Student number ....

Teacher ....

Cheltenham Girls
High School

2008
Higher School Certificate
Trial examination

Physics

TASK WEIGHTING: 35%

General Instructions
- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-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 I Pages 2 – 19
75 marks
This section has two parts, Part A and Part B

Part A – 15 marks
- Attempt Questions 1 – 15
- Allow about 30 minutes for this part

Part B – 60 marks
- Attempt questions 16 – 27
- Allow about 1 hour and 45 minutes for this part

Section II Pages 20 – 23
25 marks
- Attempt ONE question i.e. Question 28
- Allow about 45 minutes for this section

Section I - 60 marks
Part A Multiple Choice questions - 15 marks

Attempt all questions **1** to **15**. Allow about 30 minutes to complete this Part.
Select the alternative A, B, C or D, that best answers the question and indicate your choice by clearly marking your answer in the appropriate place on the Multiple Choice Answer Sheet provided.

Section I
75 marks

Part A – 15 marks
Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet for Questions 1–15.

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1 When the Apollo Moon Missions returned to Earth, the capsules re-entered the atmosphere at angles between 5.5° and 7.5°. Why was re-entry angle greater than 7.5° considered dangerous?

A The capsule might have 'bounced off' the atmosphere.
B The deceleration caused by atmospheric drag would have been too small.
C The deceleration caused by atmospheric drag would have been too great.
D The acceleration due to gravity would have increased too quickly.

2 A car drives horizontally off the edge of a 30 m high cliff. What can we predict about the car's motion during its fall?

A The acceleration will increase.
B The total energy of the car will increase.
C The vertical component of the velocity of the car will increase.
D The horizontal component of the velocity will increase.

3 If the space shuttle moved a satellite to a higher orbit, how would the energy of the satellite in the higher orbit compare to the energy of the satellite in the lower orbit?

A Both the kinetic energy and potential energy would be less.
B The kinetic energy would greater, but the potential energy would be less.
C Both the kinetic energy and potential energy would be greater.
D The potential energy would be greater, but the kinetic energy would be less.

4 Planet A has the same mass as planet B. If the acceleration due to gravity on the surface of planet A is nine times greater than the acceleration due to gravity on the surface of planet B, what is the ratio of the radii of planet A to planet B?

A 3 : 1
B 1 : 3
C 9 : 1
D 1 : 9

5 What can be inferred about a frame of reference if Newton's first law is obeyed in the frame?

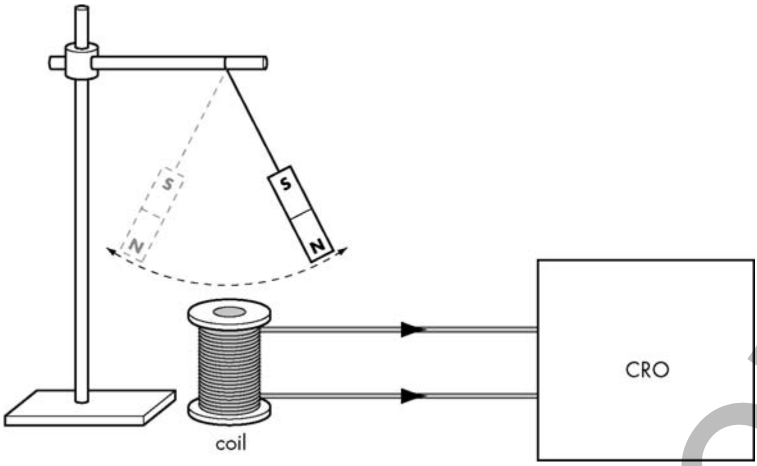
A The frame must be in a gravitational field.
B The frame must be an inertial frame.
C Einstein's special theory of relativity could not be applied to the frame.
D The frame must be a non-inertial frame.

6 The motor/generators in the latest electric cars have a dual role. They use electrical energy to power the car and they use the kinetic energy of the car to generate electricity when the car decelerates.

Which of the following principles enables the motor to carry out both roles?

A Potential energy can always be converted into kinetic energy.
B Induction motors have no commutator.
C Superconductors can be used to make very intense magnetic fields.
D The structure of a DC motor and generator are identical.

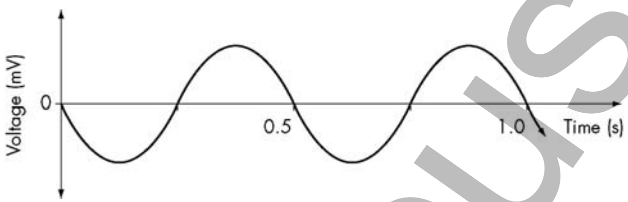
7



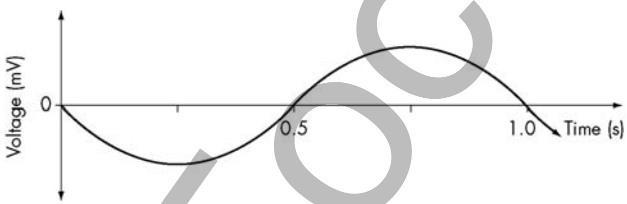
A student sets up an experiment in which a bar magnet attached to a simple pendulum with a period of 1 second swings across the top of a coil. The coil is then connected to a cathode ray oscilloscope (CRO).

Which diagram best represents the display on the CRO that would result from the magnet swinging back and forth over the coil?

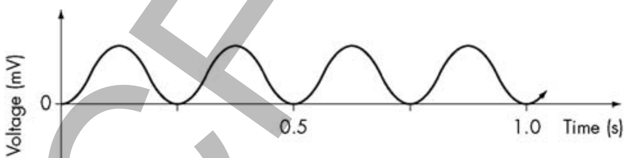
A



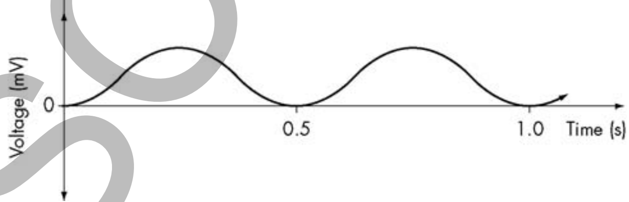
B



C



D



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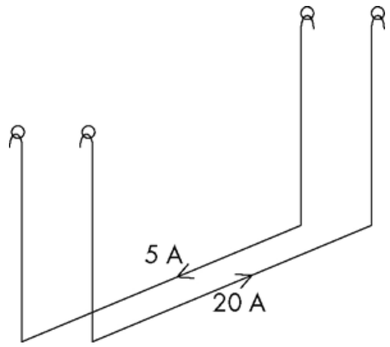


Note: To simplify the diagram, the external circuit has not been shown.

In an experiment to demonstrate the force between two wires carrying current, two identical long parallel wires are suspended from supports in such a way that a force between them will cause them to swing towards one another or away from one another. A current of 5 A is then passed through wire A and 20 A through wire B.

If the currents flow in opposite directions, what will happen to the wires?

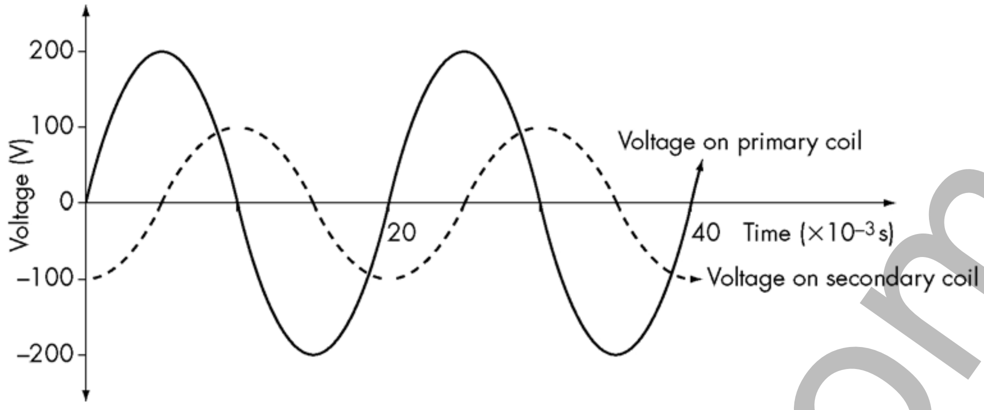
A A force of repulsion will appear between the wires and the wires will swing apart by equal amounts.

B A force of repulsion will appear between the wires and the wires will swing apart, but wire B will swing out furthest.

C A force of repulsion will appear between the wires and the wires will swing apart, but wire A will swing out furthest.

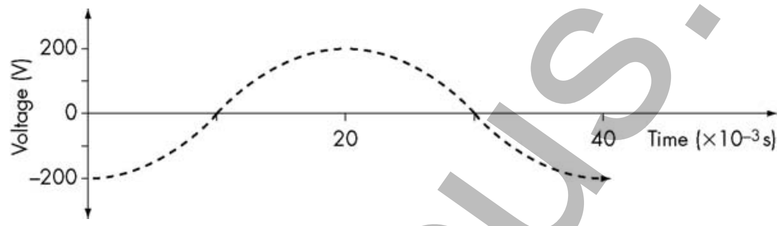
D A force of attraction will appear between the wires and they will move towards one another by equal amounts.

9

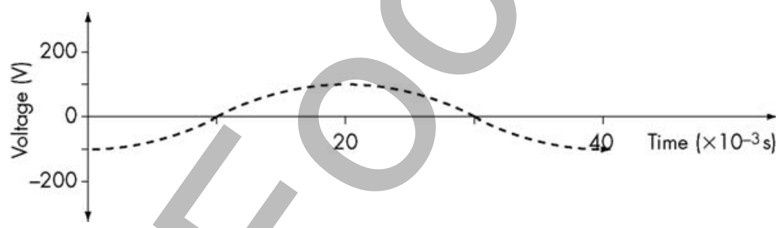


A cathode ray oscilloscope is used to display the voltage on the primary coil and secondary coil of a step down transformer. If the voltage of the input signal was doubled and the frequency halved, what would the output voltage signal look like?

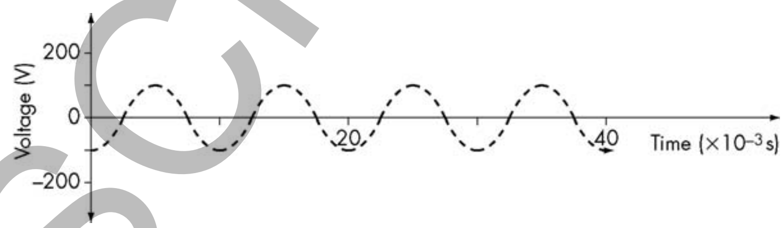
A



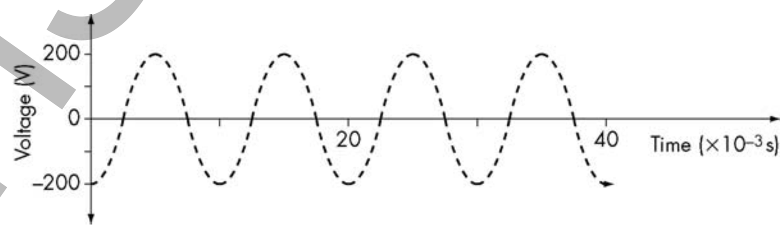
B



C



D



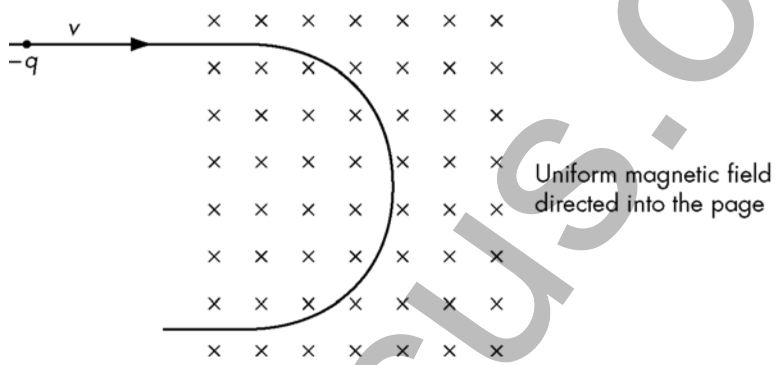
10 What is magnetic flux density?

A The product of the magnetic field strength and area
B A measure of the strength of the magnetic field
C A measure of the induced EMF
D A type of magnetic field caused by eddy currents

11 Who was the first scientist to observe and report the photoelectric effect?

A Einstein
B Planck
C Hertz
D Bragg

12



A particle with a charge of –*q* moving to the right with velocity *v*, enters a magnetic field that is directed into the page. The force on the charge produced by its motion in the magnetic filed causes the charge to move in a circular path. How would the radius of this path change if the particle was replaced by one the same mass but with a velocity of 2*v* and a charge of $-\frac{q}{2}$?

A The radius would decrease to a quarter of the previous size.
B The radius would double.
C The radius would halve.
D The radius would be four times larger.

13 Doping a semiconductor with impurity atoms can change the properties of the semiconductor. Which statement correctly identifies the change and the reason for the change?

Answer	**Doping atom**	**Change of electrical resistance**	**Reason**
A	Ga	Increases	Reduced number of electrons in the valence band
B	P	Decreases	Increased number of electrons in the conduction band
C	In	Increases	Increased number of holes in the valence band
D	As	Decreases	Increased number of holes in the conduction band

14 A modern high power ultraviolet laser can produce short light pulses containing 0.2 joules of light energy. Given that the operating wavelength of the laser is 370 nm, how many photons (light quanta) would a single pulse from the laser contain?

A 8.2×10^{38}
B 3.7×10^{17}
C 3.7×10^{14}
D 8.3×10^{35}

15 What is the main cause of electrical resistance in metals?

A The temperature of the metal
B Electron-electron scattering
C Scattering of electrons by the lattice vibrations and impurities in the lattice
D The shape of the piece of metal being tested

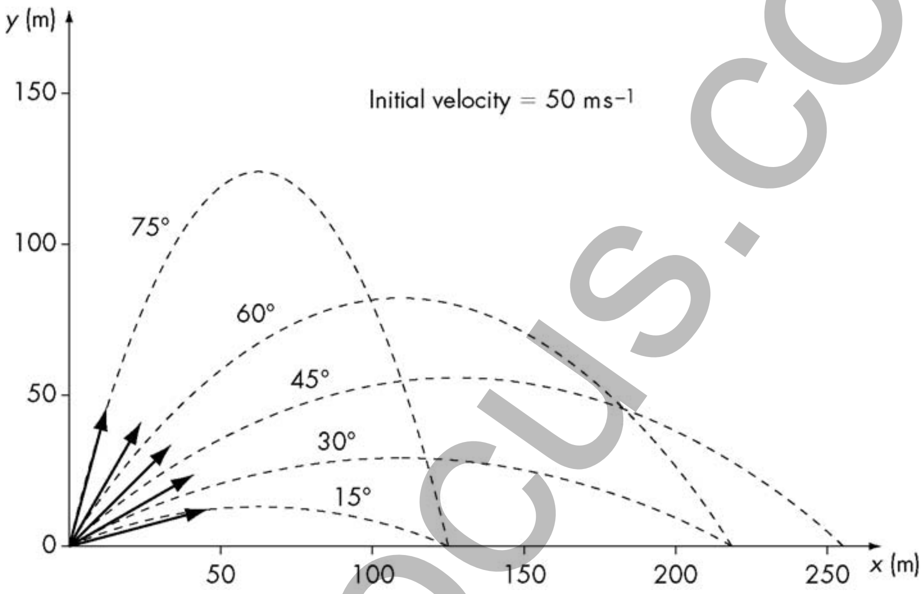
Part B – 60 marks
Attempt Questions 16–27
Allow about 1 hour and 45 minutes for this part

Answer all questions in the space provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (6 marks)



In an experiment designed to examine projectile motion, a small steel ball is fired with an initial velocity of 50 m s^{-1} at a variety of initial angles of projection.

(a) At which initial angle of projectile does the ball have the greatest initial horizontal velocity? **1**

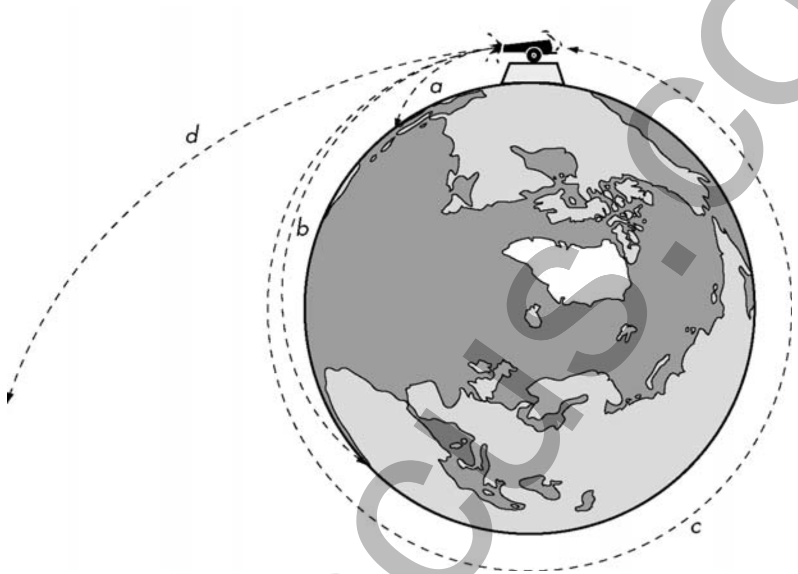
(b) At which angle of projection does the ball have the greatest initial vertical velocity? **1**

Marks

(c) Calculate the time of flight for the ball projected at 15º. **2**

(d) Compare the final velocity of the ball when it is launched at 15° to its final velocity when it is launched at 45°. Note that no calculations are required. **2**

Question 17 (6 marks)



Newton explained satellite motion using a thought experiment that involved projectiles being fired horizontally from a cannon placed on a mountain top above the atmosphere. Note that the Earth has a radius of 6371 km.

(a) Which of the projectiles shown would have been fired with the lowest initial velocity? **1**

(b) Define the term 'escape velocity'. **2**

(c) If the cannon were fired from a height of 300 km above the ground, calculate the orbital period of the satellite shown undergoing circular motion (path *c*). **3**

Question 18 (7 marks)

An alien spaceship moves past the Earth at a speed of 2.5×10^8 m s^{-1}. Measurements from the Earth indicate the spaceship has a length of 40 m in the direction of its motion and a width (perpendicular to its motion) of 10 m.

(a) For an observer in the spaceship, would time on Earth appear to be running faster or slower than time on the spaceship? Justify your answer. **2**

(b) The spaceship turns around and returns to the Earth, landing on the Earth's surface. What would an Earth-bound observer now calculate the length and width of the ship to be? **2**

(c) 'One day we will be able to travel faster than the speed of a light.' Evaluate this statement in the light of Einstein's Special Theory of Relativity. **3**

Question 19 (5 marks)

The motor effect is used in a range of important applications.

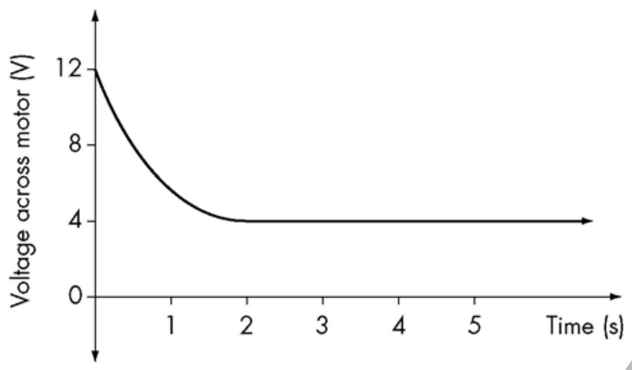
(a) What is the motor effect? **1**

(b) Draw a labelled diagram of a loudspeaker and explain how a loudspeaker converts electrical signals into sound waves. **4**

Question 20 (4 marks)

Outline the discovery of electromagnetic induction by Michael Faraday and evaluate the implications of his discovery. **4**

Question 21 (5 marks)



A student connected a DC motor to a 12 V battery and measured the voltage across the motor as a function of time after the motor was switched on.

(a) Which of the variables plotted by the student is the independent variable? **1**

(b) With reference to Lenz's law, explain the shape of the graph obtained by the student. **4**

Question 22 (6 marks)

A transformer has 200 turns on the primary coil and 12 000 turns on the secondary coil. If an AC voltage of 1000 V is placed on the primary coil, a current of 50 A is measured on the secondary coil.

(a) Where would this type of transformer be found in an electrical power distribution system, and why would it be used there? **1**

(b) Assuming the transformer is 100% efficient, calculate the current passing through the primary coil. **2**

(c) Outline why real transformers are never 100% efficient and explain what steps can be taken to improve the efficiency of transformers. **3**

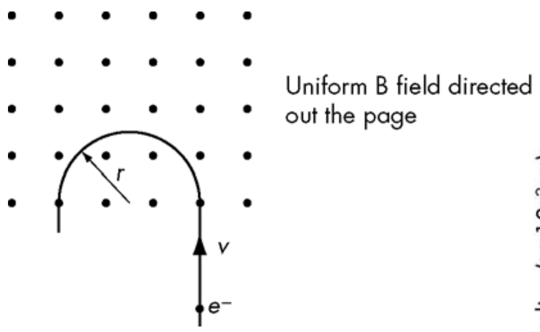
Question 23 (3 marks)

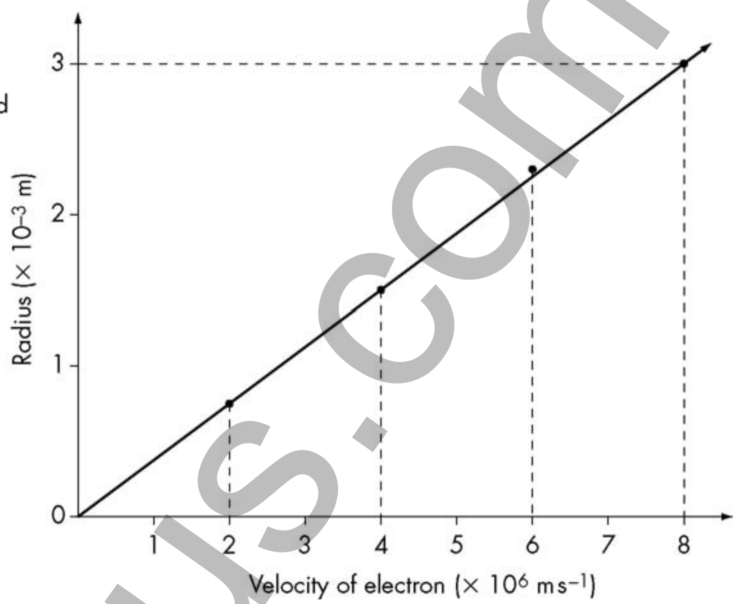
Compare the energy band structure of a conductor, a semiconductor and an insulator. **3**

Marks

Question 24 (6 marks)

A student uses a cathode gun to accelerate electrons to different velocities and then measures the radius of curvature of the path the electrons take in a magnetic field. The electrons enter the magnetic field at right angles to the field. A diagram of the experiment and a graph of the results obtained by the student are shown below.





(a) By equating the centripetal force and magnetic force on a charge moving perpendicularly to a magnetic field at a constant speed (v) derive a general expression for the radius of curvature of the charge in the field. **2**

(b) Find the gradient of the graph and its units. **2**

(c) Calculate the strength of the magnetic field used in the experiment. **2**

Question 25 (4 marks)
Describe how doping a semiconductor can influence its electrical properties. **4**

Question 26 (4 marks)
Einstein's particle theory of light radically changed the way physicists viewed the interaction of light with matter, and ushered in the era of quantum physics.

(a) Outline Einstein's hypothesis on the particle nature of light. **2**

(b) Calculate the energy of a photon of light with a wavelength of 630 nm. **2**

Question 27 (4 marks)
Concerns about the Greenhouse Effect and diminishing fossil fuel resources have renewed interest in solar energy. Outline how the semiconductor materials used in solar cells can convert light energy to electricity. **4**

End of Section I

Section II

25 marks
Attempt question 28 from this section.
Allow about 45 minutes for this section

Answer the question in a writing space provided.

Show all relevant working in questions involving calculations.

Marks

Question 28 – From Quanta to Quarks (25 marks)

(a) Rutherford discovered the atomic nucleus and suggested one of the earliest atomic models.

(i) Draw a labelled diagram of Rutherford's atomic model. **1**

(ii) Explain why Rutherford's model was criticised by scientists at the time. **2**

(iii) Rutherford's atomic model was refined and extended by Bohr, yet even Bohr's model had serious shortcomings. Outline the key deficiencies of Bohr's model. **3**

(b) The emission spectra of excited atomic hydrogen atoms can be predicted using the equation:

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

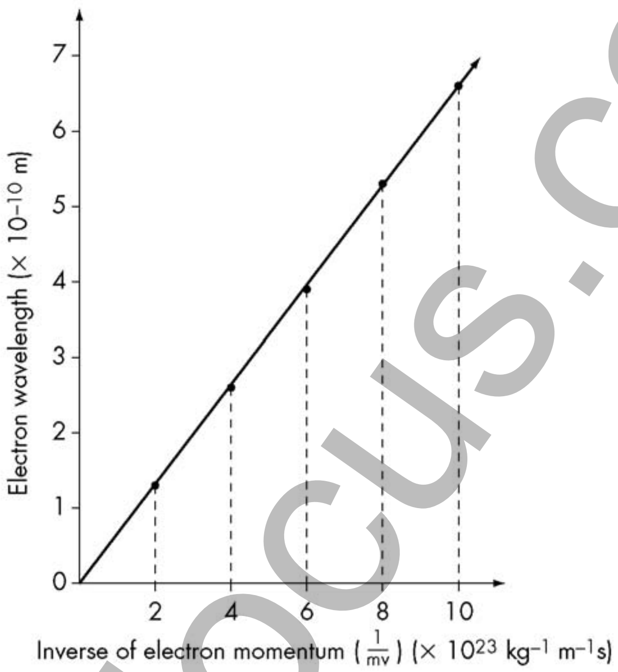
(i) Use this equation to calculate the wavelength of light associated with an electron transition from the n = 4 state to the n = 2 state in a hydrogen atom. **2**

(ii) Explain how energy is conserved when an electron makes a transition from one stationary state to another in an atom. **2**

(c) De Broglie suggested that all particles have an associated wavelength that is related to the momentum of the electron by:

$$\lambda = \frac{h}{p}$$

In a modern experiment similar to the one conducted by Davisson and Germer, electrons of known velocity were fired at a crystal lattice with known crystal plane spacing. The plane spacing and angle of diffraction of the electron beam was used to calculate the wavelength associated with electrons as a function of the speed of the electrons. The inverse of the momentum of the electrons was then plotted against the measured wavelength.

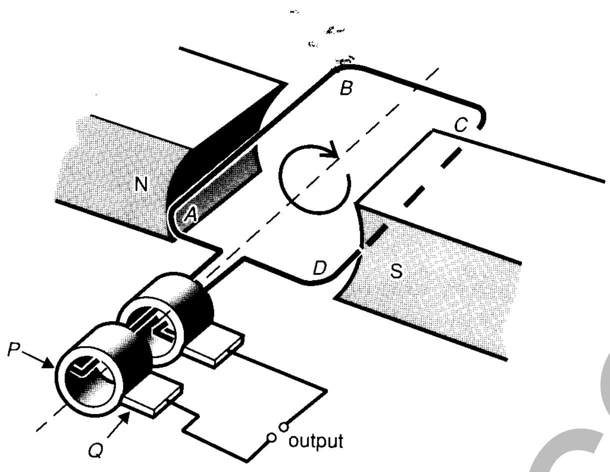


(i) Find the momentum of an electron with a de Broglie wavelength of 5×10^{-10} m. **1**

(ii) Calculate the gradient of the graph. **1**

(iii) Identify the significance of the gradient of this graph. **2**

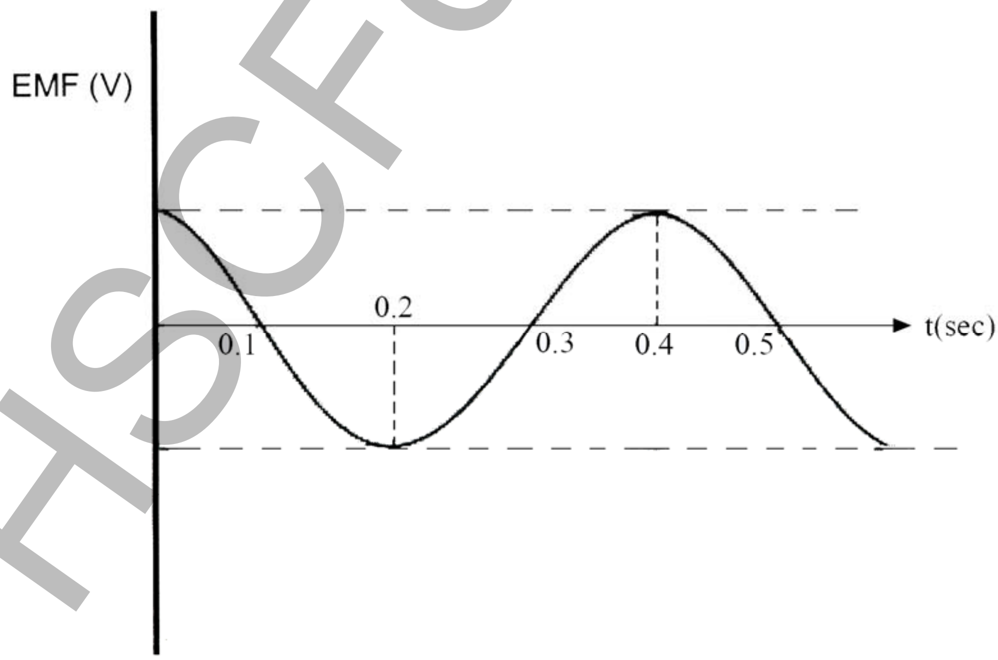
(d) The diagram below shows a simple electric generator



(i) Name the part labelled P. **1**

(ii) What would be the effect on the induced emf of doubling the number of turns in the coil if the speed of rotation was kept constant? **1**

(iii) The diagram below represents the emf generated in the coil measured against time.



Draw a graph on the diagram above to show clearly the effect on the emf if the speed of rotation of the coil is doubled. **2**

(iv) As the coil rotates faster more torque is required to maintain a constant speed of rotation. Explain this observation. **2**

(e) In your course you studied some scientists who contributed to the development of space exploration. Choose one such scientist.

(i) Identify the scientist studied. **1**

(ii) Assess the contribution to space exploration of this scientist. **2**

(f) Explain how an induction cook top produces heat. **2**

End of paper

Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^{8} m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2.0×10^{-7} N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	1.097×10^{7} m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^{3} kg m^{-3}
Specific heat capacity of water	4.18×10^{3} J kg^{-1} K^{-1}

FORMULAE SHEET

$$v = f\lambda$$

$$I \propto \frac{1}{d^2}$$

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$

$$E = \frac{F}{q}$$

$$R = \frac{V}{I}$$

$$P = VI$$

$$\text{Energy} = VIt$$

$$v_{\text{av}} = \frac{\Delta r}{\Delta t}$$

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} \quad \text{therefore} \quad a_{\text{av}} = \frac{v-u}{t}$$

$$\Sigma F = ma$$

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

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

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

$$E_p = -G\frac{m_1 m_2}{r}$$

$$F = mg$$

$$v_x{}^2 = u_x{}^2$$

$$v = u + at$$

$$v_y{}^2 = u_y{}^2 + 2a_y\Delta y$$

$$\Delta x = u_x t$$

$$\Delta y = u_y t + \tfrac{1}{2}a_y t^2$$

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

$$F = \frac{Gm_1 m_2}{d^2}$$

$$E = mc^2$$

$$l_v = l_0\sqrt{1 - \frac{v^2}{c^2}}$$

$$t_v = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$m_v = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

FORMULAE SHEET

$$\frac{F}{l} = k\frac{I_1 I_2}{d}$$

$$F = BIl\sin\theta$$

$$\tau = Fd$$

$$\tau = nBIA\cos\theta$$

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

$$d = \frac{1}{p}$$

$$M = m - 5\log\left(\frac{d}{10}\right)$$

$$\frac{I_A}{I_B} = 100^{(m_B - m_A)/5}$$

$$m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$$

$$F = qvB\sin\theta$$

$$E = \frac{V}{d}$$

$$E = hf$$

$$c = f\lambda$$

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

$$\lambda = \frac{h}{mv}$$

$$Z = \rho v$$

$$\frac{I_r}{I_0} = \frac{\left[Z_2 - Z_1\right]^2}{\left[Z_2 + Z_1\right]^2}$$

$$A_0 = \frac{V_{\text{out}}}{V_{\text{in}}}$$

$$\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_{\text{f}}}{R_{\text{i}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79	
	Au	Symbol of element
Atomic Weight	197.0	
	Gold	Name of element

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.41 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [97.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [209.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223] Francium	88 Ra [226] Radium	89–103 Actinoids	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [271] Darmstadtium	111 Rg [272] Roentgenium							

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [145] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac [227] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237] Neptunium	94 Pu [244] Plutonium	95 Am [243] Americium	96 Cm [247] Curium	97 Bk [247] Berkelium	98 Cf [251] Californium	99 Es [252] Einsteinium	100 Fm [257] Fermium	101 Md [258] Mendelevium	102 No [259] Nobelium	103 Lr [262] Lawrencium

For elements that have no stable or long-lived nuclides, the mass number of the nuclide with the longest confirmed half-life is listed between square brackets.
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (October 2005 version) is the principal source of data. Some data may have been modified.

Section I – Multiple choice Answer sheet

Name: ________________________________

Number: ______________________________

Teacher: _____________________________

	A	B	C	D
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14				
15				

Marking guidelines

Section I – Part A

1	C	
2	C	
3	D	For a satellite, PE increases with height and velocity (KE) decreases.
4	B	$mg = \frac{Gm_1m_2}{r^2}$ and hence $g \propto \frac{1}{r^2}$.
5	B	
6	D	
7	A	Lenz's law implies that current will flow in one direction when a magnet is approaching the coil and in the opposite direction when the magnet is moving away from the coil.
8	A	Newton's third law states forces will be equal and opposite; as the wires are identical, they will swing apart symmetrically.
9	A	For a transformer, input and output voltages have equal frequencies; doubling voltage on primary will double voltage on secondary as, for a transformer, $V_p \propto V_s$
10	B	Magnetic flux density is measured in Tesla.
11	C	
12	D	$qvB = \frac{mv^2}{r}$ and hence $r \propto \frac{v}{q}$
13	B	Doping increases the number of free charge carriers and hence reduces resistance, and as P is from group 5, it increases the number of conduction electrons.
14	B	$E = hf = \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\times3\times10^{8}}{370\times10^{-9}} = 5.37 \times 10^{-19}$ J Hence the number of photons = $\frac{0.2}{5.37\times10^{-19}} = 3.7 \times 10^{17}$ photons.
15	C	

Section I – Part B

Question 16(a)

Criteria	Marks
• Correct answer	1

Suggested answer:
15º

Question 16(b)

Criteria	Marks
• Correct answer	1

Suggested answer:
75º

Question 16(c)

Criteria	Marks
• Correct answer	2
• Incorrect answer but uses vertical part of the motion and correctly calculates initial vertical velocity for the ball projected at 15º	1

Suggested answer:
Using the vertical part of the motion and calling upwards vectors positive:
The initial vertical velocity $u_y = u \sin \theta = 50 \sin 15 =$ **12.94 m s^{-1}**.
Now using $v_y = gt + u_y$ and substituting $v_y = -u_y$ (as we are dealing with the whole flight), we obtain $t = \frac{-2u_y}{g}$ or $t = \frac{-2 \times 12.94}{-9.8}$ = **2.64 seconds**.

Question 16(d)

Criteria	Marks
• Answer which states that the magnitudes of the final velocities will be equal but the direction of the velocity will not be the same	2
• Only ONE of the above stated correctly	1

Suggested answer:
Both projectiles will have the same speed when they land, but the directions of the final velocity vectors will be different. (Both final velocity vectors will have a magnitude 50 m s^{-1} but the 45º vector will have equal vertical and horizontal components, while the 15º vector will have greater horizontal component.)

Question 17(a)

Criteria	Marks
• Correct answer	1

Suggested answer:
Path *a* (because it falls to the Earth in the least time).

Question 17(b)

Criteria	Marks
• A correct definition which states that the escape velocity is the **minimum** initial velocity required **to escape from the Earth's gravitational pull**	2
• A definition that fails to mention that escape velocity is the **minimum** initial velocity required to escape, OR a poorly expressed definition that includes a correct statement about escape velocity	1

Suggested answer:
The minimum initial velocity required for a projectile to ensure that it will escape from the gravitational field of a planet. That is, the minimum initial velocity required to ensure the projectile never falls down but continues to move away from the planet forever.

Question 17(c)

Criteria	Marks
• Correct answer	3
• Correct equation and substitution but wrong answer obtained	2
• States satellite equation, but incorrect or no substitution of data shown and incorrect answer given	1

Suggested answer:
Orbital radius $r = 6371 \times 10^3 + 300 \times 10^3 = 6671 \times 10^3$

$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ and hence $T = \sqrt{\frac{4\pi^2 r^3}{GM}} = \sqrt{\frac{4\pi^2 \times 6671000^3}{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}}$

T = **5412 s = 90 minutes 12 seconds**

Question 18(a)

Criteria	Marks
• Answer which indicates that, in the spaceship frame, the space traveller is at rest and the Earth is moving	2
• Correct answer, but poor or no justification	1

Suggested answer:
The time on Earth would appear to be running slower to the observer in the spaceship because the observer considers himself to be at rest while the Earth moves rapidly past.

Question 18(b)

Criteria	Marks
• Correct answer for length and width	2
• Only ONE of the above correct	1

Suggested answer:
The width would be unchanged and hence would be **10 m**. The length would be longer when the ship returned to Earth. Using Einstein's relationship for length contraction and rearranging for l_0 we obtain:

$$l_0 = \frac{l_v}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{40}{\sqrt{1-\frac{(2.5\times10^8)^2}{(3\times10^8)^2}}} = \mathbf{72.4\ m}$$

Question 18(c)

Criteria	Marks
• Clear answer that includes an evaluation statement with supporting evidence from Einstein's special theory of relativity	3
• A reasonable answer that examines the implications of Einstein's work to the possibility of faster than light travel, but fails to include an evaluation statement, OR an answer that includes an evaluation statement but fails to support it with clear evidence from Einstein's special theory	2
• A poorly constructed answer that makes at least ONE correct statement	1

Suggested answer:
The statement is incorrect because, according to Einstein's Special Theory of Relativity, no material object can move faster than the speed of light with respect to any other material body. As an object is accelerated towards the speed of light, its mass will increase in accordance with Einstein's equation $m_v = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$. As acceleration is related to the applied force by Newton's second law $a = \frac{F}{m}$, this increasing mass reduces the acceleration and prevents the object ever reaching the speed of light. (Students might talk about time dilation and length contraction and their effect on the apparent speed of a space traveller.)

Question 19(a)

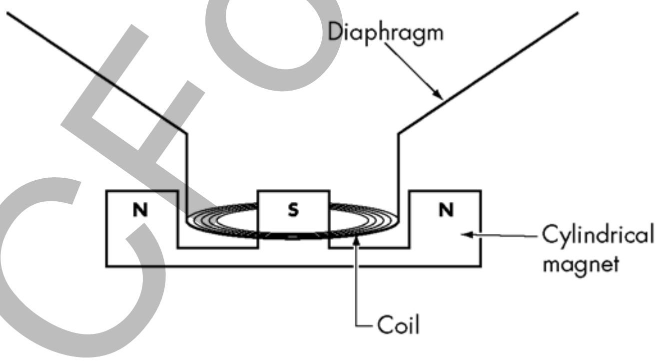
Criteria	Marks
• Correct definition	1

Suggested answer:
The motor effect is the force that appears on a current-carrying wire when it is placed in an external magnetic field. (Students may also use the mathematical definition $F = BIl \sin \theta$, where the force is perpendicular to B and l in a right-hand rule sense. But they must state that the force is the motor effect.)

Question 19(b)

Criteria	Marks
• Clear, labelled diagram and an explanation that correctly refers to the motor effect	4
• Clear explanation but unlabelled diagram, OR a correctly labelled diagram and reasonable explanation which explains the movement of the coil but not the creation of sound waves	3
• Clear explanation but no diagram, OR a clearly labelled diagram but a poor explanation	2
• Poor answer and/or diagram that makes at least ONE correct statement	1

Suggested answer:

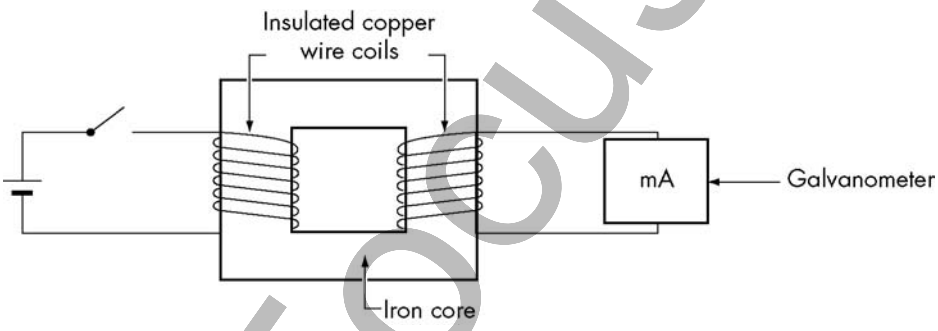


The electrical signal is applied to the coil in the loudspeaker. Because this coil is in a magnetic field current flowing in the coil will produce a motor force in the coil – either inwards or outwards, depending on the direction of the current in the coil. This force moves the coil in and out and, as the coil is connected to a diaphragm, the diaphragm also moves in and out. The motion of the diaphragm changes the air pressure, creating sound waves with a similar shape to the voltage signal applied to the coil.

Question 20

Criteria	Marks
• A clear outline of how Faraday discovered electromagnetic induction and an evaluation statement of the importance of the discovery, supported by evidence	4
• As above, without an evaluation statement but with evidence about how the invention was used, OR as above but failure to support the evaluation statement with sufficient evidence	3
• An evaluation statement about the importance supported by some evidence but no outline of Faraday's discovery, OR an outline of Faraday's discovery but no evaluation of its importance	2
• A vague answer that makes a correct statement about the discovery or importance of electromagnetic induction	1

Suggested answer:
Electromagnetic induction is the production of electricity from a change in magnetic flux. Faraday discovered electromagnetic induction when he had two insulated coils wrapped around an iron ring.



Faraday noticed that when he switched current on or off in the first coil, a current appeared in the second coil. He investigated this and soon found that a changing magnetic field in a coil produces a voltage on the coil. This was an extremely important discovery, because it led to the invention of the electrical generator and heralded in the 'age of electricity'. Faraday's invention enabled mechanical work to be changed to electricity, and would change the world profoundly.

Question 21(a)

Criteria	Marks
• Correct answer	1

Suggested answer:
Time is the independent variable.

Question 21(b)

Criteria	Marks
• A clear explanation that uses Lenz's law to explain back EMF, why the voltage across the motor decreases and why it reaches a minimum when the motor reaches operating speed	4
• An explanation that uses Lenz's law to explain how the back EMF causes a drop in voltage, but not why the voltage levels out when the motor reaches operating speed • An answer that gives a good explanation of back EMF and the shape of the curve but fails to mention Lenz's law	3
• A poor explanation that mentions Lenz's law AND back EMF	2
• A poor answer that makes a correct statement about back EMF, OR Lenz's law	1

Suggested answer:
Lenz's Law states that when a current is induced, the direction of the induced current always opposes the change that created it. When the motor is switched on it begins to turn the rotor coil which acts as a generator and the voltage produced opposes the applied voltage. This back EMF increases as the speed of the motor increases and this is why the measured voltage decreases. The back EMF reaches a maximum when the motor reaches operating speed and this is why the voltage across the motor remains at a constant value when the motor reaches operating speed.

Question 22(a)

Criteria	Marks
• Correct answer	1

Suggested answer:
This type of transformer is found at power stations where it is used to increase the generated AC voltage prior to transmission.

Question 22(b)

Criteria	Marks
• Correct answer	2
• Correct calculation of output voltage • States both transformer equations but obtains incorrect answer	1

Suggested answer:

$\frac{V_p}{V_s} = \frac{n_p}{n_s}$ and hence $V_s = \frac{V_p n_s}{n_p} = \frac{1000 \times 12\,000}{200}$ = 60 000 V

Power in = Power out, so $I_p V_p = I_s V_s$ and hence $I_p = \frac{I_s V_s}{I_p} = \frac{50 \times 60\,000}{1000}$ = 3000 A

Question 22(c)

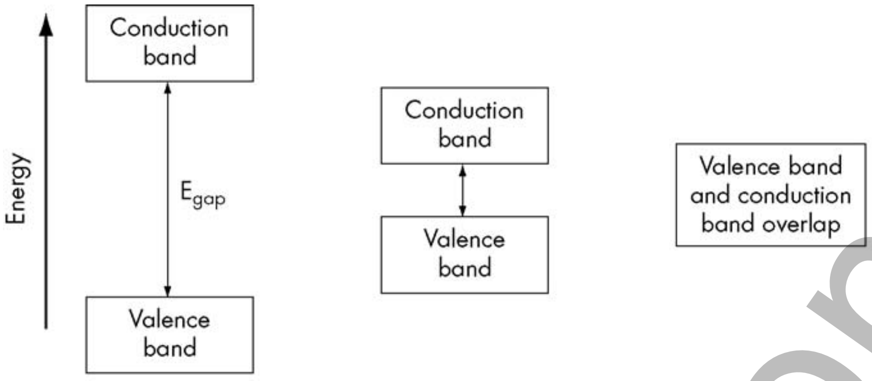
Criteria	Marks
• An answer which gives at least TWO reasons why transformers are not 100% efficient, and how (for each reason given) efficiency can be improved	3
• An answer which gives ONE reason why transformers are not 100% efficient and how (for the reason given) efficiency can be improved	2
• An answer that states why transformers are not 100% efficient but fails to explain how efficiency can be improved, OR an answer that explains how efficiency can be improved without explaining why efficiency is not 100%	1

Suggested answer:
Some of the input electrical energy in a transformer is converted into heat energy and this reduces the transformer's efficiency. The key losses are resistance heating in the iron core due to eddy currents (and changing the magnetic field of the iron core) and resistance heating in the windings. Eddy currents can be reduced by splitting the core into slices and insulating the slices (laminating the core) and resistance heating of the windings can be reduced by using lower resistance wire and by keeping the transformer at a low temperature.

Question 23

Criteria	Marks
• An answer which clearly compares the band structure of all THREE	3
• An answer that gives a good description of the band structure in each type of material, but fails to compare them	2
• An answer that only compares the band structure in TWO types of material	1

Suggested answer:



a Insulators have a large gap (>8eV)

b Semiconductors have a small energy gap (>2eV)

c Conductors have conduction and valence bands that overlap

As shown in the diagram above, insulators have a large energy gap between the valence band and the conduction band and semiconductors have a very small forbidden energy gap between the bands. Conductors have no energy gap between the bands because, in conductors, a single energy band acts as both the valence band and conduction band.

Question 24(a)

Criteria	Marks
• Correct derivation	2
• States the centripetal force equation and magnetic force equations correctly but fails to correctly derive the radius equation	1

Suggested answer:

$$F_C = F_B \text{ or } \frac{mv^2}{r} = qvB \text{ or } r = \frac{mv^2}{qvB}$$

Question 24(b)

Criteria	Marks
• Correct numerical value and units	2
• Correct numerical value OR units	1

Suggested answer:

$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{0.003 \text{ m}}{8 \times 10^6 \text{ m s}^{-1}} = \mathbf{3.75 \times 10^{-10}\ s}$$

Question 24(c)

Criteria	Marks
• Correct numerical answer	2
• Correctly states equation or uses gradient, but fails to obtain correct answer	1

Suggested answers:

$\frac{mv^2}{r} = qvB$ and hence $B = \frac{mv}{qr} = \frac{9.1\times10^{-19}\times8\times10^{6}}{1.6\times10^{-19}\times0.003} = 0.015$ Tesla

OR

Gradient = $\frac{r}{v} = \frac{m}{qB}$ = 3.75 × 10^{-10} and hence $B = \frac{m}{q(3.75\times10^{-10})}$ = 0.015 Tesla

Question 25

Criteria	Marks
• A coherent answer that describes how *p*-type or *n*-type semiconductors have additional holes or electron that can carry charge and links this to how the electrical properties of the semiconductor would change	4
• A good description of the extra free charge carriers in *p*-type and *n*-type semiconductors, but fails to make the connection between the increased charge carriers and the changed electrical properties	3
• A good description of *n*-type and *p*-type semiconductors or the electrical properties of doped semiconductors	2
• A poor answer that makes at least ONE correct statement about doping or the change in electrical properties that would result from doping	1

Suggested answer:

Pure (intrinsic) semiconductor material can be doped with low concentrations of impurity atoms to produce doped (extrinsic) semiconductors with many more free charge carriers per cm^3. If the impurity atom is from group 5 of the periodic table (e.g. phosphorus) an *n*-type semiconductor is created with one extra electron per doping atom in the conduction band.

If the doping atom is from group 3 (e.g. gallium) it creates a p-type semiconductor with an extra positive hole in the valence band per doping atom. Because doped semiconductors have more charge carriers, they have much lower resistance than pure semiconductors. The current in doped semiconductors is carried by either positive holes (*p*-type) or by negative electrons (*n*-type). These *n*- and *p*-type semiconductors have unique electrical properties when combined and can be used to make a variety of solid state devices (diodes, transistors, solar cells etc.)

Question 26(a)

Criteria	Marks
• A clear description of the particle nature of light and the relationship between photon energy and frequency (or wavelength)	2
• A clear description of the particle nature of light, OR the relationship between photon energy and frequency (or wavelength)	1

Suggested answer:
Einstein suggested that light consisted of small packets of energy, which were later called photons. The energy of the photon was related to the frequency of the light by $E = hf$ where h is the Planck constant = 6.626×10^{-34} J s.

Question 26(b)

Criteria	Marks
• Correct answer	2
• States Einstein's equation in the from $E = \frac{hc}{\lambda}$ but does not obtain correct answer (e.g. fails to use correct units)	1

Suggested answer:

$$E = hf = E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{630 \times 10^{-9}} = 3.15 \times 10^{-19} \text{ J (or 1.97 eV)}$$

Question 27

Criteria	Marks
• Clear explanation of creation of a junction potential and the use of the photoelectric effect to move electrons from the valence band to the conduction band	4
• Reasonable explanation that fails to mention the photoelectric effect, OR an explanation that mentions the photoelectric effect but does not clearly explain how a junction potential is used to produce a current	3
• An explanation that mentions semiconductor junctions and the photoelectric effect	2
• A poor answer that makes at least ONE clear statement about semiconductor junctions OR the photoelectric effect	1

Suggested answer:
Solar cells are made by placing thin sheets of *p*-type and *n*-type semiconductor material in contact. Where the semiconductors touch together, positive holes defuse from the *p* side to the *n* side of the junction, and electrons diffuse in the opposite direction, until a junction potential is created that prevents further diffusion. When a light photon strikes the junction electrons may be excited from the valence band to the conduction band due to the photoelectric effect. If the junction is connected to an external circuit these newly freed electrons will be driven around the external circuit by the junction potential.

Section II

Question 28(a) (ii)

Criteria	Marks
• A clear explanation of why the model was thought to have been unstable, OR any TWO other criticisms	2
• Incomplete explanation of instability, OR ONE other criticism	1

Suggested answer:
Rutherford's model involved an orbiting electron. Because the electron is accelerating, it should emit electromagnetic radiation, lose energy, and spiral into the nucleus. Rutherford's model also failed to explain the emission or absorption spectra of excited atomic atoms.

Question 28(a) (iii)

Criteria	Marks
• An answer that states THREE correct shortcomings	3
• An answer that states TWO correct shortcomings	2
• An answer that states ONE correct shortcoming	1

Suggested answers:
Bohr's model could not adequately explain:
- the relative intensity of spectral lines
- the spectra of atoms larger than hydrogen
- the existence of hyperfine spectral lines
- the Zeeman effect.

Question 28(b) (i)

Criteria	Marks
• Correct answer	2
• Correct substitution into equation shown, but incorrect answer obtained	1

Suggested answer:
$\frac{1}{\lambda} = R\left(\frac{1}{n_f^{\,2}} - \frac{1}{n_i^{\,2}}\right)$ so $\frac{1}{\lambda} = 1.097\times10^{7}\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$ and hence $\lambda = 486$ nm

Question 28(b) (ii)

Criteria	Marks
• Correct answer for emission AND absorption of a photon	2
• Correct for emission OR absorption of a photon	1

Suggested answer:
When an atom absorbs a photon of light, the energy of the photon is added to the energy of the atom. Energy is conserved because the difference in energy between the initial and final state of the electron is equal to the photon energy. When an excited electron in the atom relaxes to a less excited state, energy is conserved because a photon is released with an energy that is equal to the energy difference between the states.

Question 28(c)(i)

Criteria	Marks
• Correct answer	1

Suggested answers:

Reading from the graph gives $\frac{1}{mv} = 7.5 \times 10^{23}$ and hence $mv = 1.33 \times 10^{-24}$ kg m s^{-1}

OR

Using the equation $\lambda = \frac{h}{p}$, we obtain $p = \frac{h}{\lambda} = \frac{6.626 \times 10^{-34}}{5 \times 10^{-10}} = 1.33 \times 10^{-24}$ kg m s^{-1}

Question 28(c)(ii)

Criteria	Marks
• Correct answer	1

Suggested answer:

$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{6.6 \times 10^{-10}}{10 \times 10^{23}} = 6.6 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}$$

Question 28(c) (iii)

Criteria	Marks
• An answer that links de Broglie's equation to the graph to show the gradient will be equal to the Planck constant	2
• Statement that the gradient is equal to the Planck constant	1

Suggested answer:

The graph is a plot of experimental results supporting de Broglie's equation $\lambda = \frac{h}{p}$ for the electron. The gradient of the graph will be equal to the Planck constant, as:

$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{\lambda}{1/p} = \lambda p = h$$

Question 28(d) (i)

Criteria	Marks
• Correct answer	1

Suggested answers:
Slip ring

Question 28(d) (ii)

Criteria	Marks
• Correct answer	1

Suggested answers:
Induced emf doubled

Question 28(d) (iii)

Criteria	Marks
• Wave length and amplitude correct	2
• Wavelength or amplitude correct	1

Suggested answer:
A graph showing half the wavelength and twice the emf.

Question 28(d) (iv)

Criteria	Marks
• Refers to either conservation of energy OR Lenz's law AND has a logical cause and effect answer.	2
• Refers to one of the above but answer is not logically coherent.	1

Suggested answer:
More energy is produced so conservation of energy requires more energy needs to be put in. Lenz's law indicates that the induced current creates a motor effect which will oppose the motion of the coil.

Question 28(e) (i)

Criteria	Marks
• Correct answer	1

Suggested answers:
Werner Von Braun (or alternative)

Question 28(e) (ii)

Criteria	Marks
• One substantial contribution with an assessment.	2
• One substantial contribution but no assessment	1

Suggested answer:
Von Braun developed practical rockets for Germany during WW2 and then developed the US rocket program leading to the Apollo missions. Von Braun's contribution to space exploration was critical as without his rockets the Apollo missions would have been impossible.

Question 28(f)

Criteria	Marks
• Mentions changing B field, induced eddy currents and resistance in a coherent answer.	2
• Mentions two of the above in a coherent answer OR all in an illogical answer.	1

Suggested answer:
An AC current is fed to a coil below the cook top. The changing B field induces eddy currents in the pan according to Faraday's law. These eddy currents produce heat due to resistance in the pan.