Student Name:…….……………………..

Quality Assessment Tasks

2021 Higher School Certificate
Trial Examination
Physics

General Instructions

- Reading time - 5 minutes
- Working time 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheets and periodic table are provided at the back of this paper

Total marks: 100

Section 1– 20 marks

- Attempt Questions 1-20
- Allow about 35 minutes for this part

Section 2 - 80 marks

- Attempt Questions 21-36
- Allow about 2 hours and 25 minutes for this part
- For all questions involving calculations in this section show relevant working

PHYTR21_EXAM

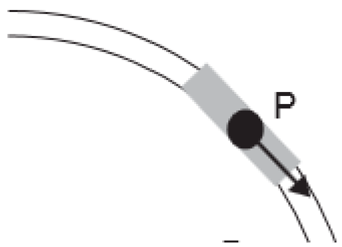
Section I
20 marks

Attempt Questions 1-20
Allow about 35 minutes for this part

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

1 The safe speed for a train taking a curve on level ground is determined by the force that the rails can take before they move sideways relative to the ground. From time to time trains derail because they take curves at speeds greater than that recommended for safe travel.

The figure shows a train at position P taking a circular curve of radius 200 m on horizontal ground, at a constant speed of 60 kmh^{-1} which happens to be the safest speed to prevent derailment for that curvature of track. The radius of a curve that could cope with a train travelling at 120 kmh^{-1} is:



(A) 50 m.

(B) 80 m.

(C) 400 m.

(D) 800 m.

2 Newton was the first person to quantify the gravitational force between two masses *M* and *m*, with their centres of mass separated by a distance *r* as

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

where G is the universal gravitational constant.

For a mass *m* on the surface of Earth (mass M) this becomes $F = gm$, where

$$g = \frac{GM}{r^2}$$

Which one of the statements does NOT describe the term g?

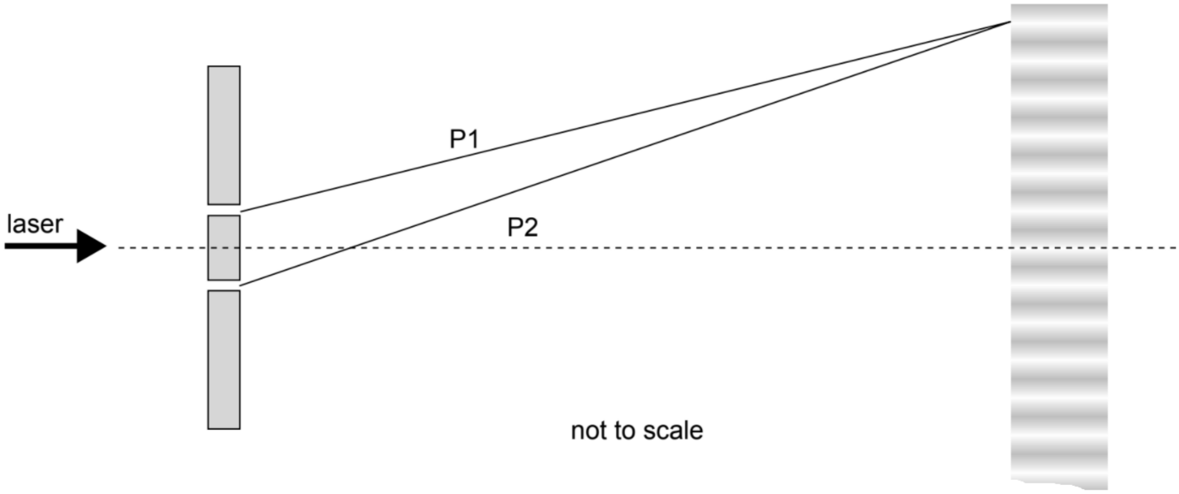
(A) g is the gravitational field at the surface of Earth.

(B) g is the force that a mass m feels at the surface of Earth.

(C) g is the acceleration of a free body at the surface of Earth.

(D) g is the force experienced by a mass of 1 kg at the surface of Earth.

3 The image below is that seen when observing a demonstration of Young's double slit experiment.



If the laser was changed from green with a wavelength of 532 nm to a red laser of 633 nm wavelength the pattern on the wall would do what?

(A) Stay the same.

(B) The alternating bands of bright light would become brighter.

(C) The alternating bands of bright light would become closer together.

(D) The alternating bands of bright light would become more separated.

4 A stone is thrown horizontally with an initial velocity of 8 ms^{-1} from a 10-metre-high cliff. How long is it before the stone hits the ground?

(A) 1.4 s

(B) 1 .7 s

(C) 1.02 s

(D) 2.04 s

5 A tyre technician is tightening a wheel nut on a tesla car. The car wheel nuts require a torque to be applied at 175 Nm to be tightened to manufacturer's specifications. Assuming the technician is using a 60 cm long torque wrench, how much force must be applied to tighten the wheel nut to specifications if the angle of the force applied to the wrench is $\Theta = 60^{o}$ at the circumference.

(A) 146 N

(B) 583 N

(C) 253 N

(D) 292 N

6 If the planet Earth rotates about its axis once every 24 hours, what is its angular speed?

(A) 7.292×10^{-5} rad s^{-1}

(B) 1.721×10^{-3} rad s^{-1}

(C) 7.272×10^{-5} rad s^{-1}

(D) 2.618×10^{-1} rad s^{-1}

7 Two parallel wires separated by a distance of 4 cm each carry a current of 2 A in the same direction. What is the magnetic field strength between the wires at a point in the plane of the two wires that is equidistant from both wires?

(A) 0 T

(B) 4.8×10^{-3} T

(C) 1×10^{-5} T

(D) 4.8×10^{-5} T

8 A charged particle moves across a magnetic field B at a velocity v. The force it experiences is:

(A) in the direction of v and perpendicular to B.

(B) in the direction of B and perpendicular to v.

(C) perpendicular to the direction of both v and B.

(D) the direction of the force depends on the direction of v only and is perpendicular to v.

9 An electron is accelerated from rest across a vacuum by a potential difference, reaching a velocity of 6.5×10^{3} ms^{-1}. It then enters a perpendicular magnetic field of 2.4×10^{-3} T, following a circular path. What is the radius of that path?

(A) 0.154 m

(B) 5.93 m

(C) 1.54×10^{-5} m

(D) 5.93×10^{7} m

10 A long tightly wound circular solenoid has 4000 turns per metre with each coil having an area of 0.01 m^2. If a current of 6 A passes through the coil which is air filled, what is the magnetic flux in a cross section of the coil?

(A) $3.01\ x\ 10^{-4}\ Wb$

(B) $2.40\ x\ 10^{-2}\ Wb$

(C) $3.01\ Wb$

(D) $240\ Wb$

11 A ball of 600 grams is kicked at an angle of 30° with the ground with an initial velocity of 28 ms^{-1}. The ball lands at the same height as from which it was kicked.
What is the time of flight of the ball?

(A) 2.86 s

(B) 1.43 s

(C) 1.51 s

(D) 3.02 s

12 When a positron of negligible kinetic energy meets and annihilates an electron of negligible kinetic energy, a pair of photons is produced.
What is the wavelength of the radiation produced by the annihilation?

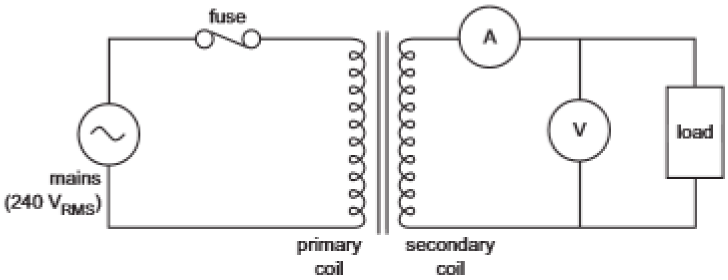
(A) $2.425 \times 10^{-12} m$

(B) $8.195 \times 10^{-14}\ m$

(C) $1.247 \times 10^{-24}\ m$

(D) $4.850 \times 10^{-12}\ m$

13 The diagram below shows a circuit diagram of a common electrical device.



A series of measurements were made in different parts of the device and are recorded in the table.

Primary coil		Secondary coil	
$I_{p\,RMS}$	$V_{p\,RMS}$	$I_{s\,RMS}$	$V_{s\,RMS}$
	240 V_{RMS}	2.2 A_{RMS}	11.3 V_{RMS}

What is the missing value of I?

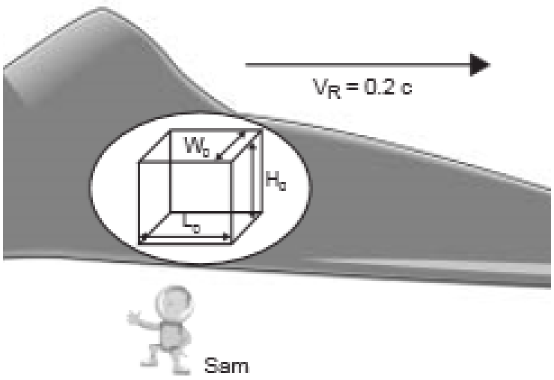
(A) 1.035 A

(B) 0.1035 A

(C) 10.35 A

(D) 103.5 A

14 A container inside a ship is observed through a window by Sam, a cosmonaut, floating freely in space. Sam observes the rocket ship travelling past at a constant speed $V_R = 0.2$ c.



The dimensions of the container, as measured by astronauts inside the rocket ship, are shown in the figure, and are the proper length L_0 that is parallel to the direction of motion of the rocket ship, the proper width W_0 that is perpendicular to the direction of motion of the rocket ship, the proper height H_0 that is perpendicular to the direction of motion of the rocket ship.
How would the dimensions as observed by Sam be best described?

(A) $L < L_0$, $W < W_0$, $H < H_0$

(B) $L < L_0$, $W < W_0$, $H = H_0$

(C) $L > L_0$, $W = W_0$, $H = H_0$

(D) $L < L_0$, $W = W_0$, $H = H_0$

15 When a charge is accelerated through a potential difference of 2000 V, its kinetic energy increases from 2.0×10^{-5} J to 6.0×10^{-5} J. What is the magnitude of the accelerated charge?

(A) 4.0×10^{-2} C

(B) 2.0×10^{-8} C

(C) 1.2×10^{-3} C

(D) 1.6×10^{-19} C

16 An incident beam of light of a known intensity and frequency *f*, which is greater than the threshold frequency, is focused on a copper metal block under vacuum. The stopping voltage is measured as V_o. What happens to the emitted photelectron current and the stopping voltage when the wavelength of the light is decreased and the intensity is increased?

(A) The current increases and the voltage decreases.

(B) The current increases and the voltage increases.

(C) The current decreases and the voltage increases.

(D) The current decreases and the voltage decreases.

17 The electron accelerator at the ARPANSA laboratory at Yallambie, near Melbourne, can accelerate an electron to a speed such that its mass appears to increase by a factor of 22.

What is the kinetic energy of the electron as it leaves the accelerator?

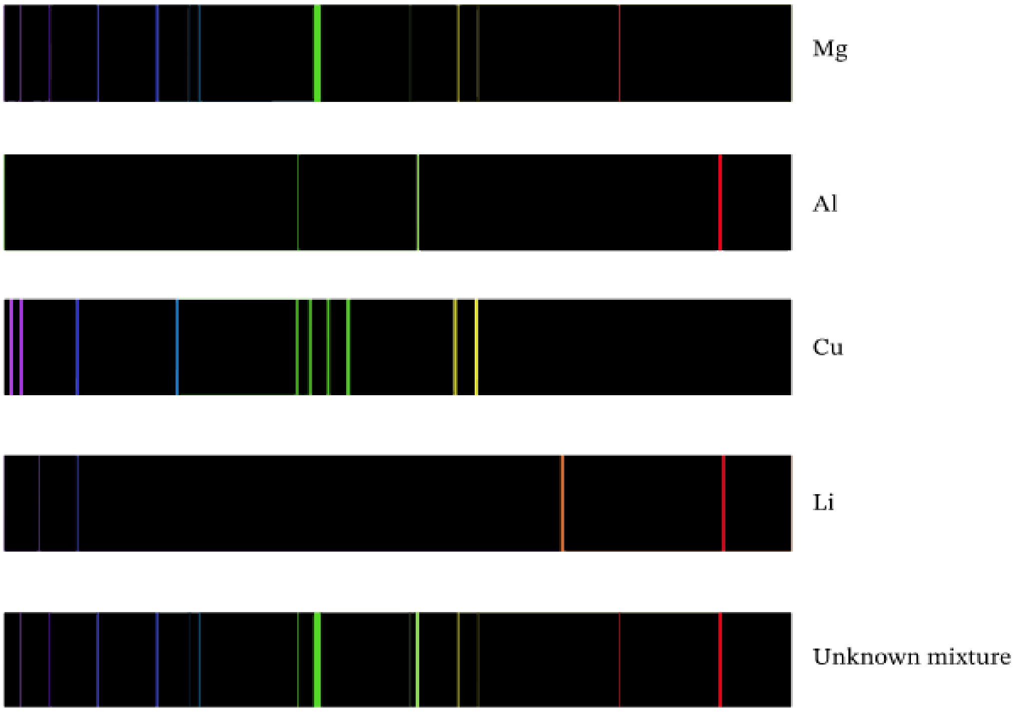
(A) 9.02×10^{-13} J.

(B) 1.72×10^{-12} J.

(C) 1.80×10^{-13} J.

(D) 5.11×10^{-6} J.

18 The emission spectra from a selection of metals and an unknown mixture of metals is shown in the figure below.



What metals are in the unknown mixture?

(A) Lithium and copper.

(B) Aluminium and copper.

(C) Aluminium and magnesium.

(D) Lithium, aluminium and magnesium.

19 The age of the Solar System was first established in1953. Clair C. Patterson of the California Institute of Technology used a uranium-lead clock to analyse rock samples that contained amounts of uranium-235 and its daughter element lead-207. Patterson was able to establish that 99.609375% of uranium-235 had transformed into lead-207 since the elements had been incorporated into the rock. Statistically the half-life of U-235 $\rightarrow$ Pb-207 takes 7.10×10^8 years. Using this data, estimate the age of the Solar System.

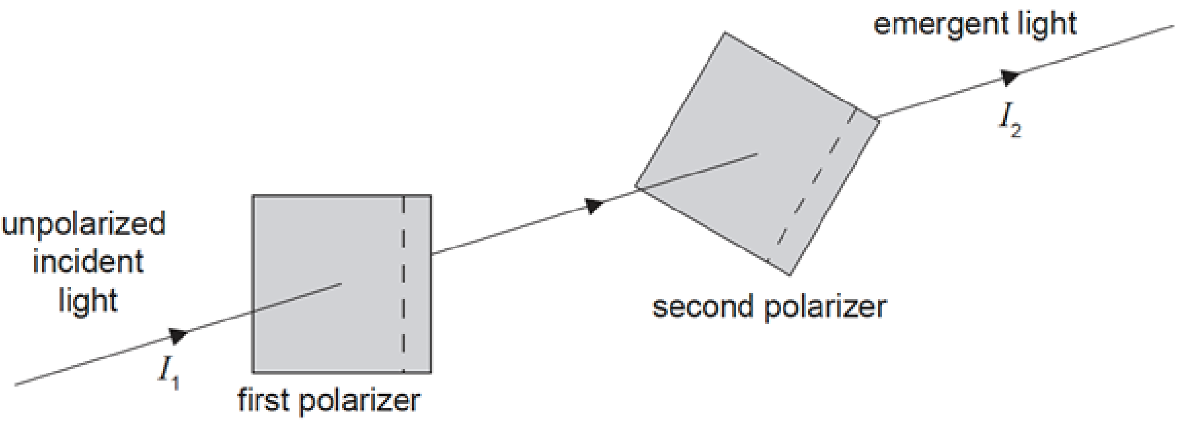
(A) 5.700 billion years.

(B) 4.620 billion years.

(C) 5.680 million years.

(D) 5.680 billion years.

20 Two polarisers have polarising axes that make an angle of 30˚ to each other. Unpolarised light of intensity I_1 is incident on the first polariser so that light of intensity I_2 emerges from the second polariser, as shown below.



The cosine of 30˚ is $\frac{\sqrt{3}}{2}$. What is the ratio of the light intensity I_2 to I_1?

(A) $\frac{3}{8}$

(B) $\frac{8}{3}$

(C) $\frac{2}{3}$

(D) $\frac{3}{\sqrt{2}}$

Section II - 80 marks
Attempt Questions 21-36
Allow about 2 hours and 25 minutes for this part

Answer the questions in the spaces provided.
These spaces provide guidance for the expected length of response.
Extra writing space is provided on pages 29 and 30. If you use this space, clearly indicate which question you are answering.

Question 21 (3 marks)

A satellite is in a circular orbit of radius 3.8×10^8 m around planet Xu with a period of 2.36×10^6 s. Calculate the mass of Xu. **3**

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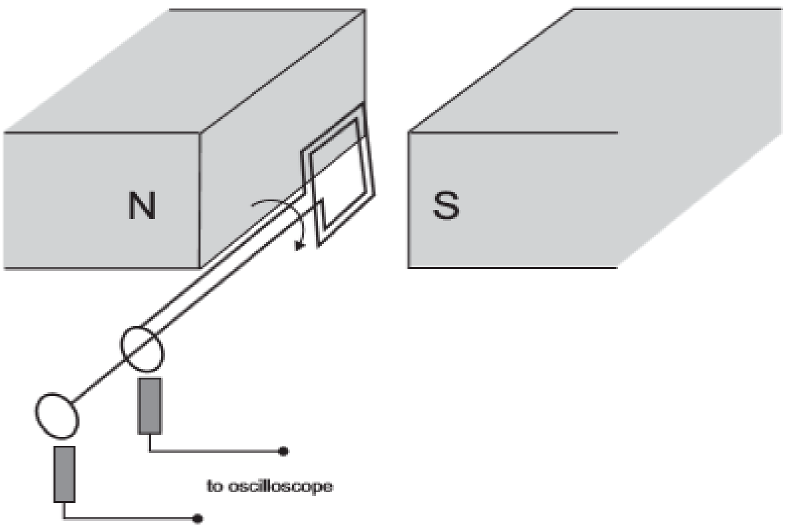
Question 22 (3 marks)

Some students are studying the emf induced by a magnetic field in a coil of wire. Their experimental apparatus consists of a coil of 50 turns of wire in a magnetic field of 2×10^{-1} T.



With the coil perpendicular to the magnetic field as shown in figure, the flux through the coil is 8×10^{-4} Wb. Calculate the cross-sectional area of the coil and the emf generated if the coil was rotated by 180^{o} in 0.2 s. **3**

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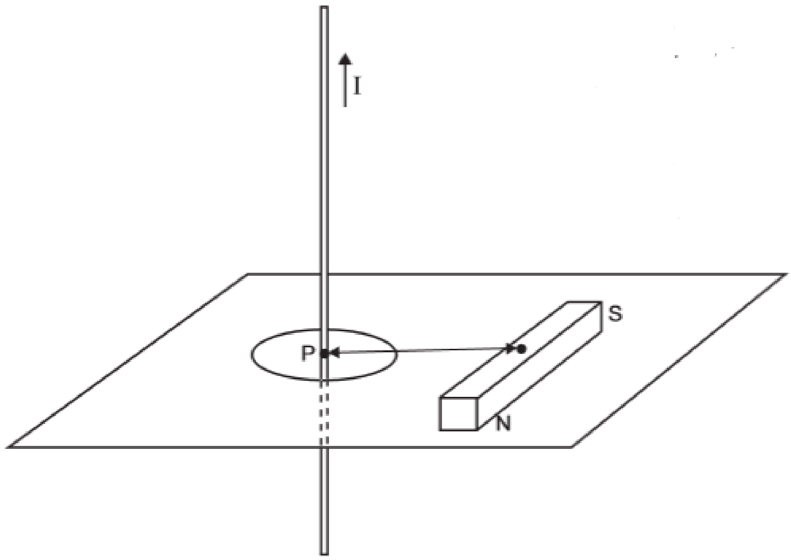
Question 23 (3 marks)

A vertical wire carrying a current I is placed opposite the centre of a permanent bar magnet as shown in the figure.



Explain why the wire moves and identify the direction of that movement of the wire with respect to the magnet when a current is switched on. **3**

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Question 24 (3 marks)

A year 12 physics class is studying Einstein's special relativity. The teacher proposes a thought experiment: Imagine you are travelling at a speed of $3 \times 10^{8} ms^{-1}$ alongside a beam of light. What would you measure the speed of a beam of light to be?

Two students put up their hands to offer an answer.
Heinrich says: You would measure the beam of light to be moving away from you at $3 \times 10^{8} ms^{-1}$.
Alberta says: You would measure the beam of light to be at rest with respect to yourself: that is, its speed would be 0 ms^{-1}.

Identify which student's answer is consistent with Einstein's theory of special relativity and explain your reasoning for that choice. **3**

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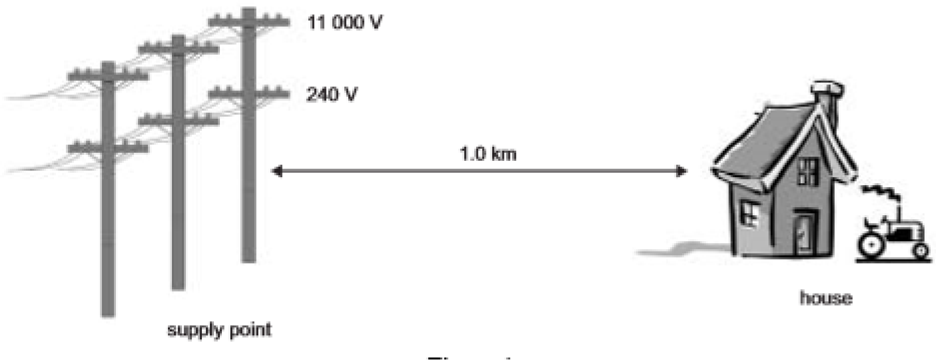
Question 25 (5 marks)

An electrician is planning a new power supply to a farmhouse. The house is 1.0 km from the existing supply. There is a choice of either a high voltage 11000 V_{RMS} AC or a lower voltage 240 V_{RMS} AC supply at this location. The 11000 V_{RMS} AC supply would require the farmer to install a step-down transformer.

All of the appliances in the house require 240 V_{RMS} AC and the expected maximum power demand is 12 000 W. The owner is keen to avoid the cost of a transformer, and so initially the electrician plans to use a 1.0 km supply line to the house from the 240 V_{RMS} supply. The electricity is metered from next to the supply lines so any energy lost during transmission to the farm must be paid for.



The electrician initially connects the house to the 240 V_{RMS} supply using lines with a total resistance of 2.0 Ω. Some of the appliances in the house are turned on to test the new supply. Measurements reveal that, under these test conditions, the current flowing is 50 A.

(a) Calculate power loss in the transmission wires when the farmhouse power demand is 12000 W. **2**

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(b) The electrician suggests that using the 11 000 V_{RMS} supply with a step-down transformer at the house could deliver the same amount of power to the house, with a significant reduction in the power loss in the supply lines.

Explain why using a high voltage 11000 V_{RMS} rather than the 240 V_{RMS} supply would reduce the power loss in the lines. **3**

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Question 26 (5 marks)

Fred is playing tennis. He serves the ball so that it leaves the racket 3.0 m above the ground. The ball leaves the racket at an angle of 8 degrees to the horizontal. At its maximum height it has a speed of $20\ ms^{-1}$.

(a) At what speed, relative to the ground, did the ball leave Fred's racket? **2**

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(b) At what horizontal distance from the point where the ball leaves the racket will it hit the ground? **3**

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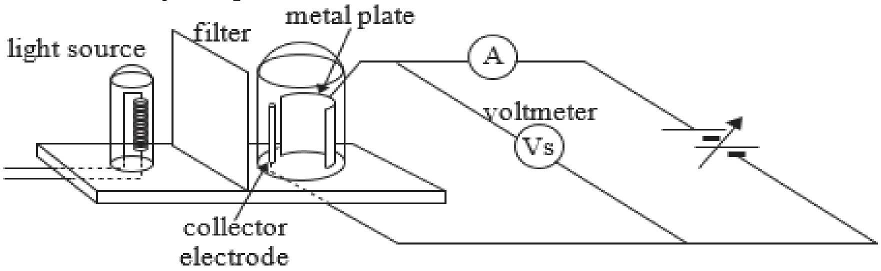
Question 27 (5 marks)

As part of a depth study investigation of the quantum model of light, a student used the apparatus below to study the photoelectric effect.



(a) What was the evidence from the photoelectric effect that demonstrated inconsistency with the wave model of light? **2**

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(b) Light of known wavelength was shone onto the metal plate and it was noted that photo electrons were emitted from the plate only at wavelengths above $300\ nm$. What was the energy of the longest wavelength radiation units that caused the ejection of photoelectrons? **3**

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Question 28 (5 marks)

Unpolarised light of intensity *I* falls normally onto a sheet of polaroid. The light transmitted through the polaroid falls on a second sheet of polaroid. A light meter determines the light transmitted through the second sheet of polaroid to be of intensity $0.2I$.

(a) At what angle was the second sheet of polaroid rotated away for the position that would allow maximum transmittance through both polaroid sheets? **3**

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(b) At what angle to the second polaroid sheet would a third sheet of polaroid need to be introduced to minimise light transmittance? **2**

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Question 29 (5 marks)

Einstein needed to make two assumptions in his development of the special relativity theory. They are his postulates:

- the speed of light in a vacuum is an absolute constant
- all inertial frames of reference are equivalent

Identify and analyse five pieces of evidence that have been gathered supporting that the postulates are true. **5**

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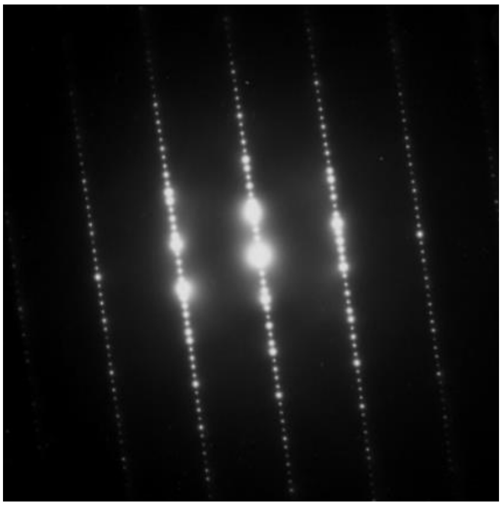
Question 30 (5 marks)

The image below shows a typical pattern obtained in a transmission electron microscope and is produced by a parallel beam of high-speed electrons interacting with a crystalline substance.



(a) Discuss the implications of this pattern for the failure of classical physics to explain the properties of the electron. **3**

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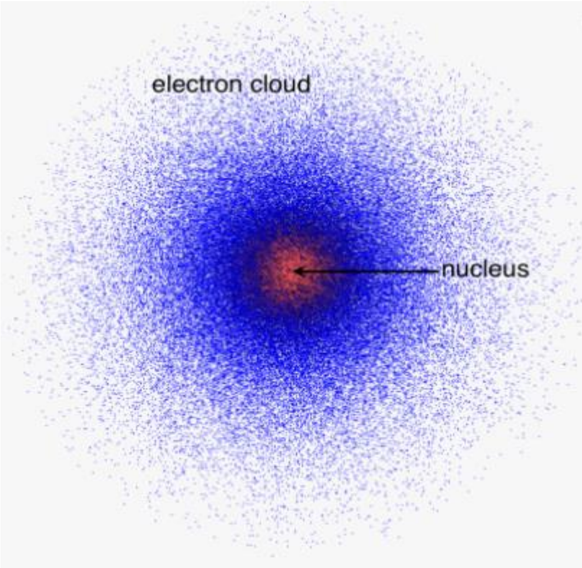
(b) The image below shows a representation of the Schrodinger model of the atom.



Analyse Schrodinger's contribution to this advanced understanding of the model of the atom. **2**

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Question 31 (6 marks)

(a) Compare and contrast Lenz's Law and Faraday's Law. **4**

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(b) Describe an example of Lenz's Law and Faraday's Law in a practical operational device. **2**

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Question 32 (4 marks)

There are consequences that derive from relativistic momentum as particles approach the speed of light.

(a) Explain why a particle with mass cannot reach the speed of light. **2**

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(b) The Large Hadron Collider aims to have collisions between protons travelling at 99.9999991% of the speed of light. Calculate the relativistic momentum of one of these protons. **2**

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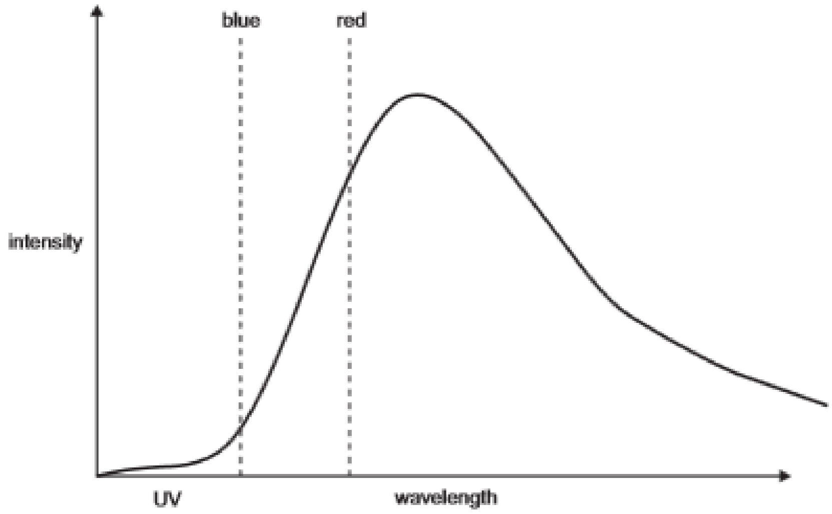
Question 33 (5 marks)

(a) The figure below shows the spectrum produced from an incandescent light globe that produces light from the effect of the resistive properties of a tungsten filament.



Discuss why it is said that incandescent light globes are inefficient at producing visible light using the information in the graph to support your answer. **2**

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(b) Why do curves such as the one produced above provide support for the particle model of light? Support your answer with a relevant equation. **3**

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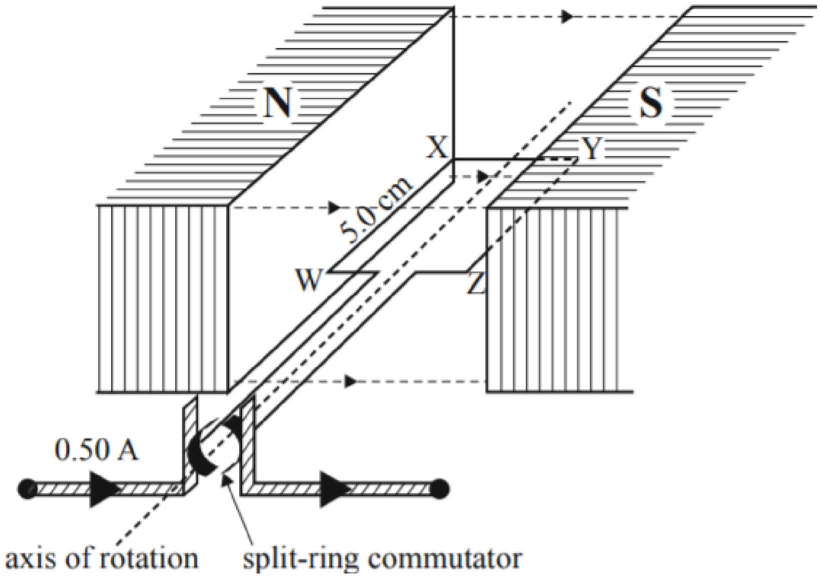
Question 34 (6 marks)

A model representing a motor is shown below.



(a) Describe what would happen to the motor if it was connected to an AC supply. **2**

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(b) What modification would be required to turn the motor into an AC motor? **2**

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(c) Describe the output voltage on an oscilloscope screen that you could expect from rotating the motor coil through three full turns at a constant speed **starting from a position which is 90º from that shown in the diagram.** **2**

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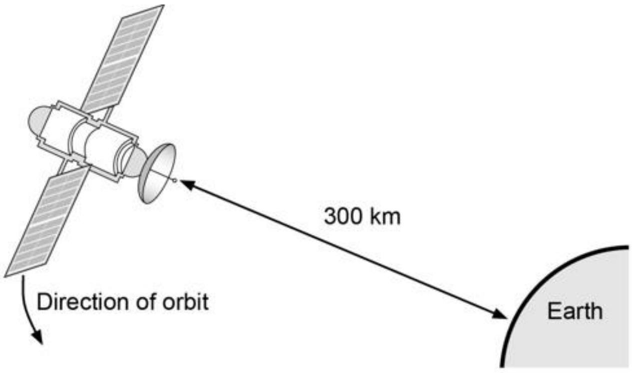
Question 35 (7 marks)

A 100 kg satellite is placed into a near circular orbit with an average path radius of 6.671×10^6 m around the Earth.



(a) Calculate the period of the satellite. **2**

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(b) Calculate the speed of the satellite. **2**

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(c) Explain why a satellite of 1000 kg at the same radius would have the same period. **3**

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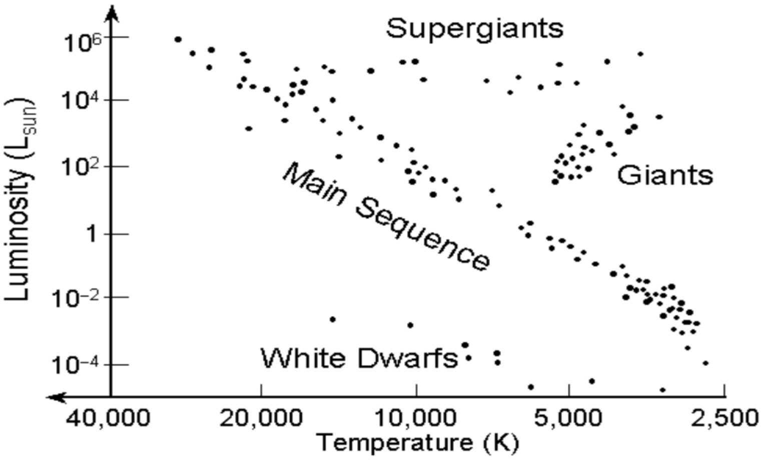
Question 36 (10 marks)



The diagram above represents a version of the Hertzsprung- Russell diagram.

(a) (i) Clearly label the area on the Hertzsprung -Russell where the stars would be expected to predominantly obtain their energy via the carbon-nitrogen-oxygen cycle. **1**

(ii) Describe the carbon-nitrogen-oxygen cycle. **3**

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(b) Analyse one other nucleosynthesis reaction other than the proton-proton chain and the carbon-nitrogen-oxygen cycle that provides energy in stars. **3**

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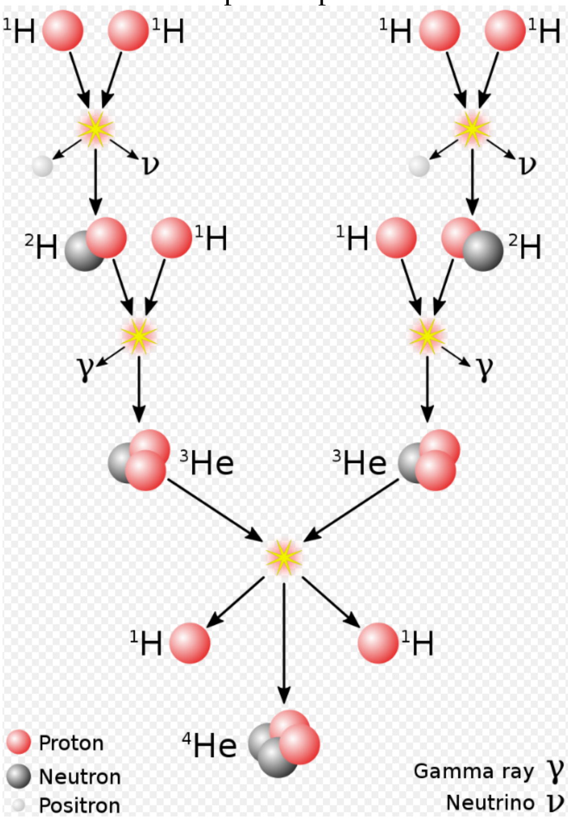
(c) The figure shows a schematic of the proton-proton chain.



Calculate the energy produced in joules from the production of a single atom of $^4He_2$ via the proton-proton chain. **3**

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Section II extra writing space
If you use this space, clearly indicate which question you are answering.

Section II extra writing space
If you use this space, clearly indicate which question you are answering.

Student Name:……………..…..……………………..

PHYSICS – MULTIPLE-CHOICE ANSWER SHEET

ATTEMPT ALL QUESTIONS

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

2021 Higher School Certificate
Trial Examination
Physics
Marking Guidelines

Section I

Multiple-choice Answer Key

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

Section II

Question 21

Criteria	Marks
• A correct calculation of the mass of Xu including correct units	3
• A correct calculation of the mass of Xu or a partially correct calculation of the mass of Xu including correct units	2
• A partially correct calculation of the mass of Xu	1

Sample answer

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

$$M = \frac{r^3 4\pi^2}{GT^2}$$

$$M = \frac{(3.8 \times 10^8)^3 \times 4 \times \pi^2}{6.67 \times 10^{-11} \times (2.36 \times 10^6)^2}$$

$M = 5.831 \times 10^{24}$ kg

Question 22

Criteria	Marks
• A correct calculation of the cross-sectional area of the coil, $\Delta\Phi$ and the emf generated	3
• A calculation of the any two of the cross-sectional area of the coil, $\Delta\Phi$ and the emf generated	2
• A calculation of the cross-sectional area of the coil or $\Delta\Phi$ or the emf generated	1

Sample answer

$\Phi = BA$

$$A = \frac{\Phi}{B} = \frac{8 \, x \, 10^{-4}}{2 \, x \, 10^{-1}} = 0.004 \, m^2$$

$\Phi i = 8 \text{ x } 10^{-4} \, Wb$
After 180^o rotation $\Phi f = -8 \text{ x } 10^{-4} \, Wb$

$$\Delta\Phi = \Phi f - \Phi i = -8 \text{ x } 10^{-4} - 8 \, x \, 10^{-4} = -1.6 \, x \, 10^{-3} \, Wb$$

$$emf = -N\frac{\Delta\Phi}{\Delta t} = -50 \, x \, \frac{-1.6 \, x \, 10^{-3}}{0.2} = 0.4 \, V$$

Question 23

Criteria	Marks
• A thorough explanation of the nature of the magnetic field surrounding the current carrying wire and its interaction with the magnetic field of the bar magnet to produce a force on the wire to the left away from the bar magnet	3
• An incomplete explanation of the nature of the magnetic field surrounding the current carrying wire and its interaction with the magnetic field of the bar magnet to produce a force on the wire to the left away from the bar magnet	2
• Some relevant information	1

Sample answer
The current flowing in the wire produces a magnetic field that takes the form of concentric circles arranged at right angles to the wire. The magnetic field is strongest in the area closest to the wire, and its direction depends upon the direction of the current that produces the field. In this case since the direction of the current is up the page the current carrying wire will have a magnetic field surrounding it that when viewed from above appears to be directed anticlockwise. The interaction between the lines of the magnetic field coming out of the bar magnet at the north pole and entering at the south pole will be that of like poles interacting and so will result in the wire deflecting away from the bar magnet to the left.

Question 24

Criteria	Marks
• A correct identification that Heinrich's answer is consistent with Einstein's theory of relativity AND a reference to Einstein's postulate that the speed of light in vacuum is the same in all inertial frames regardless of the motion of the observer or source • A correct reference to the specific situation discussed in the question	3
• An identification that Heinrich's explanation is consistent with that of Einstein's theory of special relativity with some reference to why without clearly stating Einstein's postulate	2
• An identification that Heinrich's explanation is consistent with that of Einstein's theory of special relativity	1

Sample answer

Heinrich's answer is consistent with Einstein's theory of special relativity. Einstein's special relativity is based on the postulate that the speed of light in a medium is the same in all inertial reference frames regardless of the motion of the observer or source. This postulate therefore would mean that the beam of light would appear to be travelling at the speed of light no matter what the velocity of the observer.

Question 25
25 (a)

Criteria	Marks
• A complete, correct solution	2
• A partially complete solution	1

Sample answer

When the power demand in the house is 12000 W, the current flow in the transmission wires is $I = \frac{P}{V} = \frac{12000}{240}$= 50 amps. Because of Kirchhoff's current law current in = current out so the current in the transmission lines is also 50 amps.
Power loss in the transmission lines can be calculated from

$$P = I^2R = 50^2 \times 2 = 5000\ W.$$

25 (b)

Criteria	Marks
• Makes a thorough comparison between the power loss using the 240 V and 11000 V supply with a transformer that describes and justifies why the higher voltage would be more efficient by reducing power loss in the transmission line	3
• Makes a comparison between the power loss using the 240 V and 11000 V supply with a transformer that identifies and describes why the higher voltage would be more efficient by reducing power loss in the transmission line	2
• Identifies that the 11000 V supply transmission is more efficient and describes a reason why	1

Sample answer

Because using the 240 V supply the power loss during transmission is 5000 W if the house is using 12000 W of power but if the house used an 11000 V supply for most of the transmission the current flowing in the transmission lines would be

$I = P / V$

$I = 12000 / 11000 = 1.0909$ A

The power loss would therefore be

$P = I^2R = 1.0909^2 \times 2 = 2.38$ W

This transmission power loss is negligible compared to 5000 W. The transformer close to the home would therefore be a significantly more efficient option as most of the 5000 W power transmission loss would simply be converted to unproductive heat loss.

Question 26
26 (a)

Criteria	Marks
• Correct calculation • Provides relevant working	2
• Provides relevant working	1

Sample answer

$20 / v = \cos 8^{o}$

$v = 20 / \cos 8 = 20.197\ ms^{-1}$

26 (b)

Criteria	Marks
• Correct answer • Provides relevant and correct working	3
• Provides relevant and correct working with a calculation error	2
• Provides some relevant and correct working	1

Sample answer

$\tan 8 = \frac{u_y}{20}$

$u_y = 20 \times \tan 8 = 2.8108\ ms^{-1}$

$a = -9.8\ ms^{-2}$

$s = -\ 3.0\ m$

$v^2 = u^2 + 2as = (2.8108)^2 + 2 \times -9.8 \times -3.0 = 66.7$
$v = \sqrt{66.7} = -8.167\ ms^{-1}$

$v = u + at$

$t = \frac{v - u}{a} = \frac{-8.167 - (2.8108)}{-\ 9.8} = 1.120\ s$
range $= u_x \times t = 20 \times 1.120 = 22.40\ m$

Question 27
27 (a)

Criteria	Marks
● Describes evidence that supports a particle model of light ● Describes why a wave model is not supported	2
● Describes some aspects of evidence for a particle model of light derived from the photoelectric effect observations	1

Sample answer

Classical physics predicted that energy from radiation could be absorbed slowly over time, until electrons had gained sufficient energy to escape the surface. Unless the light was of a high enough frequency, this did not happen. Electrons were released for even very low intensity radiation if it was above the threshold frequency. This observation was unable to be explained by classical wave physics. Einstein proposed that light consists of packets of energy called "photons," and that the quantity of energy of each photon is fixed and depends on its frequency. The particle model of light predicts that individual photons knock out electrons and that only photons with enough energy, that is above the threshold frequency, can do this.

27(b)

Criteria	Marks
● Correctly identifies the energy ● Applies an appropriate method to determine the energy of the longest wavelength of radiation that causes electrons to be ejected ● Provides relevant calculations	3
● Applies an appropriate method to determine the energy of the longest wavelength of radiation that causes electrons to be ejected ● Provides relevant calculations	2
● Provides a relevant calculation	1

Sample answer

$$f = \frac{c}{\lambda} = \frac{3\times10^{8}}{300\times10^{-9}} = 1 \times 10^{-15} Hz$$

$$E = hf = 6.626 \times 10^{-34} \times 1 \times 10^{-15} = 6.626 \times 10^{-19} J$$

Question 28
28 (a)

Criteria	Marks
• A correct solution	3
• A partially correct solution	2
• States that the intensity is 0.5I after the analyser	1

Sample answer

After passing through the polariser the intensity of the beam is 0.5I.
After passing through the analyser the intensity is 0.2I

$$0.2I = 0.5I cos^2\theta$$

$$\frac{0.2I}{0.5I} = cos^2\theta$$

$$0.4 = cos^2\theta$$

$$cos\theta = \sqrt{0.4}$$

$$\theta = 50.77°$$

The second sheet is rotated through 50.8°

28 (b)

Criteria	Marks
• A correct solution	2
• A partially correct solution	1

Sample answer

The third sheet would need to be introduced such that it was rotated to 90 degrees to the analyser (sheet 2) eg 140.8 degrees to the polarizer (sheet 1).

Question 29

Criteria	Marks
• Identifies and analyses five pieces of evidence related to Einstein's postulates	5
• Identifies and analyses four pieces of evidence related to Einstein's postulates	4
• Identifies and analyses three pieces of evidence related to Einstein's postulates	3
• Identifies and analyses two pieces of evidence related to Einstein's postulates	2
• Identifies and analyses one piece of evidence related to Einstein's postulates	1

Sample answer

Physicists have never measured any matter travelling faster than the speed of light suggesting it is a limiting speed. This supports that the speed of light is an absolute constant.
The particles from a Supernova can travel out at speeds which are 3% the speed of light. If the speed of light depended on the speed of the source then there should be some observable difference between the fragments which are moving away from us and those which are moving toward us. Astronomers have observed no such difference. This supports the postulate that all inertial frames of reference are equivalent.

When cosmic rays from the Sun interact with the upper atmosphere, muons are produced in the upper atmosphere then travel toward the Earth at a speed close to the speed of light. Considering the lifetime of a muon and their relativistic speed in terms of Newtonian physics, it is predicted that on average, a muon would travel 658m. But muons have been detected at the surface of the Earth so this means that they have existed for around 23 times their expected lifetime. Time dilation predicts that this result is to be expected. An observer on Earth sees the muons' time run slower. This means that the muons will exist long enough to be observed on the surface supporting that all inertial frames of reference are equivalent.

In 1971 an experiment was conducted using three synchronised atomic clocks. One was stationary on the Earth. From that location, passenger jet planes flew east and west each carrying one of the atomic clocks. The jets flew around the Earth twice and returned. The atomic clocks in the planes were compared with the atomic clock that was stationary and were found to have different times to the stationary clock as predicted by relativity showing that all inertial frames are equivalent by demonstrating time dilation.

Recent experiments have tested time dilation predictions to high precision. In 2014 a team of physicists conducted experiments using particle accelerators. They measured the rates of transitions between energy states of atoms moving at one-third the speed of light in the particle accelerator. They were then able to compare these rates with the rates of transitions of the same atoms at rest in the laboratory. The difference in rates matched Einstein's predictions of time dilation to the highest levels of precision showing that all inertial frames are equivalent by demonstrating time dilation.

Question 30
30 (a)

Criteria	Marks
• The pattern is similar to light diffraction from a single narrow slit • Identifies the image as evidence for electron or matter diffraction- a wave phenomena • Explains the significance of matter acting as a wave - de Broglie predicted matter would have a wavelength that would be dependent on its momentum and high momentum electrons show the behaviour supporting the quantum theory	3
• Two relevant pieces of information	2
• One relevant piece of information	1

Sample answer

The image looks like a light diffraction pattern produced on a screen by a coherent, monochromatic light source passing through a slit. The image is showing electron diffraction, interference effects due to the wave-like behaviour of a beam of electrons. According to Louis de Broglie and quantum theory, electrons and other particles have wavelengths that are inversely proportional to their momentum. Consequently, high-speed electrons should have short wavelengths, some of which are comparable to the spacings between atomic layers in crystals. A beam of high-speed electrons can hence undergo diffraction if directed through thin sheets of material or when reflected from crystal faces and that diffraction can be imaged as though on a screen thus the picture suggests the wavelike nature of high-speed electron beams supporting the predictions of de Broglie and supporting quantum mechanics.

30 (b)

Criteria	Marks
• Identifies the features of the Schrödinger model • Describes the implications of the model for locating an electron around a nucleus	2
• Identifies the features of the Schrödinger model	1

Sample answer

The Schrödinger model assumes that the electron is a wave and tries to describe the regions in space, or orbitals, where electrons are most likely to be found. Instead of trying to tell us where the electron is at any time, the Schrödinger model describes the probability that an electron can be found in a given region of space at a given time. This model no longer tells us where the electron is but it tells us where it might be. Where the cloud is most dense in the figure, the probability of finding the electron is greatest, and conversely, the electron is less likely to be in a less dense area of the cloud.

Question 31
31 (a)

Criteria	Marks
• Comprehensively describes similarities and differences of the laws	4
• Describes two similarities and a difference or two differences and a similarity of the laws	3
• Describes a similarity and a difference of the two laws OR describes two similarities or two differences of the two laws	2
• Describes a similarity or a difference of the two laws	1

Sample answer

Lenz's law is a consequence of conservation of energy applied to electromagnetic induction described by Faraday's law. **Faraday's law** tells us the magnitude of the EMF produced. **Lenz's law** tells us the direction that the current will flow. It states that the direction is always such that it will oppose the change in flux which produced it.
Faraday's law states the following:
When a magnetic field is incident on a coil of conductor, the magnitude of the electromotive force (EMF) induced in the coil is directly proportional to the rate of change of the inducing magnetic field perpendicular to the axis of the coil. If induction is in a transformer, the magnetic field generated by a current must be changing in time (either oscillating, rising, or falling) in order to induce a current in the second loop of the conductor. Lenz's law is actually the counterpart to Faraday's law in that it tells you the direction of the induced current, but not explicitly. **Lenz's law** is a consequence of conservation of energy applied to electromagnetic induction. When a magnetic field induces a current in a conducting coil, the induced current also generates its own magnetic field that points opposite to the inducing magnetic field. Therefore, the direction of the induced current is opposite the direction of the inducing current. If the inducing and induced fields are pointing in opposite directions, then the inducing and induced currents must also be pointing in opposite directions.

31 (b)

Criteria	Marks
• Describes an application of each law in an operational device	2
• Describes an application of a law in an operational device	1

Sample answer

An AC (alternating current) generator utilises Faraday's law of induction, spinning a coil at a constant rate in a magnetic field to induce an oscillating emf eg a 50Hz AC current.
Lenz's law is utilised in electromagnetic braking. Lenz's law states that "The current induced in a circuit due to a change or a motion in a magnetic field is so directed as to oppose the change in flux and to exert a mechanical force opposing the motion." When the current flows through the electromagnets, it acts as a temporary magnet opposing the motion. This application is used to slow bullet trains coming into stations in Japan.

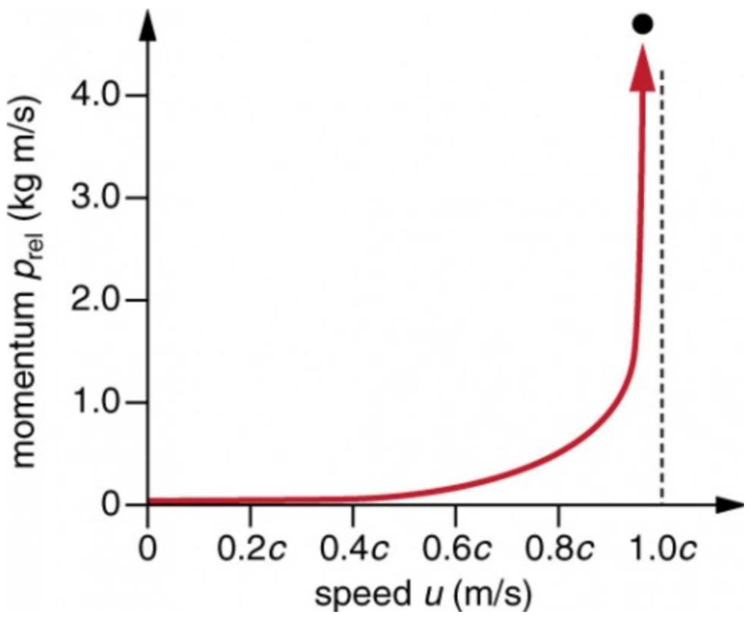
Question 32
32 (a)

Criteria	Marks
• Explains why a particle with mass cannot reach the speed of light in terms of mass dilation and the energy involved	2
• Provides some relevant information related to mass dilation as to why a particle with mass cannot reach the speed of light	1

Sample answer

As objects travel faster and faster, they undergo mass dilation – the greater the mass dilation, the more energy that has to be added to achieve acceleration, so you never get to the speed of light.

At low velocities, relativistic momentum is apparently equivalent to classical momentum. Relativistic momentum approaches infinity as the velocity of the object approaches c. This implies that an object with mass cannot reach the speed of light. It would require infinite work to be done on the object to increase its kinetic energy to attain a velocity of c. This relationship of relativistic momentum to speed is shown in the figure.



32 (b)

Criteria	Marks
• A correct calculation of the relativistic momentum	2
• A partially correct calculation of the relativistic momentum	1

Sample answer

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

$$p_v = \frac{1.673\ x\ 10^{-27}\ x\ 0.999999991\ x\ 3\ x\ 10^{8}}{\sqrt{\left(1 - \frac{299{,}999{,}997.3^2}{9\ x\ 10^{16}}\right)}}$$

$$p_v = 3.74\ x\ 10^{-15}\ \ kgms^{-1}$$

Question 33
33 (a)

Criteria	Marks
• A correct analysis of the graph • A description that refers to the graph and identifies why the incandescent globe is inefficient	2
• A correct analysis of the graph	1

Sample answer

The peak wavelength of the graph is below the red visible light. That radiation is in the infrared range of the spectrum. Only a small portion of the area under the graph is in the visible part of the spectrum. Hence the majority of the electromagnetic energy emitted by the globe is electricity being converted into heat. Most of the electrical energy is being transformed into radiation of longer wavelength than the visible spectrum.

Question 33
33 (b)

Criteria	Marks
• An analysis of the graph • An identification that the light globe was acting as a black body • An identification of the necessity for the curve to be explained by light being quantized and that there is not enough energy available to produce the high frequency photons • Provides a relevant equation	3
• An analysis of the graph • An identification that the light globe was acting as a black body	2
• A relevant piece of information	1

Sample answer

In the classical theory, a warm object would emit thermal radiation at all wavelengths, including arbitrarily short wavelengths, for example a light bulb could emit its thermal radiation as gamma rays. That does not happen as shown in the figure. The peak radiation emitted is in the infrared and gamma rays are not emitted at all. Planck assumed that radiation is not emitted continuously but in discrete units, the "quanta". For long wavelengths with low energy this means little change; but for short wavelengths or high energy radiation, there is not enough energy available to emit many of these high energy quanta, completely changing the characteristics of the emission from that which is observed. Planck found out that he could explain the shape of the curve observed if he assumed that light was only emitted in discrete quanta of $E = h\nu$, where ν is frequency and h is Planck's constant.

This was the first evidence for a particle theory of light and although on its own not conclusive, it did cause others like Einstein to accept that radiation existed as photons or light particles.

Question 34
34 (a)

Criteria	Marks
• Identifies the motor coil will not rotate • Describes that the motor would vibrate and heat energy would result	2
• Identifies or describes one of the above	1

Sample answer

The motor would not rotate at all and would start humming and would create vibrations, as a torque produced by positive and negative cycle of the AC would cancel out each other. DC motor would be heated up.

34 (b)

Criteria	Marks
• Statement that the split ring commutator must be replaced • Statement that the split ring commutator must be replaced with a pair of slip rings	2
• Statement that the split ring commutator must be replaced	1

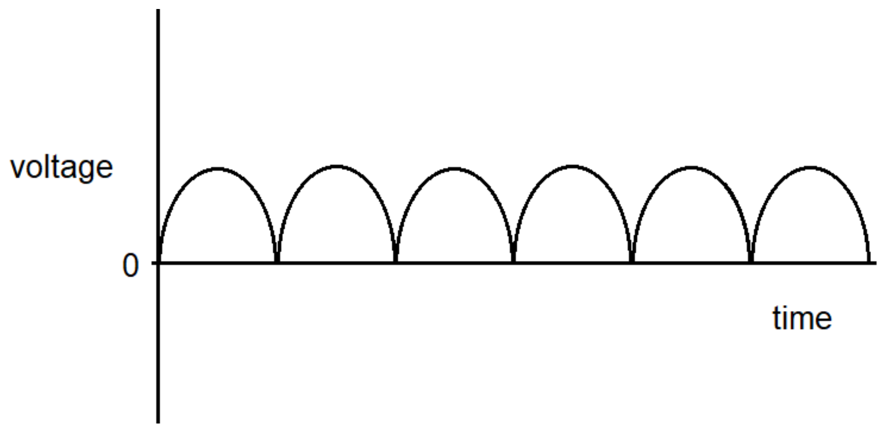
Sample answer

The replacement of the split ring commutator with a pair of slip rings.

34 (c)

Criteria	Marks
• Correct shaped commencing at 0 V output with correct number of crests	2
• Correct shaped wave	1

Sample answer



Question 35
35 (a)

Criteria	Marks
• A correct calculation	2
• A partially correct calculation	1

Sample answer

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

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

$$T = \sqrt{\frac{(6.671\ x\ 10^6)^3\ x\ 4\ \pi^2}{6.67\ x\ 10^{-11}\ x\ 6.0\ x\ 10^{24}}}$$

T = 5412 s

35 (b)

Criteria	Marks
• A correct calculation	2
• A partially correct calculation	1

Sample answer

$$v = \frac{2\pi r}{T} = \frac{2\pi\ x\ 6.671\ x\ 10^6}{5.412\ x\ 10^3}$$

v = 7745 ms^{-1}

35 (c)

Criteria	Marks
• Equates centripetal force and gravitational force experienced by the satellite • Demonstrates the cancellation of common factors • Recognises the implication that v is independent of mass	3
• Equates centripetal force and gravitational force experienced by the satellite • Demonstrates the cancellation of common factors	2
• Equates centripetal force and gravitational force experienced by the satellite	1

Sample answer

The satellite can be assumed to be in circular motion and the centripetal force experienced by the satellite can be equated to the gravitational force experienced by the satellite.

Therefore

$$\frac{m_{sat}\ v^2}{r_{sat}} = \frac{G\ m_{sat}\ M_{Earth}}{r_{sat}^2}$$

cancelling the mass of the satellite that appears on both sides of the equation and multiplying both sides of the equation by r_{sat} leads to

$$v^2 = \frac{GM_{Earth}}{r_{sat}}$$

or

$$v = \sqrt{\frac{G\ M_{Earth}}{r_{sat}}}$$

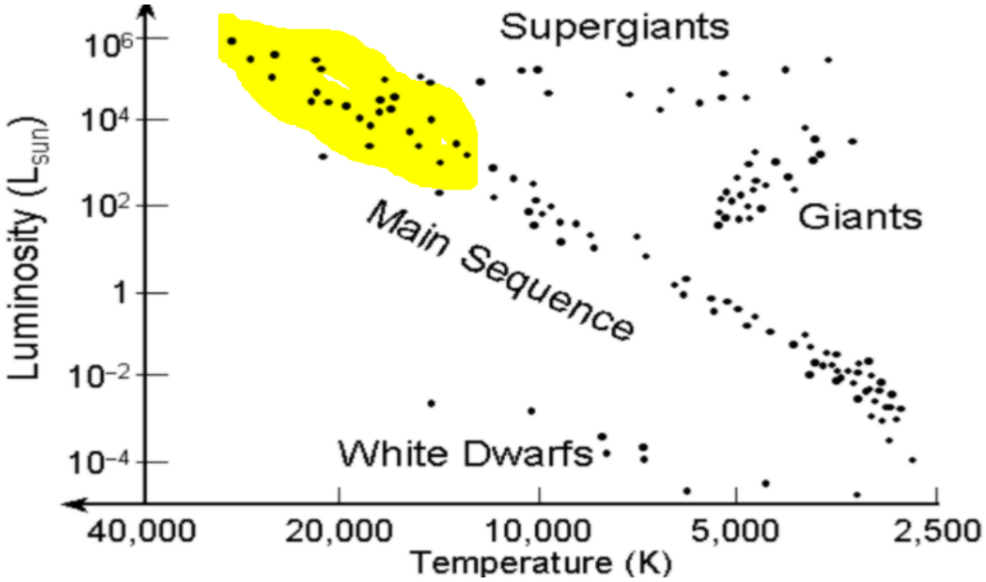
thus, the velocity of the satellite is independent of the mass of the satellite.

Question 36

36 (a) (i)

Criteria	Mark
• A correct location and marking of where stars are likely to be undergoing CNO nucleosynthesis	1

Sample answer



Highlighted area is where CNO is likely.

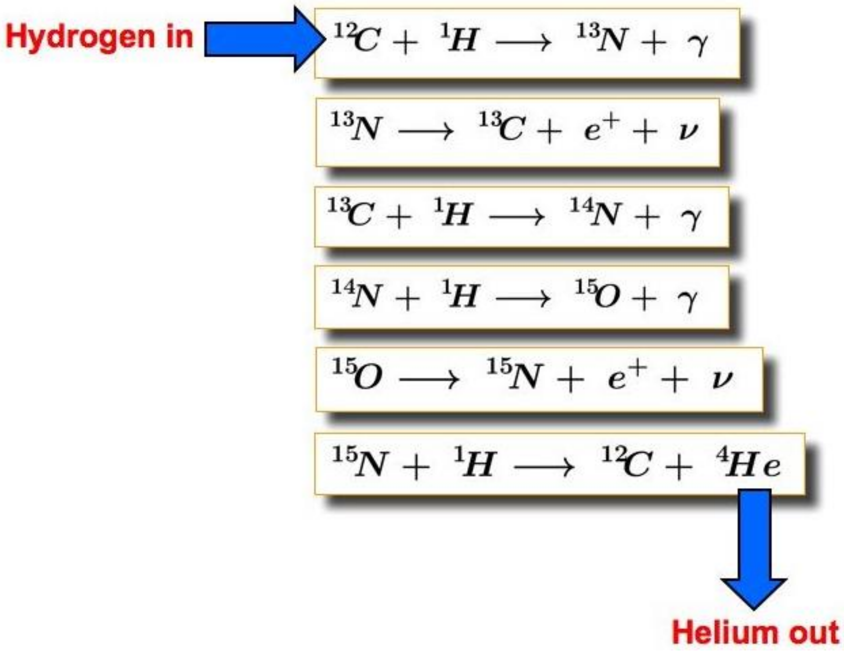
36 (a) (ii)

Criteria	Marks
• Provides an extensive detailed description of the CNO process	3
• Provides a thorough description of the CNO process with omissions	2
• Provides a description of some aspects of the CNO process	1

Sample answer

A carbon-12 nucleus captures a proton and emits a gamma ray, producing nitrogen-13.

Nitrogen-13 is unstable and emits a beta particle, decaying to carbon-13.
Carbon-13 captures a proton and becomes nitrogen-14 via emission of a gamma-ray.
Nitrogen-14 captures another proton and becomes oxygen-15 by emitting a gamma-ray.
Oxygen-15 becomes nitrogen-15 via beta decay.
Nitrogen-15 captures a proton and produces a helium nucleus (alpha particle) and carbon-12, which is where the cycle started.



36 (b)

Criteria	Marks
• Provides a comprehensive and detailed analysis of the named nucleosynthesis process	3
• Provides a thorough analysis of the named nucleosynthesis process with appropriate details	2
• Provides an analysis of the named nucleosynthesis process with some detail	1

Sample answer

The triple alpha process.

Helium accumulates in the cores of stars as a result of the proton–proton chain reaction and the carbon–nitrogen–oxygen cycle. In the triple alpha process a nuclear fusion of two helium-4 nuclei produces beryllium-8. Generally, this is unstable, and decays almost immediately back into smaller nuclei but rarely before this decay a third helium nuclei fuses with the beryllium-8 nucleus to produce an excited resonance state of carbon-12, called the Hoyle state. This excited carbon -12 nearly always decays back into three alpha particles, but once in about 2420 times the excited carbon -12 releases energy and changes into the stable base form of carbon-12. The triple alpha process becomes more common after a star runs out of hydrogen to fuse in its core. It begins to contract and heat up. The central core temperature of such stars rises to around six times hotter than the Sun's core, and the helium nuclei fuse fast enough to get past the beryllium-8 barrier and this results in the production of significant amounts of stable carbon-12 releasing around 7.275 MeV with each carbon 12 formed.

36 (c)

Criteria	Marks
• A correct series of calculations	3
• Two correct calculations	2
• One correct calculation	1

Sample answer

The overall reaction is

$$4H_1^1 \rightarrow He_2^4 + 2e_1^0 + 2\nu$$

Calculating the mass loss in the overall reaction.
Mass of reactants - mass of products = mass loss in the reaction

Mass or reactants
$4 \times 1.673 \times 10^{-27} = 6.692 \times 10^{-27}$ kg

Mass of products
$2 \times 1.673 \times 10^{-27} + 2 \times 1.675 \times 10^{-27} + 2 \times 9.109 \times 10^{-31} = 6.6978 \times 10^{-27}$ kg

Mass lost = $6.692 \times 10^{-27} - 6.6978 \times 10^{-27} = 5.822 \times 10^{-30}$ kg

Now
$E = mc^2 = 5.822 \times 10^{-30} \times (3 \times 10^8)^2 = 5.24 \times 10^{-13}$ J

Therefore energy produced is 5.24×10^{-13} J

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Section I

Question	Marks	Content	Syllabus Outcomes
1	1	Mod 5 Circular motion	PH12–4, PH12–12
2	1	Mod 5 Motion in Gravitational Fields	PH12–7, PH12–12
3	1	Mod 7 Light: Wave Model	PH12-6, PH12–14
4	1	Mod 5 Projectile Motion	PH12–5, PH12–6, PH12–12
5	1	Mod 5 Circular Motion	PH12–6, PH12–12
6	1	Mod 5 Circular Motion	PH12–6, PH12–12
7	1	Mod 6 The Motor Effect	PH12–4, PH12–6, PH12–13
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Section II

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