Sydney Boys High School

NESA Student Number:

2025 Trial Exam

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using blue or black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper
- SHOW ALL WORKING
- Write your NESA number in ALL of the boxes provided

Total marks: 100

Section I – Multiple Choice

- 20 marks
- Allow about 35 minutes for this section

Section II – Free Response

- 80 marks
- Allow about 2 hours and 25 minutes for this section

Answer the multiple choice questions on the separate answer sheet using a pencil.

Make sure you rub out any incorrect answer completely.

Section I

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. An object is flying in a circle of radius 5.0 m with a constant speed. One revolution takes 4.0s. What is the object's centripetal acceleration?

A. $12.3\ ms^{-2}$

B. $24.0\ ms^{-2}$

C. $7.9\ ms^{-2}$

D. $8.0\ ms^{-2}$

2. Which one of the following is required for the function of a DC electric motor?

A. A rotating magnetic field

B. An alternating electric current

C. A slip-ring commutator

D. A split ring commutator

3. With what speed must a projectile be launched horizontally off a cliff, 200.0 m above the ocean, so that it lands exactly 50.0 m from the base of the cliff?

A. $6.4\ m\ s^{-1}$

B. $7.8\ m\ s^{-1}$

C. $9.9\ m\ s^{-1}$

D. $12.2\ m\ s^{-1}$.

4. A positively charged particle (1.6×10^{-19}C) travelling at 3.0×10^{5} ms^{-1}, enters a magnetic field of strength 2.0T.
What is the force experienced by the particle, assuming the entry angle to the direction of the magnetic field is 30 degrees?

A. 4.8×10^{-14} N
B. 8.4×10^{-14} N
C. 2.4×10^{-14} N
D. 9.6×10^{-14} N

5. The table below shows the transition between electron orbits in the Bohr Model of the hydrogen atom.

Option	Initial Electron energy level	Final Electron energy level
A	1	4
B	2	5
C	4	2
D	5	3

Which transition corresponds to an electron absorbing the highest energy photon?

A. A
B. B
C. C
D. D

6. The mass of Mars is 6.4 x 10^{23} kg. The radius of Mars is 3.4 x 10^{6} m. How much faster does a rocket need to be traveling to leave Earth's gravitational influence compared to Mars' gravitational influence?

A. 0.2 times
B. 1.2 times
C. 2.2 times
D. 3.2 times

7. A spaceship is travelling at *0.9c* when an astronaught aboard is instrucated to clean the ship. Mission control is watching from Earth and sees the astronaught cleaning for exactly 30 mins.
How long did the cleaning take from the astronaughts' frame of reference?

A. 6.8 mins
B. 13.1 mins
C. 68.9 mins
D. 94.8 mins

8. A circular coil of wire with a radius of 0.04 m and 500 circular loops is placed in an electromagnet with the magnetic field decreasing at a rate of 0.200 Ts^{-1}. The angle between the plane of the coil and the magnetic field is 30 degrees.
What is the magnitude of the induced emf?

A. 0.251 V
B. 0.435 V
C. 0.870 V
D. 1.53 V

9. Einstein considered many thought experiments prior to his paper on special relativity. In one, he is running with velocity *c* alongside a beam of light.

What did Einstein speculate he would see?

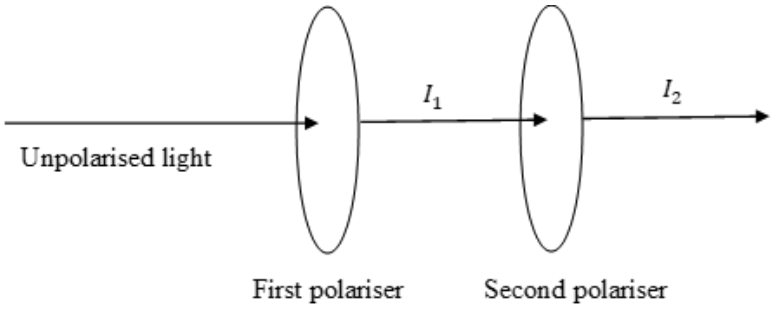
A. An oscillating electromagnetic wave propagating at *c*.

B. An oscillating electromagnetic wave propagating at *2c*.

C. A non-oscillating electromagnetic wave propagating at *c*.

D. A non-oscillating electromagnetic wave propagating at *2c*.

10. Unpolarised light is incident upon two consecutive polarisers as shown. Both polarisers are fixed and cannot be rotated. The original intensity of I_2 is zero.



A third polariser is then placed between the first and second polariser at an angle θ to the first polariser. With this third polariser in place, the Intensity of I_2 now becomes 25% of the unpolarised light.

Which of the below represents the expression $\cos^2 \theta \times \cos^2(90- \theta)$?

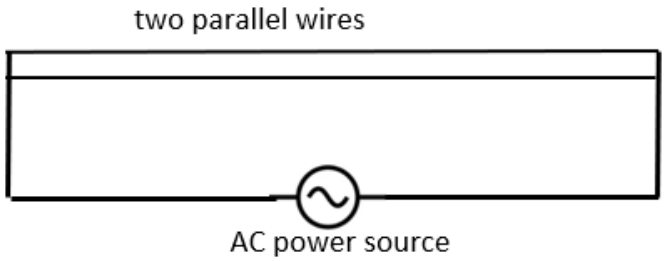
A. 1

B. 2

C. 0.5

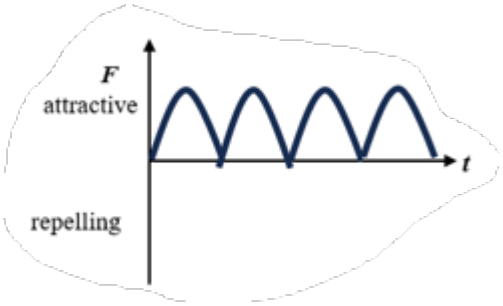
D. 1.5

11. Two long, identical wires are arranged parallel to each other and connected to the same AC source, as shown:

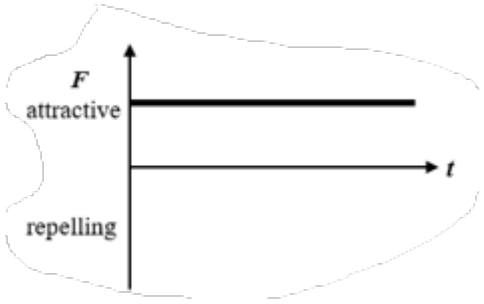


Which graph best shows the force between the two wires?

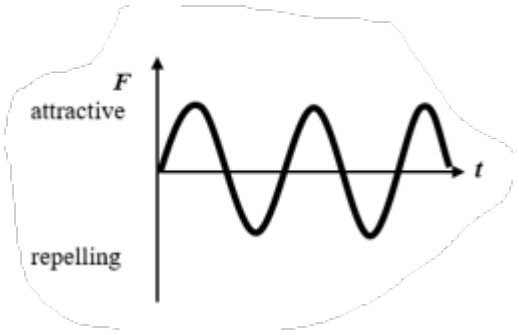
A.



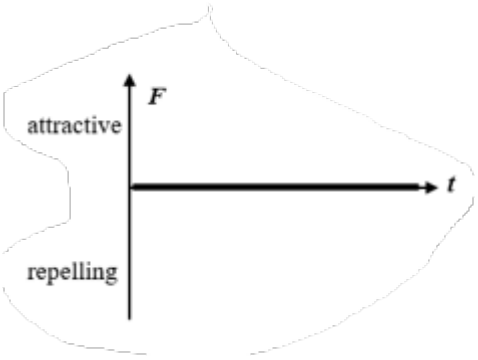
B.



C.



D.



12. Which form of electromagnetic radiation has the highest energy per photon?

A. X-rays.
B. Ultraviolet.
C. Infared.
D. Microwaves.

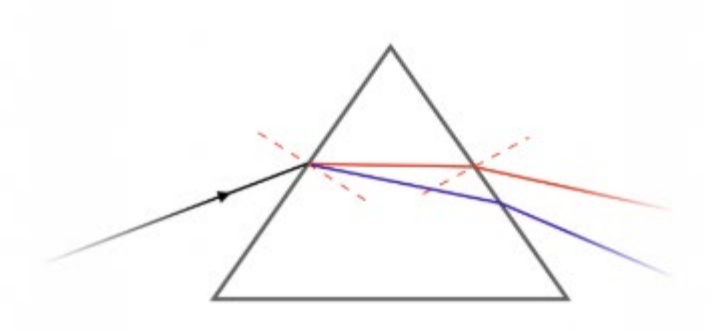
13. Which change would result in the greatest increase in the gravitational force between two objects?

A. Double the distance between the objects.
B. Double the mass of one object.
C. Double the mass of both objects.
D. Halve the mass of both objects.

14. Which of the following observations could not be explained by Rutherford's atomic model?

A. Most alpha particles passed through gold foil.
B. Some alpha particles were deflected at large angles.
C. Atoms are mostly empty space.
D. Atoms emit discrete spectral lines.

15. When white light passes through a prism, red light bends less than violet light.



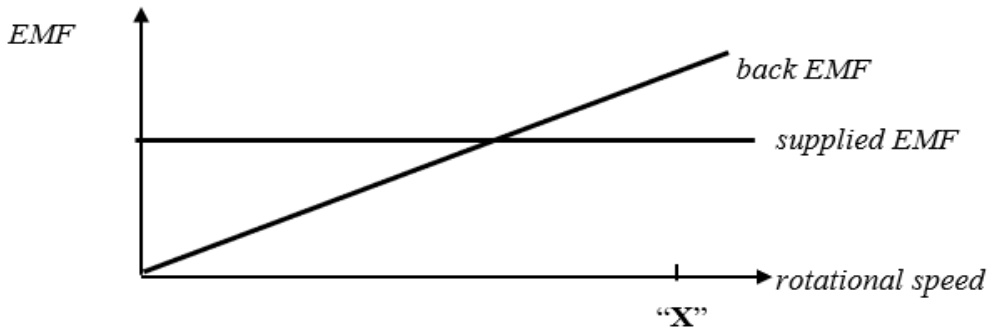
This is because:

A. Violet light has a shorter wavelength.
B. Red light has a higher frequency than violet light.
C. Red light travels slower in glass than violet light.
D. Red photons have more energy than violet photons.

16. As a satellite following an elliptical orbit moves closer to Earth, what happens to its kinetic and potential energy?

A. Both kinetic and potential energy increase.
B. Kinetic energy increases, potential energy decreases.
C. Both kinetic and potential energy decrease.
D. Kinetic energy decreases, potential energy increases.

17. The supplied EMF and back EMF generated by a rotating motor are graphed below:

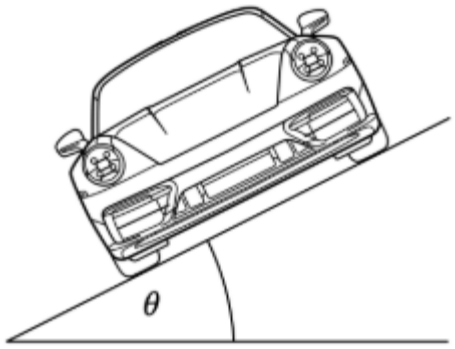


The motor is made to rotate at a speed **X**, with no load, as shown on the graph.

At this rotational speed, when the motor is left to rotate freely, with no mechanical load, it will:

A. slow down until it is stopped.
B. begin to speed up.
C. remain spinning at the same speed.
D. begin to slow down.

18. The diagram shows a car on a frictionless banked curve.



Which of the following factors primarily determines the banking angle needed to negotiate the curve safely?

A. The mass of the car.
B. The speed of the car.
C. The width of the tires.
D. The type of surface material.

19. Incomplete flux linkage in a transformer will cause:

A. greater resistence in the secondary coil.
B. a lower primary voltage.
C. a lower secondary voltage.
D. more eddy currents in the core.

20. A beam of light passes through a diffraction grating. Compared to passing through a single slit, the diffraction grating causes:

A. Broader and less distinct fringes.
B. Narrower and more distinct fringes.
C. No interference at all.
D. Complete polarisation of the light.

End of Multiple Choice

2025 **Trial Exam**

NESA Student Number:

Physics

Section II

Answer Booklet I

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

Instructions

- Write your NESA Student Number at the top of every booklet.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet I and II. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (6 marks) **Marks**

A lunar rover is navigating the surface of the Moon, where the gravitational acceleration is 1.62 ms^{-2}. The rover has a mass of 200 kg.

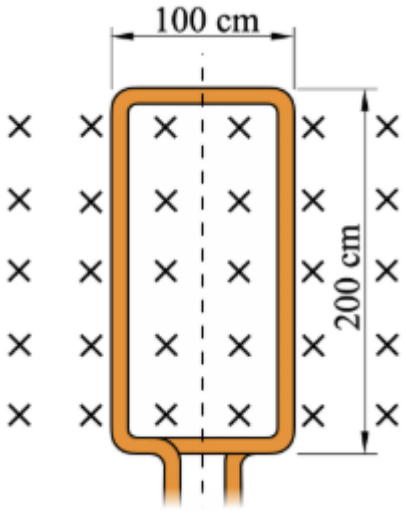
It drives over a circular hill of radius 30 m at a constant speed of 8.0 ms^{-1}.

(a) Calculate the normal force acting on the rover at the top of the hill. **3**

(b) Explain the differences in normal force if the same hill were on Earth instead of the Moon. **3**

Question 22 (5 marks) **Marks**

A rectangular coil with 20 turns is placed in a uniform magnetic field of 0.30 T, as shown below. The coil is rotated at a constant angular velocity of 150 rpm about an axis perpendicular to the magnetic field.



(a) The diagram above shows the coil at a particular instant in its rotation. Using this diagram, explain why the induced emf is at a minimum as the coil is in the position shown above. **2**

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(b) Determine the maximum induced emf generated in the coil after it has rotated through 90 degrees from its shown position.

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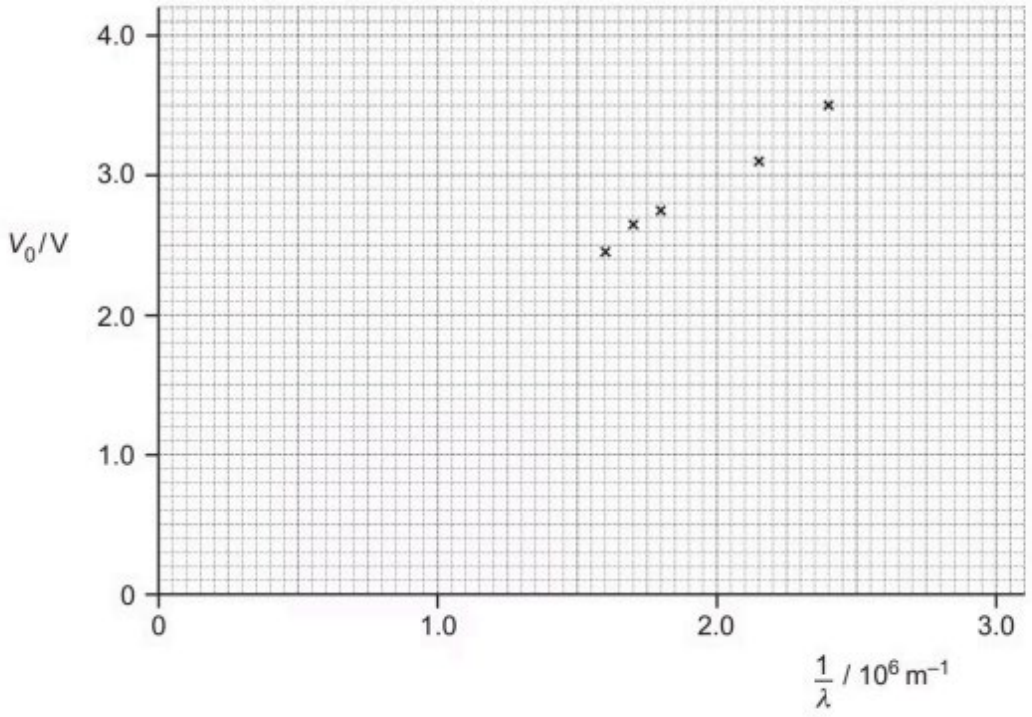
Question 23 (8 marks) **Marks**

An approximate value of the Planck constant *h* can be determined in the laboratory using light-emitting diodes (LEDs). An LED suddenly starts to conduct and emit monochromatic light when the potential difference across an LED exceeds a minimum value V . The potential difference V and the wavelength λ of the emitted light are related by the equation:

$$V_0 = \left(\frac{hc}{e}\right) \text{ x } \frac{1}{\lambda}$$

where e is the elementary charge and c is the speed of light in a vacuum. The graph below shows some data points plotted by a student on a V against $\frac{1}{\lambda}$ graph for five different LEDs.



The potential difference across each LED was measured using a digital voltmeter with divisions ±0.01V. The values for the wavelengths are accurate and were provided by the manufacturer of the LEDs. The value of V was determined by directly observing the state of the LED in the brightly lit laboratory.

(a) Draw the straight line of best fit on the graph above and determine the gradient of the line. **2**

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Question 23 continues over page

(b) Determine the experimental value of h for this investigation. Show your working **3**

(c) Calculate the percentage difference between your value in (b) and the accepted value of the Planck constant **1**

(d) Identify the two types of errors shown by the data in the graph and suggest how you could have refined the experiment to reduce or eliminate these errors. **2**

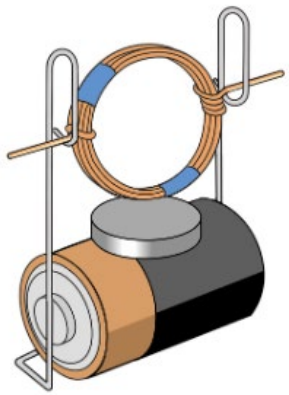
Question 24 (4 marks) **Marks**

Projectile A is launched at 60 degrees from the horizontal. Projectile B is launched at 45 degrees from the horizontal when projectile A is halfway through its flight.

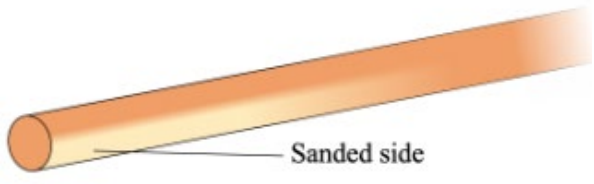
If the projectiles have the same range, determine the ratio of projectile B's initial velocity to projectile A's if they land at the same time. **4**

Question 25 (10 marks) **Marks**

Students, in class, constructed a simple electric motor with an insulated copper coil, paperclips, magnet, and a battery as shown below.



The teacher instructed the students to only sand one side of the copper wire, as shown below, where it contacted the paperclips.



(a) Identify which part of a DC motor works in the same way as the half-sanded wire section? **1**

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(b) Explain and justify the sanding instruction. **4**

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Question 25 continues over page

(c) One student did not follow the instruction properly and sanded both sides of the wire.

Describe what will happen to this student's coil when the power is turned on. **2**

(d) When the students measured the currents through their motors, the student who did not sand their wire correctly noticed their current was significantly higher than the other students.

Explain this observation. **3**

Question 26 (6 marks) **Marks**

Explain how Maxwell's equations predicted the existence of electromagnetic waves and outline how this prediction was later verified experimentally. **6**

End Answer Booklet I

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If you use this space, CLEARLY indicate which question you are answering.

NESA Student Number:

Section II

Answer Booklet II

Marks

Question 27 (5 marks)

The moon is Earth's only natural satellite. It has a mass of 7.35 x 10^{22} kg and, on average, the distance from the centre of the Moon to the surface of the Earth is 3.84 x 10^{8} m.

(a) Show the force due to gravity between the Moon and the Earth is 1.93 x 10^{20} N. **2**

(b) A large rock is stationary in space and located at a distance 1.0 x 10^{7} m from the centre of an unknown planet. It takes 1.0 MJ of work to move the rock to a stationary point 2.0 x 10^{7} m from the centre of the unknown planet.

Calculate how much work needs to be done to move the rock from 2.0 × 10^{7} m away from the centre of the unknown planet to a stationary point 8.0 × 10^{7} m from the centre of the unknown planet. **3**

Question 28 (5 marks) **Marks**

A green lazer with a wavelength of 530 nm is directed at a diffraction grating with a spacing of 3.2 μm, projecting a pattern on a screen 85 cm away. The lazer is then replaced with electrons accelerated through 150 V.

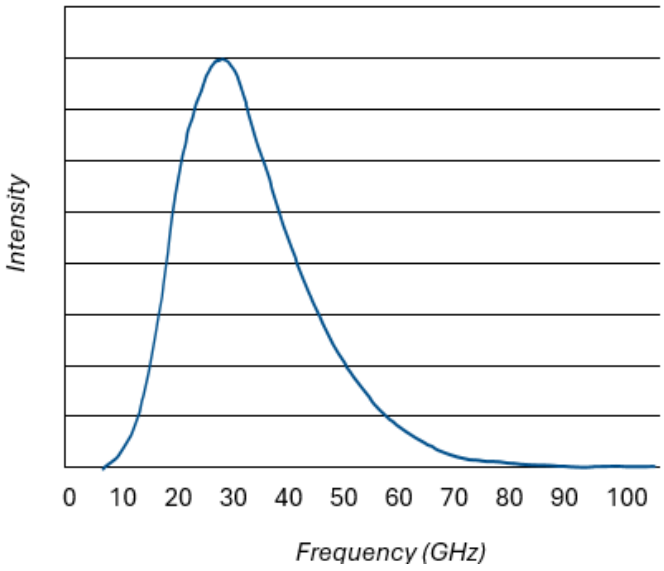
Determine how many electron diffraction fringes appear between the central maximum and the first-order bright fringe of the green lazer. **5**

Question 29 (3 Marks) **Marks**

Describe how TWO experiments have contributed to our understanding of the nucleus of the atom. **3**

Question 30 (5 marks) **Marks**

The diagram below shows the black body radiation distribution of Earth.



(a) Show that the temperature of Earth is 290 K. **2**

(b) A second curve showing the sun's black body radiation is to be drawn on the diagram.
Explain the differences that will be seen between the Sun's curve and the Earth's. **3**

Question 31 (5 marks) **Marks**

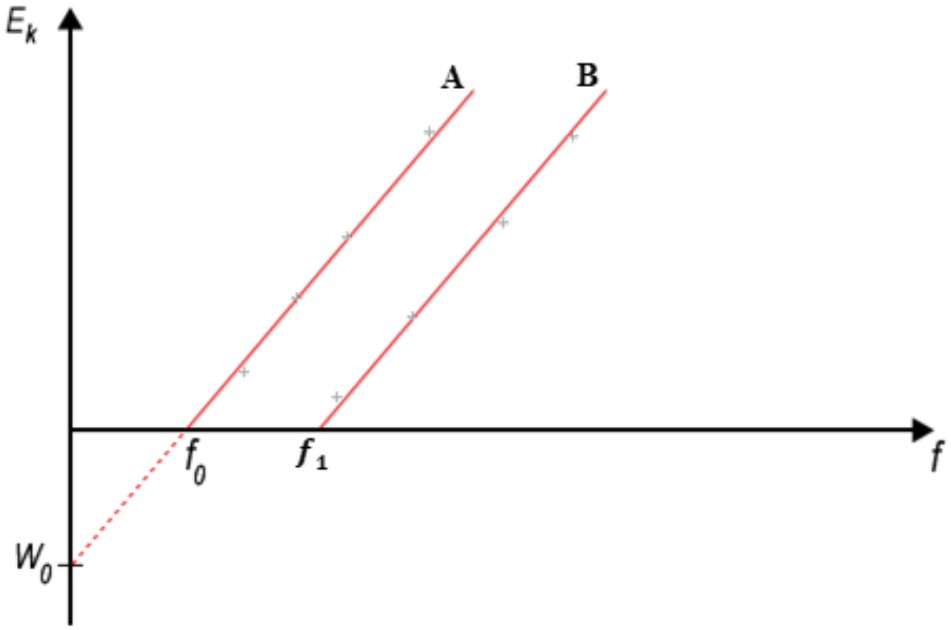
An AC induction motor operates by using a rotating magnetic field produced by a three-phase AC power supply.

(a) Explain how an AC induction motor produces torque in the rotor without direct electrical contact. **3**

(b) Describe one advantage and one limitation of using an AC induction motor compared to a DC motor **2**

Question 32 (5 marks) **Marks**

The graph shows the relationship between the frequency of light used to irradiate two different metals, A and B, and the maximum kinetic energy of photoelectrons emitted.
The graph was obtained by supplying a stopping voltage to a photocurrent at various frequencies of light, such that the photocurrent was 0.



(a) Describe the stopping voltage and photocurrent measured from both metals in the region where frequency increases from f_0 to f_1. Assume the radiation intensity is constant. **2**

Metal	Description of Voltage and Photocurrent between f_0 and f_1.
A	Stopping Voltage: …… …… Photocurrent: …… ……
B	Stopping Voltage: …… …… Photocurrent: …… ……

Question 32 continues over the page

(b) Explain how an experimental result of the photoelectric effect was able to support the concept of quantisation. **3**

Question 33 (3 marks)

A student recreated Milikan's experiement and found the elementary charge on the oil drops to be 1.85×10^{-19} C. They then recreated Thomson's experiment and calculated the charge to mass ratio to be 1.81×10^{11} Ckg^{-1} **3**

Quantitatively assess the accuracy of their results.

Question 34 (2 marks) **Marks**

A 1W beam of EMR transfers 1J per second from one point to another.

With reference to the particle model of light, contrast a 1W beam of Infared light with a 1W beam of Ultraviolet light. **2**

Question 35 (3 marks)

(a) A planet orbits the Sun in an elliptical path. The distance between the planet and the Sun varies as the planet moves in its orbit. Explain, using the relevent law, how the speed of the planet changes as it moves along its orbit. **2**

(b) Given that the orbit of a planet is nearly circular, the time taken for one full revolution around the Sun is 365 days, and the average radius of the orbit is 1.5×10^{11} m, calculate the orbital speed of the planet. **1**

Question 36 (5 marks) **Marks**

The Bohr model of the atom explains the energy of photons emitted when an electron falls from an initial orbit n_i to find an orbit of n_f.

The values of $\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ for the values of n_i and n_f from 1 to 6 for Hydrogen are shown in the table.

n_f \ n_i	1	2	3	4	5	6
1	–	0.7500	0.8889	0.9375	0.9600	0.9722
2	–	–	0.1389	0.1875	0.2100	0.2222
3	–	–	–	0.0486	0.0711	0.0833
4	–	–	–	–	0.0225	0.0347
5	–	–	–	–	–	0.0122
6	–	–	–	–	–	–

(a) Identify why some values in the table are blank. **1**

(b) Calculate the energy of the photon emitted when an electron falls from $n_i = 5$ to $n_f = 3$ **4**

END OF PAPER

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2025 SBHS Physics Trial Answers

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

Question 21 (a)

Criteria	**Marks**
Correctly calculates the normal force, showing correct working and substitution. States that rover leaves the surface.	3
Shows correct working with a minor error in substitution or final calculation.	2
Identifies the correct relevant formula(s) or attempts correct working.	1

Sample answer:

$$-F_c = F_g + F_N$$

$$F_N = -\frac{mv^2}{r} - F_g$$

$$F_N = -\frac{200\times 8^2}{30} - (200 \times -1.62)$$

$$F_N = -103 \text{ N}$$

Because the answer is negative, the rover has left the surface.

$$\therefore F_N = 0$$

1 mark awarded for attempt at calculation to work out normal force, taking into consideration of both gravitational and centripetal force. If only gravitational OR centripetal was used, no marks were awarded. To get ALL three marks, students must have stated that normal force cannot be negative and therefore the rover does not stay in contact with the surface.

Question 21 (b)

Criteria	Marks
Clearly explains how and why the normal force would be greater on Earth, making specific reference to gravitational acceleration and centripetal force requirements.	3
Provides a general explanation of either how or why the normal force changes, with partial reference to gravity or motion.	2
Identifies that the normal force would be different but gives a vague or incomplete reason.	1

Sample answer:

On Earth, the gravitational acceleration is much larger (9.8 m s^{-2} compared to 1.62 m s^{-2} on the Moon).
This means the rover's weight would be much greater on Earth. Since the normal force is the difference between gravitational force and the required centripetal force,

FN=−mv2r−FgFN=−mv2r−Fg

, the larger gravitational force on Earth would result in a larger normal force compared to the Moon.
Thus, the rover would maintain contact with the surface more easily on Earth, and the normal force would not fall to zero as quickly.

One mark was awarded about any generic statement referring to acceleration due to gravity being much greater for Earth and therefore making the weight force greater. If a calculation was attempted in line with student response from part a) another mark was awarded (carry on error). Two marks in total were also awarded if students stated that normal force was greater but centripetal force stayed the same. Three marks were only awarded if students stated that normal force was great enough for rover to stay on Earth compared to moon.

Question 22 (a)

Criteria	Marks

Clearly explains that no change in magnetic flux occurs when the coil plane is parallel to the magnetic field direction.	2
Identifies that the emf is zero but gives limited or incomplete explanation.	1

Sample answer:

At this instant, the plane of the coil is perpendicular to the magnetic field, so the magnetic flux is at a maximum. However, the rate of change of flux is zero at this point in the rotation, so no emf is induced.

Students had to state that flux was at maximum at given point BUT change in flux was minimum to get 2 marks. No marks if response stated that flux was 0. No marks for just use of calculus with no justification.

Question 22 (b)

Criteria	**Marks**
Correctly calculates the induced emf using Faraday's Law, correctly finding flux change and time.	3
Shows correct working using Faraday's Law with a minor error in substitution or arithmetic.	2
Identifies appropriate method to find emf from flux change over time.	1

2 marks for only minor error in answer. If students calculated time incorrectly only 1 mark was awarded.

Sample answer:

$\Phi = BA = 0.3 \times (1.0 \times 2.0)$

$\Phi = 0.6$ Wb

$T = \frac{60}{150} = 0.4$ s per revolution

$\Delta t = \frac{0.4}{4} = 0.1$ s

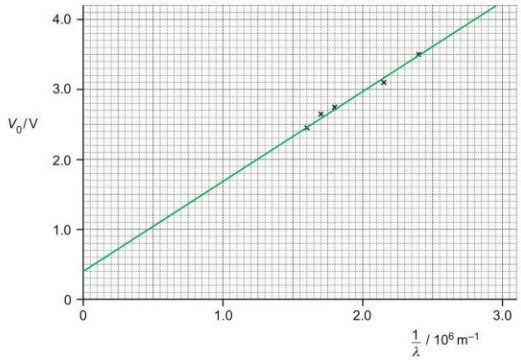
$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$

$\varepsilon = 20\frac{0.6}{0.1}$

$\varepsilon = 120$ V

Question 23

(a) Draw the line of best fit: A straight line with non-zero V0 intercept; [1 mark]



- $gradient = \frac{\Delta V_0}{\Delta\frac{1}{\lambda}} = \frac{3.6 - 0.4}{(2.5 \times 10^6)} = 1.3 \times 10^{-6}$ [1 mark]

Answer had to be between 1.2-1.4 x 10^{-6}

(b))

List the known quantities:

- Gradient = 1.3×10^{-6}
- $V_0 = \left(\frac{hc}{e}\right) \times \frac{1}{\lambda}$

From the data booklet:

- speed of light in a vacuum, $c = 3.00 \times 10^8$ m s^{-1}
- elementary charge, $e = 1.60 \times 10^{-19}$ C

Determine the equation for the gradient:

- $gradient = \frac{V_0}{\frac{1}{\lambda}} = \frac{hc}{e}$ [1 mark]

Rearrange the gradient equation for h and substitute in the values:

- $h = \frac{e \times gradient}{c} = \frac{(1.60 \times 10^{-19}) \times (1.3 \times 10^{-6})}{3.00 \times 10^8}$ [1 mark]
- $h = 6.9 \times 10^{-34}$ J s [1 mark]

Answer between 6.4 and 7.5 x 10^{-34} (carry on allowed)

(c)

iii) Calculate the percentage difference between your value in **(ii)** and the accepted value of the Planck constant.

List the known quantities:

- Planck constant from part (ii) = 6.9×10^{-34} J s

From the data booklet:

- Planck constant, $h = 6.63 \times 10^{-34}$ J s

Calculate the percentage difference in both values:

- $\%\ difference = \frac{difference\ in\ values}{accepted\ value} \times 100\%$
- $\%\ difference = \frac{(6.9 \times 10^{-34}) - (6.63 \times 10^{-34})}{6.63 \times 10^{34}} \times 100\%$
- $\%\ difference = 4.072 = 4.1\ \%$ [1 mark]

Carry on allowed

(d)

There are **random errors** / the data points are spread about the line of best fit; Take (many) repeat readings (of V) and average or test more LEDs of **different frequency**[1 mark]

There is a **systematic error** / the line does not pass through the origin; Conduct the experiment in a darkroom / use (black)tube over the LED to view when it is lit / use a (digital) voltmeter with no zero error; [1 mark]

Question 24

Criteria	**Marks**
Correctly determines ratio of velocities showing full working	4
Determines a value for the velocity ratio with minor error.	3
Correctly determines an expression for time of flight for either projectile A or B using appropriate trigonometric substitution.	2
Identifies the need to compare horizontal displacements or discusses timing of the two projectiles. May correctly write or use a formula for time of flight.	1

Sample answer:

to max height

$v_y = u_y + a_y t$

$t = \frac{u \sin\theta}{g}$ $\quad \Sigma t = \frac{2u \sin\theta}{g}$

$t_B = t_A \div 2$

Proj A

$t_A = \frac{2u_A \sin 60}{g}$

$= \frac{u_A \sqrt{3}}{g}$

Proj B

$t_B = \frac{u_A \sin 60}{g}$

$= \frac{u_A \sqrt{3}}{2g}$

$u_{A_x} = u_A \cos 60$ $\quad u_{B_x} = u_B \cos 45$

$u_{A_x} = \frac{u_A}{2}$ $\quad u_{B_x} = \frac{u_B \sqrt{2}}{2}$

$\Delta x_A = u_{A_x} \cdot t_A$

$= \frac{u_A}{2} \times \frac{u_A \sqrt{3}}{g}$

$= \frac{u_A^2 \sqrt{3}}{2g}$

$\Delta x_B = u_{B_x} \cdot t_B$

$= \frac{u_B \sqrt{2}}{2} \cdot \frac{u_A \sqrt{3}}{2g}$

$= \frac{u_A \cdot u_B \sqrt{6}}{4g}$

$\Delta x_A = \Delta x_B$

$\frac{u_A^2 \sqrt{3}}{2g} = \frac{u_A u_B \sqrt{6}}{4g}$

$2u_A^2 \sqrt{3} = u_A u_B \sqrt{6}$

$2u_A \sqrt{3} = u_B \sqrt{6}$

$\frac{u_B}{u_A} = \frac{2\sqrt{3}}{\sqrt{6}}$

$\frac{u_B}{u_A} = \sqrt{2} = 1.41$

$u_A : u_B = 1 : 1.41$

OR.

$\Delta x_A = \Delta x_B$

$u_A \cos 60\, t_A = \frac{1}{2} u_B \cos 45\, t_A$

$\frac{u_A}{u_B} = \frac{1}{2} \cdot \frac{\cos 45}{\cos 60} \cdot \frac{t_A}{t_A}$

$\frac{u_A}{u_B} = \frac{1}{2} \cdot \sqrt{2}$

$= \frac{1}{\sqrt{2}}$

$u_B : u_A = \sqrt{2} : 1$

$= 1.41 : 1$

Question 25 (a)

Criteria	Marks
Correctly identifies the commutator.	1

Sample answer:

The commutator.

Question 25 (b)

Criteria	Marks
Clearly explains that sanding is required to expose the conductive copper *and* justifies how half-sanding allows controlled current flow for continuous rotation.	4
Identifies the need to expose the copper *and* attempts to link half-sanding to motor operation.	3
Identifies either exposing copper **or** intermittent current flow, with limited or no clear justification.	2
Mentions sanding affecting operation but provides minimal explanation.	1

Sample answer:

The wire is initially coated with an insulating layer, so sanding is required to expose the conductive copper underneath to allow current to flow into the coil. Sanding only one side of the wire ensures that current only flows during part of the rotation. When the bare copper side contacts the paperclip, current flows, generating a magnetic field and torque. When the insulated side contacts the paperclip, current is interrupted, allowing the coil to continue spinning without being pulled backward. This intermittent current flow is essential for maintaining continuous rotation in one direction.

NOTE: the current doesn't cause a change in flux, the spinning of the coil does. (the motor effect)

The B is provided by the magnet – this is not a lenz's law question.

Question 25 (c)

Criteria	Marks
Correctly describes that the coil will oscillate back and forth or not spin properly.	2
Identifies that the coil will not spin correctly but with limited or incorrect description.	1

Not spinning = 0

Sample answer:

If both sides are sanded, current will flow continuously regardless of the coil's orientation.
This causes the magnetic torque to reverse direction halfway through each rotation, making the coil oscillate back and forth instead of spinning continuously.

Note: it says describe the motion NOT EXPLAIN

Question 25(d)

Criteria	Marks
Correctly explains that the absence of back emf leads to a higher current because the supply voltage is not opposed.	3
Identifies reduced back emf or higher current but with limited explanation.	2
States current would be higher but without clear or correct reasoning.	1

Sample answer:

In a normal motor, the spinning coil generates a back emf that opposes the supply voltage, reducing the net current through the circuit.
Since the student's coil was not rotating properly, little or no back emf was generated. Without back emf to oppose the battery voltage, the full voltage was applied across the low-resistance coil, resulting in a much higher current compared to other students.

Question 26

Criteria	Marks
Clearly explains how Maxwell's equations predict electromagnetic waves through changing electric and magnetic fields, and outlines all of Hertz's experimental verification.	6
Explains electromagnetic wave prediction and mentions experimental verification but with some minor omissions or lack of clarity.	5
Correctly explains the prediction or correctly outlines experimental verification, but only partially addresses the other. OR Explains the EM wave prediction with 1-2 errors AND outlines experiments with 1-2 ommisions.	4
Describes either the prediction or the experimental verification with limited explanation.	3
Identifies that Maxwell predicted electromagnetic waves or that Hertz verified them, with little detail.	2
Makes a minimal relevant statement about electromagnetic waves.	1

Sample answer:

Maxwell's equations describe how changing electric fields produce magnetic fields, and changing magnetic fields produce electric fields. He predicted that a self-sustaining electromagnetic wave could propagate through space as oscillating electric and magnetic fields reinforcing each other.
Maxwell calculated that these waves would travel at a speed close to the known speed of light, suggesting that light itself is an electromagnetic wave.

This prediction was later verified by Heinrich Hertz in 1887. Hertz generated radio waves using an oscillating electric spark and detected them with a simple loop antenna. He observed that the radio waves could reflect, refract, polarise, interfere, and diffract, confirming that they behaved like light and other known electromagnetic waves, thus validating Maxwell's prediction.

Question 27a

Criteria	Marks
▪ Shows all correct substitutions to calculate force	2
▪ Makes a correct substitution into a relevant equation	1

Suggested Answer:

$$F = \frac{GMm}{r^2} = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 7.35 \times 10^{22}}{(3.84 \times 10^{8} + 6.371 \times 10^{6})^2}$$

$$\therefore F = 1.93 \times 10^{20}\ N$$

NOTE: Marks were awarded here for SUBSTITIONS – not providing the correct answer as this is in the question. If you DID NOT substitute the radius of the Earth into the equation you ARE NOT being awarded full marks.

Question 27b

Criteria	Marks
▪ Correctly calculates work, showing relevant substitutions	3
▪ Makes some relevant progress towards calculating work	2
▪ Makes a correct substitution into a relevant equation	1

Suggested Answer:

$$W = \Delta U = U_f - U_i$$

$$1.0 \times 10^6 = \frac{-GMm}{2.0 \times 10^7} - \frac{-GMm}{1.0 \times 10^7}$$

$$GMm\left(\frac{1}{1.0 \times 10^7} - \frac{1}{2.0 \times 10^7}\right) = 1.0 \times 10^6$$

$$\therefore GMm = 2.0 \times 10^{13}\ Nm^2$$

$$W = GMm\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$$

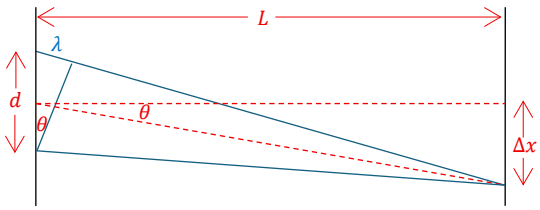
$$= 2.0 \times 10^{13}\left(\frac{1}{2.0 \times 10^7} - \frac{1}{8.0 \times 10^7}\right)$$

$$\therefore W = 750\ kJ$$

Question 28

Criteria	Marks
▪ Correctly calculates the number of electron fringes	5
▪ Correctly calculates Δx_e	4
▪ Correctly calculates λ_e OR ▪ Correctly calculates Δx_{laser}	3
▪ Correctly calculates v_e OR ▪ Makes some progress towards calculating Δx_{laser}	2
▪ Makes a correct substitution into a relevant equation	1

Suggested Answer:



For Laser:

$\lambda = 530 \times 10^{-9}\ m$

$d = 3.2 \times 10^{-6}\ m$

$L = 0.85\ m$

$m = 1$

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

$$\sin\theta = \frac{\lambda}{d} \rightarrow \theta = \sin^{-1}\frac{530 \times 10^{-9}}{3.2 \times 10^{-6}} = 9.53°$$

$$\tan\theta = \frac{\Delta x}{L} \rightarrow \Delta x = L\tan\theta$$

$$\therefore \Delta x = 0.85 \times \tan 9.53° = 0.1427\ m$$

For Electron beam:

$V = 150\ V$

$q_e = 1.602 \times 10^{-19}\ C$

$m_e = 9.109 \times 10^{-31}\ kg$

To calculate speed:

$$W = \Delta K$$

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

$$\therefore v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2 \times 1.602 \times 10^{-19} \times 150}{9.109 \times 10^{-31}}}$$

$$v = 7.263 \times 10^{6}\ ms^{-1}$$

For wavelength:

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{9.109 \times 10^{-31} \times 7.263 \times 10^{6}}$$

$h = 6.626 \times 10^{-34}\ Js$

$$\therefore \lambda = 1.0 \times 10^{-10}\ m$$

Distance to diffraction fringe (small angle approximation):

$$sin\,\theta = tan\,\theta = \frac{\Delta x}{L}$$

$$\therefore \frac{d\Delta x}{L} = m\lambda$$

$$\Delta x = \frac{\lambda L}{d} = \frac{1.0 \times 10^{-10} \times 0.85}{3.2 \times 10^{-6}}$$

$$\Delta x = 2.656 \times 10^{-5}\ m$$

∴ The amount of electron beam fringes that would appear between the central maxima and the first order fringe of the laser is $\frac{0.1427}{2.656 \times 10^{-5}} = 5372$.

NOTE: *full marks were not awarded for rounding UP the number of electron fringes. Also the question asks for the electron fringes between the central maxima and 1st order fringe – NOT between n=1 and n=-1 fringes.*

Question 29

Criteria	**Marks**
• **Describes TWO relevant experiments in detail**	**3**

• **Relates results of the relevant experiment to an aspect of the nucleus**
  • **Gieger – Marsden: Most go through -> Empty space, small deflections -> positive charge, few large angle deflections -> dense nucleus**
  • **Joliot – Currie: alpha strikes Be foil, releases neutral radiation, strikes paraffin, emits protons.**
  • **NOTE: property must be linked with correct result**	

• **Outlines TWO relevant experiments correctly** **OR** • **Describes ONE relevant experiment in detail**	**2**
• **Provides some relevant information**	**1**

Sample answer:

Geiger and Marsden bombarded a thin gold foil using alpha particles. Their results found that almost all the particles passed through, with the very occasional particle having a very large deflection, implying that most of the atom was empty space with a small, dense nucleus.

Chadwick's experiment involved alpha particles impacting a beryllium target, ejecting a then unknown particle. Analysis of the unknown radiation showed that it was neutral, but identity was still unknown. This radiation was directed to impact a paraffin wax target, which would dislodge protons into detecting equipment. Through analysis of conservation of momentum and energy, Chadwick calculated the existence of neutrons, particles with zero charge that existed within the nucleus.

Question 30 a

Criteria	**Marks**
• Calculates temperature using Wien's Law • As long as working out is clearly shown, either 30GHz or 30 THz accepted	2
• Some relevant information	1

Sample answer:

Using Wien's Law:

$$f = 30 \times 10^9 Hz$$

$$\lambda_{max} = \frac{b}{T} = \frac{c}{f_{max}}$$

$$T = \frac{b \times f_{max}}{c} = \frac{2 \cdot 898 \times 10^{-3} \times 30 \times 10^9}{3 \times 10^8} = 0 \cdot 2898K$$

Question 30 (b)

Criteria	**Marks**
• Explains TWO differences between the black body radiation curves • Valid reasoning for the differences given	3
• Explains ONE difference between the black body radiation curves • Or • Two differences identified, with incorrect or incomplete reasoning	2
• Describes a difference between the curves	1

Sample answer:

- *Peak intensity of the sun will be further to the RIGHT, since a higher temperature body will release a higher number of photons with higher frequency (lower wavelength)*. And we're graphing frequency
- *The Peak is not only higher for the sun, but the sun's curve is higher than the Earth's at all wavelengths. Thus, the area under the sun's curve is greater, since a larger, hotter object will emit more photons of all frequencies.*

Question 31 (a)

Criteria	**Marks**
• **Identifies that a rotating magnetic field is produced by the stator**	**3**

• **Explains that this changing B induces an I in the rotor with the use of relevant laws** • **Describes the interaction between induced I and B produces a F that results in torque**	
• **2 of above**	**2**
• **Provides some relevant information**	**1**

Sample answer:

In an AC induction motor, the stator is supplied with a three-phase alternating current, which creates a rotating magnetic field. This changing magnetic field passes through the rotor and, according to Faraday's Law of Electromagnetic Induction, induces a current in the rotor conductors.
The induced current in the rotor interacts with the rotating magnetic field from the stator. According to the motor effect, a force is exerted on the rotor conductors, producing a torque that causes the rotor to turn in the same direction as the magnetic field. This occurs without any physical electrical connection to the rotor, as current is induced rather than supplied directly.

Question 31 (b)

Criteria	**Marks**
• **States a valid advantage AND a limitation** • **Note: Induction motors are cheaper and easier to construct than DC motors, and efficiency of the motors depends on operating range (excluding brush losses)**	**2**
• **States a valid advantage OR a limitation**	**1**

Sample answer

One advantage of an AC induction motor is that it does not require brushes or a commutator, reducing maintenance and increasing durability.
However, a limitation is that it requires an external AC power supply and is less efficient at low speeds compared to DC motors, which can provide better torque control.

Question 32 (a)

Criteria	Marks
• **Describes the stopping Voltage and Photocurrent for metals A and B**	**2**
• **Provides some relevant information**	**1**

Sample answer:

Metal	Description of Voltage and Current between f0and f1
A	*Stopping Voltage: Increasing* *Photocurrent: constant*
B	*Stopping Voltage:0* *Photocurrent: 0*

Question 32 (b)

Criteria	Marks
• **Explains how an experimental result involving the photoelectric effect supported Einstein's quantisation theory** • **Needs to clearly show the results contradicting classical theory (time delay, threshold frequency)**	**3**
• **Describes some finding(s) of the photoelectric effect**	**2**
• **Provides some relevant information**	**1**

Sample answer:

When light shone on the metal, classical predictions assumed that, due to light being a wave, at low intensities there would be a delay as atoms absorb the low amounts of energy to be lifted. However, there was no delay between the absorption of light and the emission at any intensity. Hence, the energy was either absorbed, or not absorbed at all. This implied that the energy was discreetly packaged into quanta.

Other answers could include:

- *Below the threshold frequency, no electrons were emitted no matter the intensity.*

- *The size of the current did not change with frequency once the threshold frequency was met, but only with intensity.*

Question 33

Criteria	Marks
• **Correctly Quantitatively assesses the <u>ACCURACY</u> of BOTH the charge on e- and q/m ratio**	**3**
• **Correctly Quantitatively assesses the Accuracy OR Error of either the charge on e- OR q/m ratio of an e-**	**2**
• **Provides some relevant information**	**1**

Sample answer:

$$q\ \%Acc = 1 - \left|\frac{1.85 \times 10^{-19} - 1.6 \times 10^{-19}}{1.6 \times 10^{-19}}\right| = \mathbf{84.4\%}$$

$$^{q}/_{m} = \frac{1.602 \times 10^{-19}}{9.109 \times 10^{-31}} = 1 \cdot 759 \times 10^{11} Ckg^{-1}$$

$$^{q}/_{m}\ \%Acc = 1 - \left|\frac{1.81 \times 10^{11} - 1.759 \times 10^{11}}{1.759 \times 10^{11}}\right| = \mathbf{97.1\%}$$

Question 34

Criteria	Marks
• **Explains that the energy of beam is constant but number of photons is different**	**2**
• **Provides some relevant information**	**1**

Sample answer

Light is quantised into packets of energy called photons, which is defined as E=hf. As infrared light has a lower frequency than UV, IR photons carry less energy. Thus, a 1W beam would carry more photons than a UV beam.

Question 35 a

Criteria	Marks
• **Explains how the velocity changes due to LCOE or Kepler's second law**	**2**
• **Provides some relevant information**	**1**

Sample answer

Question 35 b

Criteria	Marks
• **Correctly calculates velocity**	**1**

Sample answer

$$v_0 = \frac{D}{T} = \frac{2\pi r}{T} = \frac{2\pi \times 1.5 \times 10^{11}}{365 \times 24 \times 3600} = \mathbf{3.0 \times 10^4 ms^{-1}}$$

Question 36 a

Criteria	Marks
• Identifies the initial state must be higher, more energetic, further out than the final state	1

Sample answer

This chart demonstrates the emission of a photon from an atom. This will not occur if the nf is greater or equal to ni, as the electron cannot drop in energy; requiring absorption instead.

NOTE: not enough just to say that the wavelength is negative, needs to show physical reasoning for it

Question 36 b

Criteria	Marks
• Substitutes table entries into formula, correctly calculates and identifies correct means of obtaining photon energy from wavelength	4
• Substitutes table entries into formula and correctly calculates OR • Further identifies correct means of obtaining photon energy from wavelength	3
• Identifies correct formula(e) AND • Selects correct table entries	2
• Identifies correct formula OR • Selects table entries appropriate for identified transition	1

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = R\left(\frac{1}{3^2} - \frac{1}{5^2}\right) = 1.097 \times 10^7(0.0711) = 779967m^{-1}$$

$$E = hf = \frac{hc}{\lambda}$$

$$E = 6.626 \times 10^{-34} \times 3 \times 10^8 \times 779967 = 1.55 \times 10^{-19}J$$

$$\boldsymbol{E = 1.55}$$