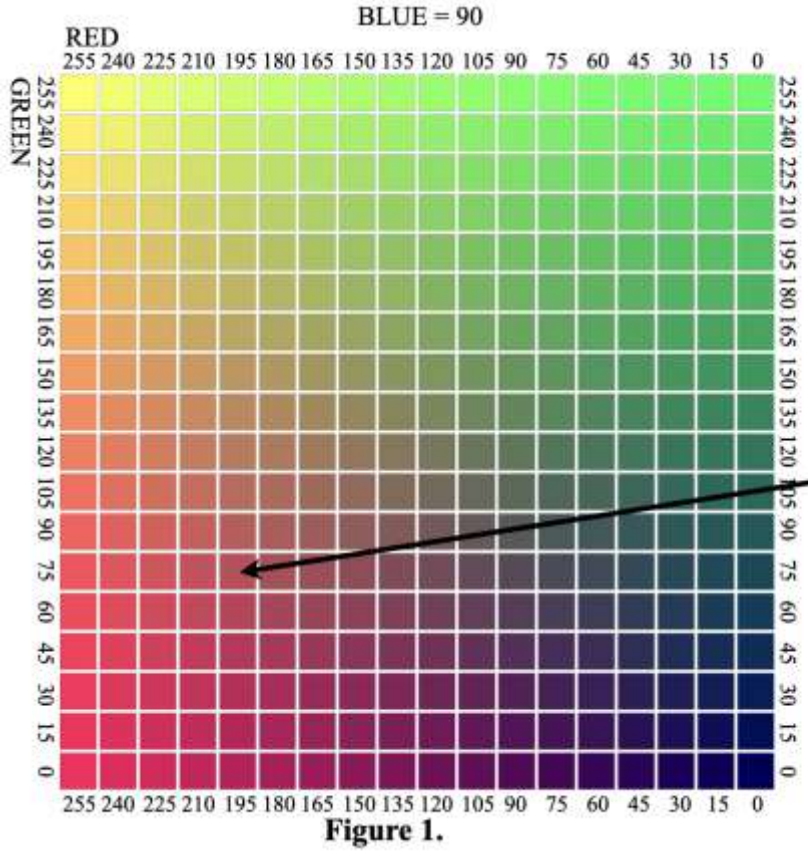


Figure 1.

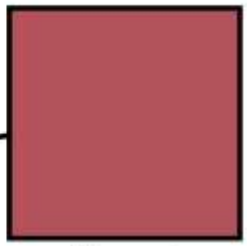


Figure 2.

Determine how much a liquid crystal cell rotated the light supplied to the Red sub-pixel from its original plane of polarisation to produce the pixel colour indicated in figure 2.

Question 25 (6 marks)

(a) Describe a valid historical method to measure the speed of light. **4**

(b) Outline how the described method had a limitation in the precision of its measurement. **2**

Question 26 (4 marks)

A physics student, who is also a train model enthusiast, is combining their two interests to undertake a study in electromagnetic induction. They rig up one of their trains with a strong bar magnet on its load carriage and has its track pass through a solenoid. The solenoid is attached to a galvanometer to measure the induced current.

They notice that the train exits the solenoid tunnel with a lower speed than when it entered and does not begin to accelerate to a normal operating speed for a small distance after exiting.

Explain their observations.

Question 27 (6 marks)

In 1905 Albert Einstein produced his Nobel Prize winning paper 'On a Heuristic Viewpoint Concerning the Production and Transformation of Light'.

In the paper Einstein proposed a new model of light. Explain why this new model was necessary and describe how it accounted for the experimental observations.

Question 28 (6 marks)

A banked circular curve has been built on a suburban road for a design speed of 80 km h^{-1}. The curve has a radius of 202 m.

If the co-efficient of friction is between the tyre and the road is 0.8, what is the maximum speed that will allow cars to take the turn without sliding off the road?

Question 29 (4 marks)

Explain how, in terms of the magnetic field strengths created by current carrying conductors, Newton's 3rd law is related to the interaction between two parallel current carrying wires.

Question 30 (6 marks)

Critically evaluate an experimental anomaly that classical atomic models could not account for, which necessitated the shift to quantum mechanical descriptions, such as the quantized Balmer series and Schrödinger's wave mechanics.

Question 31 (4 marks)

A common fusion reaction inside main sequence stars is the proton-proton chain.

(a) One reaction within this chain ejects a positron. How does this positron produce greater energy than its kinetic energy? **2**

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(b) Another reaction within this chain produces a gamma wave as a result of the production of a helium-3 nucleus from a proton and a deuteron. **2**

Given the data below, determine the energy of the gamma wave.

$\text{Mass of deuteron} = 2.014102\ \text{u}$
$\text{Mass of proton} = 1.007276\ \text{u}$
$\text{Mass of helium} - 3 = 3.016029\ \text{u}$

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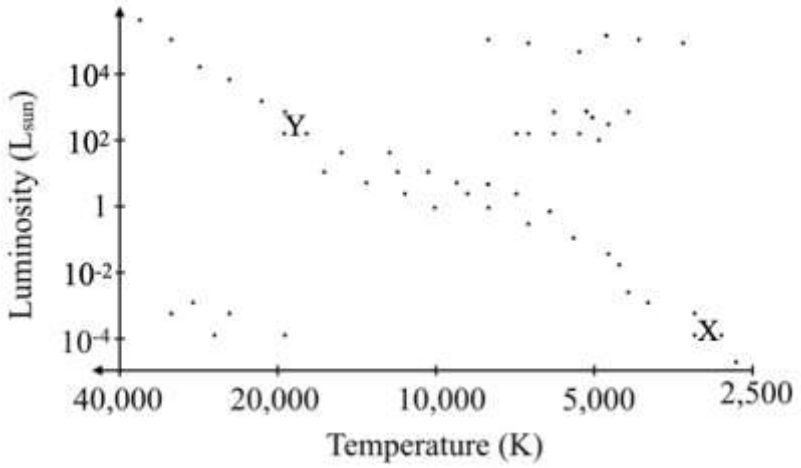
Question 32 (4 marks)

Einstein proposed a thought experiment that presented a problem and would lay the foundations for his theory of special relativity. The experiment placed a passenger inside a train travelling at the speed of light. The passenger attempts to view their reflection in a mirror placed in front of them. Outline the two possible results of the experiment and why they posed a problem for Einstein.

Question 33 (4 marks)

Below shows a Hertzsprung-Russel diagram with two labelled stars, X and Y.



During its life cycle, star Y will transition from the main sequence. Explain why star X will not share this transition.

Question 34 (6 marks)

(a) A newly discovered radioactive isotope undergoes decay, emitting alpha, beta, and gamma radiation. Compare the properties of these types of radiation and discuss how they contribute to the transmutation of the isotope. **4**

(b) Calculate the remaining mass of the isotope after three half-lives if it began as a 10-gram sample. **2**

END OF EXAM

PEM

2024 Trial HSC Physics Marking Guidelines

Section I

Multiple-choice Answer Key

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

Section II

Question 21 (a)

Criteria	Marks
Correctly calculates the orbital velocity.	4
Shows correct working to solve for orbital velocity with error in substitution Or Calculates the orbital velocity using only the altitude.	3
Determines correct orbital velocity formula.	2
Attempts to find orbital velocity with appropriate formulas.	1

Sample answer:

$\frac{mv^2}{r} = \frac{GMm}{r^2} \quad where\ r = R + h$

$v_{orbital} = \sqrt{\frac{GM}{R+h}}$

$v_{orbital} = \sqrt{\frac{6.67\times10^{8}\times6.42\times10^{23}}{3.39\times10^{6}+4\times10^{5}}}$

$v_{orbital} = 3360 \text{ m s}^{-1}$

Question 21 (b)

Criteria	Marks
Correctly calculates the mass.	4
Shows correct working to solve for mass with error in substitution.	3
Shows some progress in determining mass.	2
Attempts to solve using correct formulas.	1

Sample answer:

$$\Delta E = \frac{-GMm}{2r_f} - \frac{-GMm}{2r_i}$$

$$\Delta E = m\left(\frac{-GM}{2r_f} - \frac{-GM}{2r_i}\right)$$

$$m = \Delta E \Big/ \frac{-GM}{2r_f} - \frac{-GM}{2r_i}$$

$$m = 2.7 \times 10^8 \Big/ \frac{-6.67\times10^{-11}\times6.42\times10^{23}}{2\times(3.39\times10^6+8\times10^5)} - \frac{-6.67\times10^{-11}\times6.42\times10^{23}}{2\times(3.39\times10^6+4\times10^5)}$$

$$m = 501 \text{ kg}$$

Question 22 (a)

Criteria	Marks
Describes a low -reluctance path or concentration of flux and relates to efficiency.	3
Describes a low -reluctance path and concentration of flux.	2
Describes a low -reluctance path or concentration of flux Or Relates flux to efficiency.	1

Sample answer:

The main role of an iron core in a transformer is to enhance the efficiency of electromagnetic induction. The iron core firstly provides a low-reluctance path for the magnetic flux generated by the primary winding allowing the magnetic field to flow easily through the core, increasing the efficiency of energy transfer. The presence of the iron core helps concentrate the magnetic flux improving the coupling between the primary and secondary windings. This concentration reduces flux leakage improving the overall efficiency of the transformer.

Question 22 (b)

Criteria	Marks
Provides a complete justification for lamination and explains that the orientation of laminations does not affect the core's ability to channel magnetic flux.	5
Provides a complete justification for lamination, linking the reduction in eddy currents to both energy efficiency and sustained functionality in magnetic flux linkage.	4
Connects reduced eddy currents to decreased heat and energy losses.	3
Describes how lamination reduces eddy current magnitude by confining them to smaller loops.	2
Identifies the reduction of eddy currents as the purpose of lamination.	1

Sample answer:

Eddy currents, which are induced within the core due to changing magnetic fields, create heat and energy losses. By constructing the core with insulated, thin layers of iron sheets, these currents are restricted to smaller loops, significantly reducing their intensity and associated losses. The laminations, oriented parallel to the magnetic field, do not hinder the core's function. They preserve the core's magnetic permeability, ensuring efficient flux linkage and maintaining transformer efficiency while minimizing the negative effects of eddy currents.

Question 22 (c)

Criteria	Marks
Correctly determines the output current.	4
Shows correct working to solve for output current with error in substitution.	3
Calculates output current without accounting for energy efficiency.	2
Attempts to solve using correct formulas Or Calculates output power.	1

Sample answer:

$P_{input} = VI$

$P_{input} = 11000 \times 0.5$

$P_{input} = 5500 \text{ W}$

$P_{output} = P_{input} \times \eta$

$P_{output} = 5500 \times 0.95$

$P_{output} = 5225 \text{ W}$

$P_{output} = V_{secondary} \times I_{secondary}$

$I_{secondary} = \frac{P_{output}}{V_{secondary}}$

$I = \frac{5225}{220}$

$I = 24 \text{ A}$

Question 23

Criteria	Marks
Correctly determines the horizontal range.	6
Correctly determines the total time of flight.	5
Correctly determines components of the total time of flight.	4
Correctly determines the range and height of the motor burn and attempts to solve for projectile motion from end of motor burn.	3
Attempts to determine the time of flight Or Correctly determines the range and height of the motor burn.	2
Attempts to solve using correct formulas.	1

Sample answer:

$v = 82 \qquad \theta = 20 \qquad t_1 = 2.5$

$a = \frac{v-u}{t_1}$

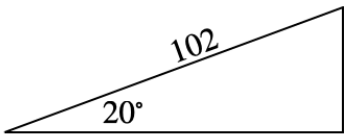
$a = \frac{82-0}{2.5}$

$a = 32.8 \text{ m s}^{-2}$

$\Delta s = ut_1 + \frac{1}{2}at_1^2$

$\Delta s = \frac{32.8 \times 2.5^2}{2}$

$\Delta s = 102 \text{ m}$



$\Delta y_1 = 102 \sin 20$

$\Delta y_1 = 34.8 \text{ m}$

$\Delta x_1 = 102 \cos 20$

$\Delta x_1 = 95.8 \text{ m}$

$v_y = u_y + at_2$

$t_2 = \frac{0-82 \sin 20}{-9.8}$

$t_2 = 2.9 \text{ s}$

$v^2 = u^2 + 2a\Delta y_2$

$\Delta y_2 = \frac{0-(82 \sin 20)^2}{2 \times -9.8}$

$\Delta y_2 = 40.1 \text{ m}$

$-(\Delta y_1 + \Delta y_2) = ut_3 + \frac{1}{2}at_3^2$

$t_3 = \sqrt{\frac{-2(\Delta y_1 + \Delta y_2)}{a}}$

$t_3 = \sqrt{\frac{-2(34.7+40.1)}{-9.8}}$

$t_3 = 3.91 \text{ s}$

$\Delta t = t_1 + t_2 + t_3$

$\Delta t = 9.27 \text{ s}$

$\Delta x = u_x t$

$\Delta x = 82 \cos 20 \times 9.27$

$\Delta x = 715 \text{ m}$

Question 24

Criteria	Marks
Calculates the correct angle.	4
Correctly uses Malus' law.	3
Correctly calculates the intensity as a percentage.	2
Correctly identifies the red sub-pixel intensity value.	1

Sample answer:

$$I = \frac{Pixel\ intensity\ value}{Max\ intensity\ value} \times 100$$

$$I = \frac{195}{255} \times 100$$

$$I = 76.5\%$$

$$\theta = \cos^{-1}\left(\sqrt{\frac{I}{I_o}}\right)$$

$$\theta = \cos^{-1}\left(\sqrt{\frac{76.5}{100}}\right)$$

$$\theta = 29^\circ$$

$$\theta_{rotated} = 90 - 29$$

$$\theta_{rotated} = 61^\circ$$

Question 25 (a)

Criteria	Marks
Describes a historical method that demonstrates validity.	4
Describes a valid historical method.	3
Gives some details of a valid historical method.	2
Identifies a valid historical method.	1

Sample answer:

Ole Rømer's method to measure the speed of light involved observing the eclipses of Io, a moon of Jupiter. Rømer noticed that the timing of Io's eclipses varied depending on Earth's position relative to Jupiter. He deduced that light has a finite speed, which became apparent through the varying eclipse timings as the distance between Earth and Jupiter changed due to their orbital movements. Rømer calculated the speed of light by measuring the time differences in Io's eclipses over a period when Earth and Jupiter were moving apart compared to when they were moving towards each other, leading to his ground-breaking conclusion that light travels at a finite speed.

Question 25 (b)

Criteria	Marks
Outlines a component of the method that impacts precision of measurement.	2
Identifies a component of the method that impacts precision of measurement.	1

Sample answer:

The precision of his observations was constrained by the clocks available in the 17th century, which were not capable of measuring small time intervals. Additionally, the telescopes used lacked the refinement to precisely determine the exact moment Io emerged from or entered Jupiter’s shadow, further impacting the precision of the timing measurements.

Question 26

Criteria	Marks
Uses Lenz's law and Faraday's to explain the difference in speed entering and exiting the solenoid and the delay in acceleration.	4
Uses Lenz's law and Faraday's to explain the difference in speed entering and exiting the solenoid.	3
Identifies Lenz's law or Faraday's to explain a change in train motion.	2
Provides some relevant information.	1

As the train enters the solenoid, the magnetic field of the magnet in the second carriage is not yet strong enough to have a visible effect so it enters at full speed. When the bar magnet enters the solenoid, the changing magnetic field inside the solenoid induces an electromotive force (EMF) in the solenoid according to Faraday's Law. This induced EMF generates a current in the solenoid, which in turn produces its own magnetic field.

According to Lenz's Law, the direction of the induced EMF will be such that it opposes the change in magnetic flux that produced it. Consequently, the magnetic field created by the induced current in the solenoid opposes the magnet's motion. This opposing magnetic field acts against the direction of the train's motion, resulting in a decrease in the train's speed as it passes through the solenoid.

This interaction effectively extends beyond the physical confines of the solenoid, causing the train to experience a force that opposes its motion for a short distance even after it has left the solenoid whilst the magnetic field is within a short range. It is this continued magnetic interaction that delays the train's return to normal operating speed.

Question 27

Criteria	Marks
Links Einstein's model to the experimental observations of the photoelectric effect, effectively explaining the necessity and function of the model and the inconsistency of the classical wave model.	6
Links Einstein's model to the experimental observations of the photoelectric effect, effectively explaining the necessity and function of the model.	5
Describes how the wave model could not explain the photoelectric observations.	4
Describes how the model explains an observed result.	3
Describes Einstein's model.	2
Identifies the Einstein's model.	1

Sample answer:

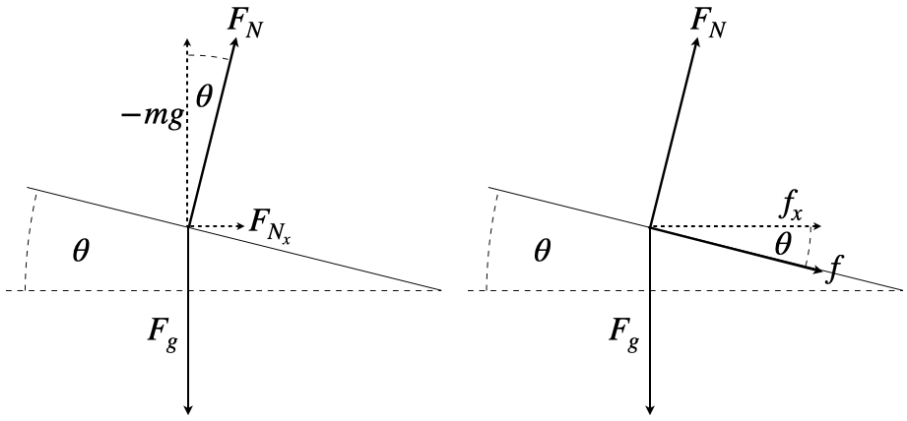
Einstein introduced the concept of light as quantized packets of energy, which he called "light quanta" or photons. Einstein's model was necessary due to the observed phenomenon that light could eject electrons from a metal surface when certain frequency thresholds were met, regardless of the light's intensity. This observation contradicted the wave theory, which predicted that light's energy, being a function of its amplitude, should increase with intensity at any frequency.

His model accounted for these observations by suggesting that light's energy is not distributed uniformly but in discrete packets. Each photon carries energy quantized as $E = hf$, where h is Planck's constant and f is the frequency of the light. This model explained why no electrons are ejected below a certain frequency because the individual photons do not have enough energy to overcome the electron's binding energy, regardless of the number of photons (or the light's intensity).

Question 28

Criteria	Marks
Correctly calculates maximum speed.	6
Shows correct working to solve for maximum speed with error in substitution.	5
Makes progress towards solving for maximum speed.	4
Correctly determines design speed and attempts to solve for maximum speed.	3
Correctly determines design speed or shows substantial relevant working.	2
Attempts to determines design speed or shows relevant working.	1

Sample answer:



For design speed (no friction)

$F_{N_x} = -mg \tan\theta$

$F_c = F_{N_x}$

$\frac{mv^2}{r} = -mg \tan\theta$

$\theta_{design} = \tan^{-1}\left(\frac{v^2}{-gr}\right)$

$\theta_{design} = \tan^{-1}\left(\frac{(80 \div 3.6)^2}{9.8 \times 202}\right)$

$\theta_{design} = 14^\circ$

For design angle (with friction)

$f = \mu F_N$

$f = \mu\left(\frac{-mg}{\cos\theta}\right)$

$f_x = f\cos\theta$

$f_x = \frac{-\mu mg}{\cos\theta} \times \cos\theta$

$f_x = -\mu mg$

$F_c = F_{N_x} + f_x$

$\frac{mv^2}{r} = -mg\tan\theta - \mu mg$

$mv^2 = -mgr\tan\theta - \mu mgr$

$v = \sqrt{-gr\tan\theta - \mu gr}$

$v = \sqrt{(9.8 \times 202 \times \tan 14) + (0.8 \times 9.8 \times 202)}$

$v = 45.6 \text{ m s}^{-1} \rightarrow 164 \text{ km h}^{-1}$

Question 29

Criteria	Marks
Provides a detailed explanation that clearly relates Newton's Third Law to the magnetic fields created by current-carrying conductors including both scenarios (currents in the same and opposite directions) with reference to the forces being equal and opposite.	4
Provides a correct explanation but may miss details in the same and opposite current directions. The relation to Newton's Third Law is correctly identified but not elaborated.	3
Explanation addresses only one scenario (either currents in the same direction or in opposite directions) or vaguely refers to Newton's Third Law without clear connection to the forces between the wires.	2
The response identifies that there is a force between the wires or Identifies Newton's Third Law without linking it to the interaction between the wires.	1

Sample answer:

According to Newton's Third Law, every action has an equal and opposite reaction. In the context of two parallel current-carrying wires, each wire generates a magnetic field that affects the other. When currents are in the same direction, the magnetic fields interact to produce an attractive force between the wires. If the currents are opposite, the interaction results in a repulsive force. These forces are examples of Newton's Third Law because the force one wire exerts on the other is always equal in magnitude and opposite in direction.

Question 30

Criteria	Marks
Critically evaluates an experimental anomaly with clear links to quantum mechanics including the quantized Balmer series and Schrödinger's model.	6
Evaluates in general terms an experimental anomaly with clear links to quantum mechanics including the quantized Balmer series and Schrödinger's model.	5
Evaluates in general terms an anomaly with connection to quantum mechanics including reference to Balmer series or Schrödinger's model.	4
Provides some evaluation of an anomaly with basic link to the need for quantum mechanics and mentions Balmer series or Schrödinger's model.	3
Identifies an anomaly with minimal critique or links to quantum mechanics and makes an attempt to reference Balmer series or Schrödinger's model.	2
Identifies an experimental anomaly with vague or incorrect link to quantum mechanics and lacks detail on Balmer series and Schrödinger's model.	1

Sample answer:

The classical atomic models, like those proposed by Rutherford and Bohr, faced significant challenges when confronted with certain experimental anomalies. A critical example is the observation of the Balmer series in the hydrogen emission spectrum. According to classical physics, an accelerating electron in an orbit should emit electromagnetic radiation continuously, losing energy and spiral into the nucleus, which does not happen. However, the Balmer series demonstrated discrete energy levels. Electrons only emitted radiation at certain frequencies corresponding to transitions between these levels, contradicting the classical idea of a continuum of energies.

Quantum mechanics emerged to resolve this discrepancy. Schrödinger's wave mechanics, in particular, replaced the classical orbits with wave functions, providing a probability distribution for the position of electrons. His model successfully explained the fixed energy levels as a natural consequence of the wave-like behaviour of electrons, which could only resonate at certain frequencies, or 'standing waves,' within an atom.

This shift to quantum descriptions was not just a refinement of existing theories but a paradigm shift, offering predictions that aligned with experimental data and resolved the apparent contradiction of the stability of atoms, the discrete energy levels observed in spectra, and the fundamental nature of electron behaviour within atoms.

Question 31 (a)

Criteria	Marks
Describes the annihilation process resulting in the conversion of the entire mass of both the positron and electron into gamma-ray photons.	2
Identifies that the positron annihilates with an electron.	1

Sample answer:

The positron soon encounters an electron and undergoes annihilation. This annihilation process is significant because when a positron and an electron collide, they annihilate each other, converting their entire mass into energy in the form of gamma rays according to Einstein's equation $E = mc^2$. This energy release is substantially greater than the kinetic energy of the positron alone.

Question 31 (b)

Criteria	Marks
Correctly calculates the energy released.	2
Calculates mass defect.	1

Sample answer:

$m_{reactants} = 2.014102 + 1.007276$

$m_{reactants} = 3.021378$ u

$Mass\ defect = m_{reactants} - m_{He}$

$Mass\ defect = 3.021378 - 3.016029$

$Mass\ defect = 0.005349$ u

$E = 0.005349 \times 931.5$

$E = 4.983$ MeV

Question 32

Criteria	Marks
Explains why both outcomes are a problem to classical physics.	4
Explains why one outcome is a problem to classical physics.	3
Describes two outcomes.	2
Describes one outcome.	1

Sample answer:

Reflection Visible: If the passenger sees their reflection, it implies that light from the passenger's face is able to travel to the mirror and reflect back at the speed of light, despite the train's own light-speed velocity. This would contradict classical mechanics which suggests that the light should not be able to catch up with the mirror.

Reflection not visible: If the reflection is not visible, this would represent way to determine a non-inertial frame of reference without an external reference. This would violate the classical physics principle of relativity.

Question 33

Criteria	Marks
Links convection current and low mass to differences in life cycles.	4
Links low mass to differences in life cycles.	3
Describes differences in life cycles.	2
Identifies low mass as a determinising factor in difference or Identifies transition of star Y.	1

Sample answer:

Star X has a lower mass and consequently lower core temperature, which results in slower nuclear fusion processes primarily through the proton-proton chain. Its lower mass means that gravitational forces are less, allowing convection currents to form, pulling helium out from the core and hydrogen in, increasing the hydrogen fusion efficiency. As such, it will not reach the temperature necessary to fuse heavier elements and thus avoid the more complex life cycles of larger stars such as Y. Instead of expanding into red giants and undergoing explosive events like supernovae, star X is predicted to gradually exhaust their hydrogen fuel, cool, and fade directly into white dwarfs, bypassing the red giant phase entirely.

Question 34 (a)

Criteria	Marks
Compares the properties of alpha, beta, and gamma radiation and discusses how each type contributes to the transmutation of the isotope, explaining changes in atomic number and mass number associated with each type of decay.	4
Explains the properties of alpha, beta, and gamma radiation in detail, including their effects on interacting materials and their relative ionizing capabilities.	3
Compares properties of all three types of radiation (alpha, beta, and gamma), mentioning at least one distinguishing feature for each (e.g., mass, charge, penetrating power).	2
Identifies basic properties of at least two types of radiation (alpha, beta, or gamma).	1

Sample answer:

Alpha, beta, and gamma radiations are three distinct types of radiation emitted by unstable nuclei during radioactive decay. Alpha radiation consists of helium nuclei and carries a +2 charge. It is the heaviest and most charged among the three, which makes it the least penetrating but highly ionizing. Beta radiation is composed of high-energy, high-speed electrons or positrons, carrying a -1 or +1 charge, respectively. Beta particles are lighter than alpha particles and can penetrate further into materials but are less ionizing. Gamma radiation, on the other hand, consists of photons, carries no charge, and is the most penetrating but the least ionizing of the three.

In the transmutation of a radioactive isotope, alpha decay decreases the mass number by 4 and the atomic number by 2, essentially transforming the element. Beta decay changes the neutron to a proton or vice versa, thus altering the atomic number and leading to the formation of a new element. Gamma decay, however, involves the release of excess energy from a nucleus without changing the number of protons or neutrons, thereby not leading to transmutation but stabilizing the isotope.

Question 34 (b)

Criteria	Marks
Correctly calculates remaining mass.	2
Attempts to calculate remaining mass using appropriate formula and half-life.	1

Sample answer:

$N_t = N_o \left(\frac{1}{2}\right)^n$

$N_t = 10 \left(\frac{1}{2}\right)^3$

$N_t = 1.25 \text{ g}$

Physics

2024 Trial HSC Examination Mapping Grid

Part A

Question	Marks	Outcome
1	1	PH12-12
2	1	PH12-13
3	1	PH12-14
4	1	PH12-13
5	1	PH12-15
6	1	PH12-13
7	1	PH12-15
8	1	PH12-14
9	1	PH12-13
10	1	PH12-15
11	1	PH12-12
12	1	PH12-14
13	1	PH12-15
14	1	PH12-12
15	1	PH12-14
16	1	PH12-12
17	1	PH12-14
18	1	PH12-13
19	1	PH12-12
20	1	PH12-12

Part B

Question	Marks	Outcome
21 (a)	4	PH12-12
21 (b)	4	PH12-12
22 (a)	3	PH12-13
22 (b)	5	PH12-13
22 (c)	4	PH12-13
23	6	PH12-12

Question	Marks	Content
24	4	PH12-14
25 (a)	4	PH12-14
25 (b)	2	PH12-14
26	4	PH12-13
27	6	PH12-14
28	6	PH12-12
29	4	PH12-13
30	6	PH12-15
31 (a)	2	PH12-14
31 (b)	2	PH12-14
32	4	PH12-14
33	4	PH12-15
34 (a)	4	PH12-15
34 (b)	2	PH12-15