NO. OF COPIES: 30

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STUDENT NUMBER: | | | | |

PYMBLE LADIES' COLLEGE

2002
TRIAL EXAMINATION

Physics

General Instructions
- Reading time - 5 minutes
- Working time - 3 hours
- Write using black or blue pen
- Draw diagrams in pencil
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided
- Write your Student Number at the top of this page and other pages where indicated, including the multiple choice answer sheet

Total marks – 100

Section 1
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 – 30
- Allow about 1 hour and 45 minutes for this part

Section II
25 marks
- Attempt all sections of Question 31
- Allow about 45 minutes for this section

Section I
75 marks

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

Use the multiple-choice answer sheet.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: $2 + 4 =$ (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

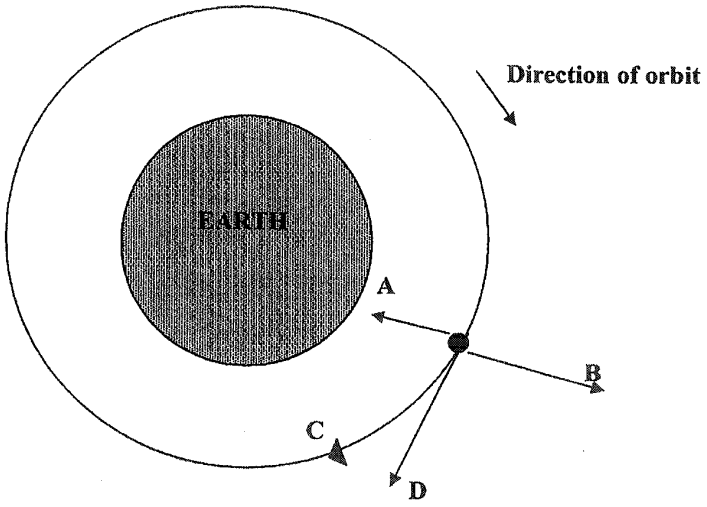
If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word ***correct*** and drawing an arrow as follows.

Question 1

A satellite is orbiting the Earth in a clockwise direction, when viewed as shown in the diagram below. If the gravitational force of the Earth were to suddenly disappear, in which of the directions shown on the diagram (A, B, C or D) would the satellite move?



(A) A (B) B (C) C (D) D

Question 2

According to the special theory of relativity, which of the following statements is true?

(A) The speed of light in space is less if an observer travels at constant speed away from the source of the light.

(B) The speed of light in space is the same irrespective of the motion of the source and the observer.

(C) The speed of light in space is less if the observer is stationary and the light source is moving at constant velocity towards him.

(D) The speed of light in space is greater if an observer travels at constant speed towards the source of the light.

Question 3

An astronaut is in a spacecraft travelling at half the speed of light (c/2). He measures the length of the spacecraft to be 50.0 metres. A person is on the surface of a planet that the spacecraft passes and also measures the length. What length will the person on the planet measure the spacecraft to be?

(A) 43.3 m

(B) 70.7 m

(C) 57.7 m

(D) 35.4 m

Question 4

A rocket is in orbit above the Earth, R metres from the Earth's centre. At this height the rocket has a gravitational potential energy of **P** joules. The rocket then fires its engines and moves to a higher orbit. The new orbit is 3R metres from the Earth's centre. How has the gravitational potential energy changed?

(A) It has decreased by ⅓ **P** joules.

(B) It has increased by ⅓ **P** joules.

(C) It has decreased by ⅔ **P** joules

(D) It has increased by ⅔ **P** joules

Question 5

A satellite is orbiting the Earth at a radius of 6.88×10^6 m from the Earth's centre. How long does it take to complete one orbit?

(A) 1.24×10^4 s

(B) 5.67×10^3 s

(C) 5.07×10^3 s

(D) 1.11×10^2 s

Question 6

Two parallel wires each have a current of 1.5 A flowing through them. The wires are 5 cm apart and the currents in the wires are in the same direction. What is the magnitude of the force per metre between the two wires?

(A) 9.0×10^{-6} N m^{-1}

(B) 9.0×10^{-8} N m^{-1}

(C) 9.0×10^{-6} N

(D) 9.0×10^{-8} N

Question 7

Who discovered the generation of an electric current by a moving magnet?

(A) Michael Faraday

(B) James Clerk Maxwell

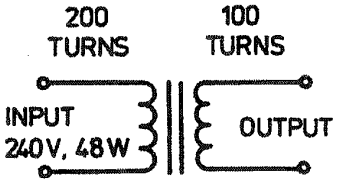
(C) Heinrich Hertz

(D) Hans Oersted

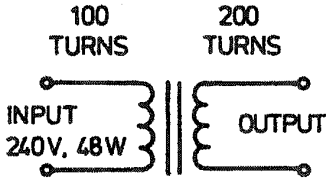
Question 8

The ideal transformers shown in the diagram below all have an input voltage of 240 V and operate at a power of 48 W. Which transformer would give an output current of 4 A?

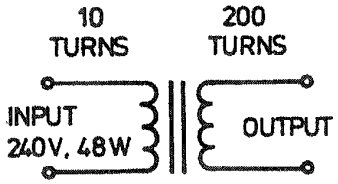
(A)



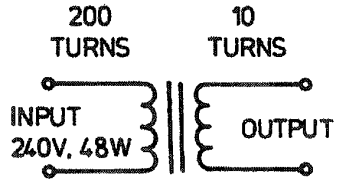
(B)



(C)

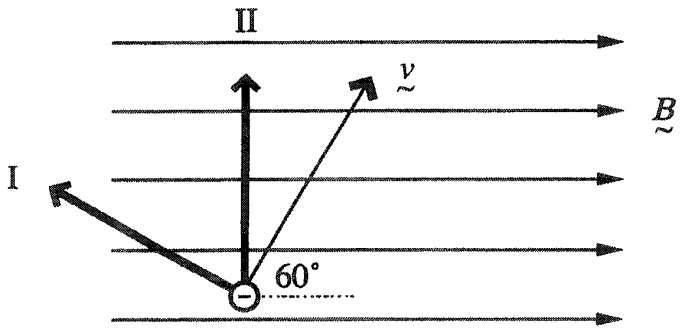


(D)



Question 9

An electron with a velocity v enters a uniform magnetic field B at 60° to the direction of B.



What will be the direction of the force on the electron?

(A) In the direction marked I.

(B) In the direction marked II

(C) Vertically down, into the page.

(D) Vertically up, out of the page.

Question 10

A wire coil consists of 100 loops, each of area 4 cm^2. The loop is placed in a magnetic field of strength 1.2 T and a current of 1.5 A is passed through it. What is the maximum torque the coil could experience?

(A) 7.2×10^{-2} N m

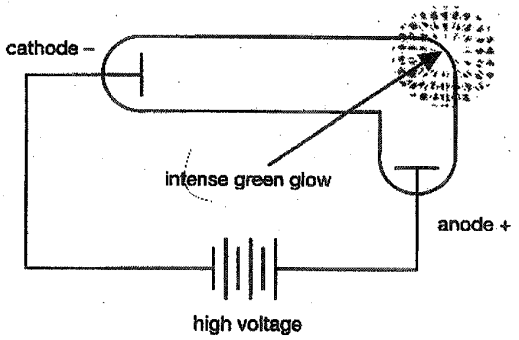
(B) 7.2×10^{2} N m

(C) 7.2 N m

(D) 7.2×10^{-4} N m

Question 11

Before the nature of cathodes rays was understood, Sir William Crookes conducted a series of detailed experiments. In an early experiment he constructed a bent glass tube with electrodes at either end as shown in the diagram below.



What could Crookes deduce from this particular experiment?

(A) That the rays were particles.

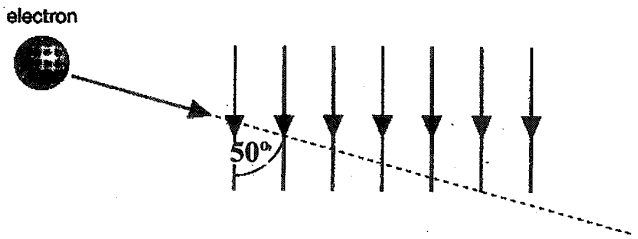
(B) That the rays were emitted from the anode.

(C) That the rays travelled in a straight line.

(D) That the rays were a form of electromagnetic radiation.

Question 12

The diagram below shows an electron passing through a magnetic field at an angle of 50° as shown. The strength of the magnetic field is 2 T. The speed of the electron is 3×10^6 ms^{-1}.



What is the magnitude of the force on the electron?

(A) 0 N

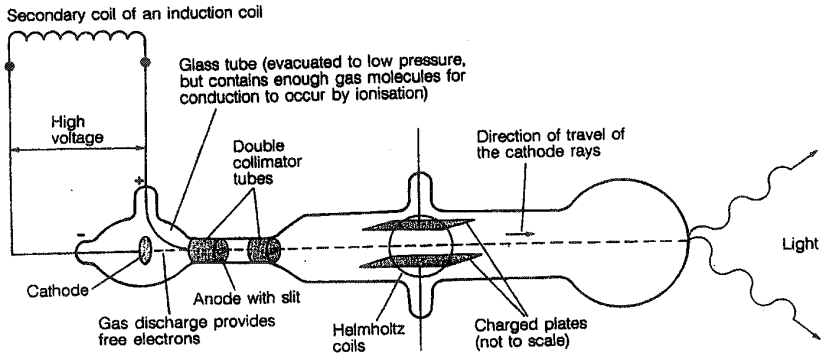
(B) 9.60×10^{-13} N

(C) 6.17×10^{-13} N

(D) 7.35×10^{-13} N

Question 13

The diagram below shows apparatus similar to that used by J.J. Thomson in a important experiment investigating the properties of electrons.



What was Thomson able to determine using this apparatus?

(A) The mass of an electron.

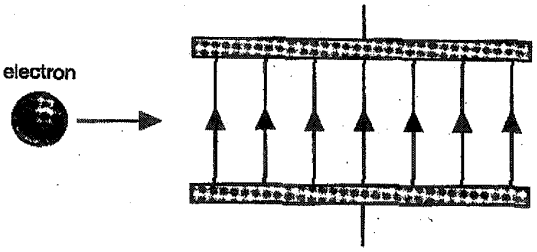
(B) The charge on an electron.

(C) The ratio of charge to mass for an electron.

(D) That electrons had both particle and wave properties.

Question 14

The diagram below shows an electron entering a region of uniform electric field between two parallel plates. The plates are separated by a distance of 1.5 cm and have a potential difference of 50 V across them.



What is the force on the electron when it enters the electric field?

(A) 5.3×10^{-16} N upwards

(B) 5.3×10^{-16} N downwards

(C) 5.3×10^{-18} N upwards

(D) 5.3×10^{-18} N downwards

Question 15

The Meissener effect for superconductors can be demonstrated by the levitation of a small magnet above a superconducting material that has been cooled below its critical temperature.

Why did the magnet levitate?

(A) Because the superconductor excludes and reflects the magnetic field produced by the magnet

(B) Because an opposing magnetic field is produced inside the semiconductor due to Lenz's law

(C) Because an opposing magnetic field is produced inside the magnet due to Lenz's law

(D) Because the magnet excludes and reflects the magnetic field produced by the semiconductor

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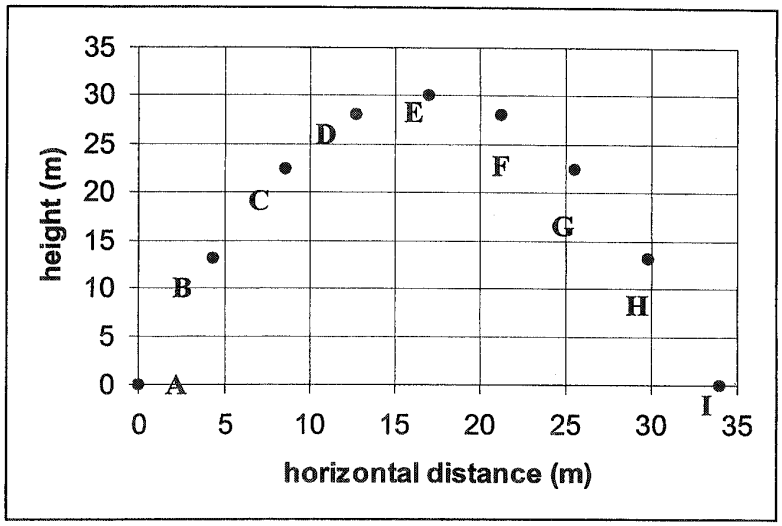
Part B Extended Answers - 60 marks
Attempt Questions 16–24
Allow about 1 hour and 45 minutes for this part
Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 16 (5 marks) **Marks**

The diagram below is the record of a stroboscopic photograph of the motion of a projectile fired on Earth

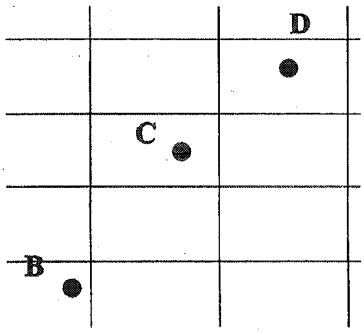


The total distance travelled horizontally is 34 m.

(a) In the space below is an enlarged section of the diagram above. On it draw vectors (using arrows) to represent

i) the resultant velocity at point C and **1**

ii) the acceleration of the projectile at point C **1**



(b) State the magnitude of the vertical component of the projectile's velocity at the point labelled E in the diagram at the top of the question.

1

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(c) Calculate the **initial** vertical component of the velocity of the projectile, i.e. at the point labelled A in the diagram at the top of the question. 2

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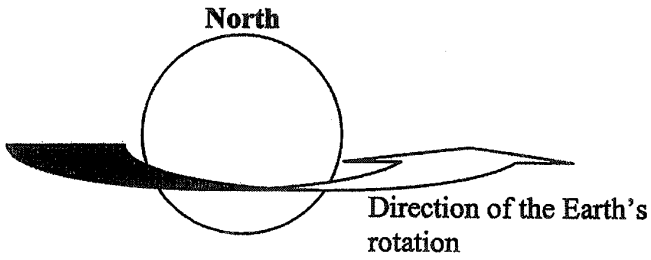
Question 17 (2 marks) **Marks**

A point on the Earth's surface moves from the West towards the East due to the Earth's rotation, as shown in the diagram below.



Explain how this can be used to assist in the launch of a rocket. **2**

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Question 18 (8 marks)

Marks

The Michelson-Morley experiment was performed to detect the 'aether wind'. **4**

(a) Describe the experiment

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(b) State what was observed during the experiment. **1**

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(c) Evaluate the significance of the observed result. **3**

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Question 19 (3 marks)

Marks

(a) State the principle of relativity. **1**

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(b) Describe an observation that illustrates this principle. **2**

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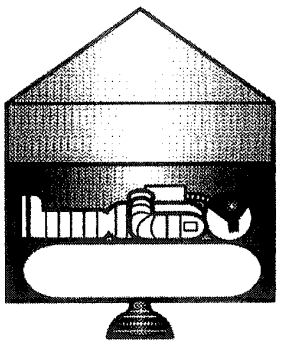
Question 20 (2 marks)

Marks

The diagram below represents an astronaut in a rocket.



(a) On the diagram show and clearly identify the forces acting on the astronaut during the rocket launch. **1**

(b) Compare the relative size of these forces just after lift-off. **1**

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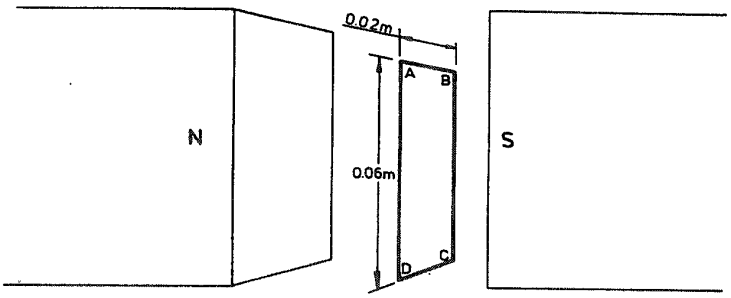
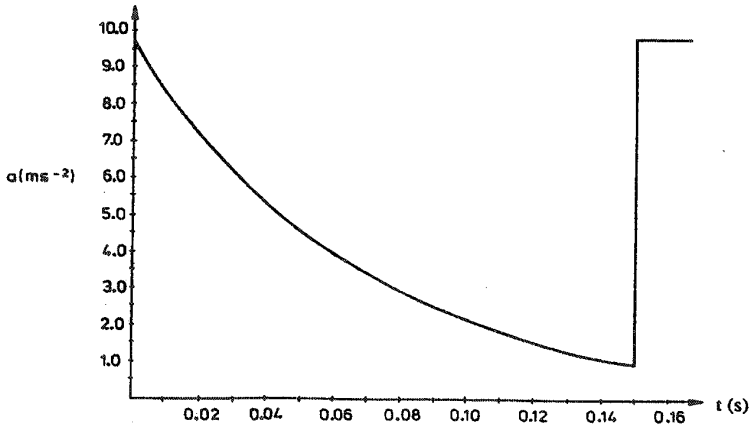
Question 21 (4 marks)

Marks

A rectangular metal loop ABCD of mass 1.6×10^{-3} kg is positioned in a uniform horizontal magnetic field of strength 0.4 T as shown below. The height of the loop is 0.06 m; its width is 0.02 m. The edge CD is level with the bottom of the magnetic field.



The loop is dropped, the edge CD immediately falls out of the field. The graph below shows how the acceleration of the loop varies with time, as it falls.



Analyse the graph for the time period shown. 4

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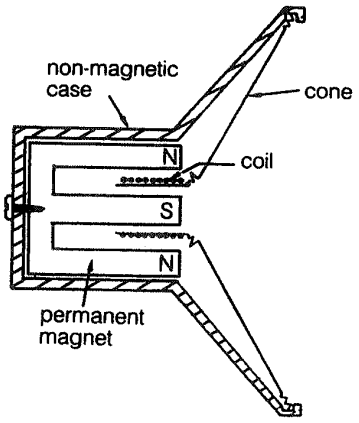
Question 22 (3 marks) **Marks**

The diagram below shows a cross-section of a loudspeaker.



The coil is a coil of wire that carries the electric current from the amplifier. Explain how the loudspeaker works in terms of the motor effect. **3**

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Question 23 (6 marks)

Marks

During this course you performed a first-hand investigation to determine how a number of factors affected the size of the current generated in a coil with the use of a magnet.

(a) State two of the factors you studied.

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(b) Describe the method you used to investigate each of these factors and state the results obtained.

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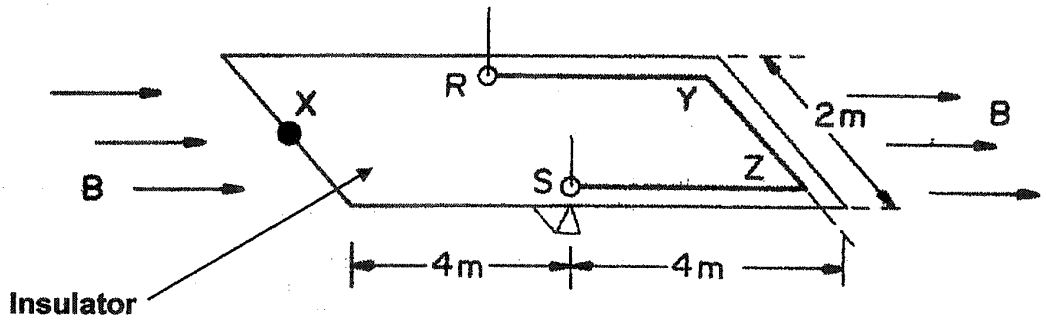
Question 24 (2 marks) **Marks**

The diagram below shows a simple current balance. It operates on the same principle as a see-saw.



The loop of wire RYZS is mounted on an insulator as shown and is able to pivot along the line RS. All of this is then placed in a uniform magnetic field B as shown. The loop is balanced when there is no current passing through it. When a mass is placed at X a current needs to flow in the loop in order for this apparatus to remain horizontal.

Explain (no calculations required) how this apparatus could be used to find the mass of an object placed at X if the field strength B is known. 2

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Question 25 (3 marks)

Marks

Iron cores are used in transformers to increase the strength of the magnetic fields. However, energy can be lost due to heating effects in these iron cores.

(a) State the origin of this heating. 1

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(b) Explain how this heating loss can be reduced. 2

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Question 26 (2 marks)

Marks

One advantage that an induction motor has over other types of electrical motors is that there are no brushes or commutators. This means there is no friction to wear parts away.

(a) State the purpose of the commutator and brushes in other kinds of AC motors. 1

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(b) State why the induction motor does not need these components. 1

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Question 27 (5 marks)

Marks

(a) Describe the difference between conductors, insulators and semiconductors in terms of band structures. **3**

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(b) Describe how 'doping' a semiconductor can change its electrical properties. **2**

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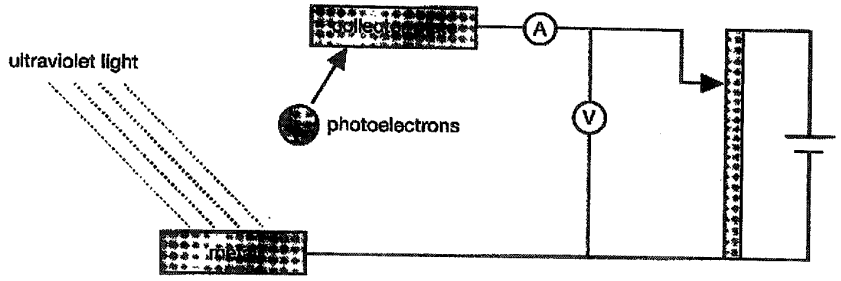
Question 28 (6 marks)

Marks

The diagram below shows an experimental setup for studying the photoelectric effect.



(a) Outline Einstein's explanation of the photoelectric effect in terms of photons. **3**

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(b) Identify how Einstein's explanation was related to blackbody radiation. **1**

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(c) Infrared radiation penetrates dust in interstellar space and allows astronomers to view stars in the process of forming. Calculate the wavelength of infrared radiation with photons of energy 0.15 eV. **2**

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Marks

Question 29 (3 marks)

Explain the operation of a solar cell that consists of an n-type and a p-type semiconductor materials joined to form a junction. **3**

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Question 30 (6 marks) **Marks**

Outline the experimental method used by the Braggs to determine crystal lattice structure. **3**

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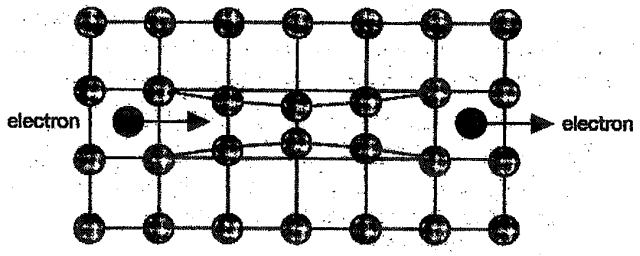
(b) The diagram below shows electrons moving through the lattice of a superconductor.



With reference to the diagram, outline the theory put forward by Bardeen, Cooper and Stirrer (BCS) to explain electrical conductivity in superconductors. **3**

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Section II

25 marks
Answer Question 31 - Sections (a) – (h)
Allow about 45 minutes for this section

Answer the question on the writing paper provided. Extra writing paper is available.

Write your student number on every piece of writing paper.

Show all relevant working in questions involving calculations.

Question 31 - From Quanta to Quarks (25 marks)

(a) Outline the main features of the model of the atom proposed by Rutherford after his experiment involving the scattering of alpha particles from gold foil. (Do not describe his experiment). 3

(b) Bohr developed the Rutherford model of the atom further, by proposing additional postulates. State Bohr's postulates. 2

(c) Bohr's model was able to successfully predict the visible spectral lines of the hydrogen atom.

(i) Calculate the wavelength of the spectral line produced by an electron transition from the fourth energy level (n = 4) to the second energy level (n = 2) in the hydrogen atom. 2

(ii) Calculate the energy of the photons emitted in the production of this spectral line. 2

(d) Identify the difficulties with the Rutherford-Bohr model of the atom. 4

Question 31 continues on next page

PLC

Physics Trial 2002
Marking scheme

Section I

Total marks (75)
This section has two parts, Part A and Part B

Part A **Multiple choice Total marks (15)**

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

	Answers	Outcomes		Answers	Outcomes		Answers	Outcomes
1.	D	H6	6.	A	H9	11.	C	H2
2.	B	H6	7.	A	H1	12.	D	H9
3.	A	H6	8.	D	H7	13.	C	H1
4.	D	H9	9.	D	H9	14.	B	H9
5.	B	H9	10.	A	H9	15.	A	H10

Part B **Extended answers**

Question 16 Outcomes assessed: H6, H12, H13

a)

Criteria	Marks
• Both vectors correct – acceleration vertically down, velocity a tangent to the curve • Acceleration either 1 or 0 –no half mark • Velocity not tangent – pointing to point D minus ½	2

b)

Criteria	Marks
• 0	1

c)

Criteria	Marks
• $x_y = 30$ m up positive $v_y = 0$ $a = -9.8$ m s^{-2} $u_y = ?$ $v^2 = u^2 + 2as$ $0 = u_y^2 + 2(-9.8)30$ $u_y^2 = 588$ $u_y = 24.2$ m s^{-1} minus ½ for - no or incorrect units - calculation error after correct substitution minus 1 for - failure to have displacement and acceleration in opposite directions. This needs to be clear in working - no working	2

Criteria	Marks
A clear explanation that mentions the following • the rocket already has the rotational velocity of the Earth's surface • the rocket is launched towards the east • the change in velocity caused by burning fuel is added to the initial rotational velocity to give the velocity needed for a stable orbit	2
• Only two points mentioned or three present but not clear	1 ½
• Only one point or two points but unclear	1

Question 18 Outcomes assessed: H1, H13, H14

a)

Criteria	Marks
Either a clear description of the following or a labelled diagram(s) with enough description to be clear. Points needed are: • A single light ray is split into 2 rays that travel equal distances at right angles to each other (½) • Each was reflected off one of two mirrors (½) • The reflected rays travelled back and were recombined (1) • The whole apparatus could be rotated (1) • The interference pattern that occurred when the reflected rays combined was observed (1)	4
Diagram used but unlabelled – all points present when diagram and writing considered OR Labelled diagram but incomplete or only partly correct BUT written description complete and correct OR One of first two points missing	3 ½
Points missing (see above)	3 - 1
Unlabelled/partly labelled diagram and no written description	½

b)

Criteria	Marks
States clearly that no change in the interference pattern was observed as the apparatus was rotated. (No ½ mark)	1

c)

Criteria	Marks
Clear explanation involving the following • As apparatus rotated there should have been a changing interference pattern due to the aether wind • No change indicated that the aether wind did not exist • This gave experimental support to the assumptions in Einstein's theory, that the aether did not exist Maximum of 2 if there is no evaluation	3

Question 19 Outcomes assessed: H6, H13

a)

Criteria	Marks
Clear statement to the effect that the laws of physics are the same in all inertial or non-accelerating frames of reference	1

b)

Criteria	Marks
Clear description indicating why the frame of reference is inertial and what will happen	2
Description unclear OR It is not indicated why the frame of reference is an inertial one	1

Question 20 Outcomes assessed: H6, H13

a)

Criteria	Marks
2 forces only shown – force due to gravity down and reaction force up No mark if a third force is shown	1

b)

Criteria	Marks
Force up is larger than force down	1

Question 21 Outcomes assessed: H6, H9, H13, H14

a)

Criteria	Marks
An analysis which • Describes the change in acceleration with time, ie decreases at a decreasing rate (1) • States a value of acceleration at one time (½) • Accounts for the acceleration being less than 9.8 m s^{-2} in terms of the forces acting (1) • Accounts for the continued decrease in acceleration as velocity increases (½) • Accounts for sudden increase in acceleration (1)	4

Question 22 Outcomes assessed: H9, H13, H14

Criteria	Marks
Explanation involving: • Coil is in the magnetic field of the permanent magnet (½) • When the current flows through the coil it experiences a force (½) • Coil moves in and out making the cone move as well (½) • Which produces sound waves (½) • Size of current determines size of force and therefore amplitude of movement (1)	3

Question 23 Outcomes assessed: H13

a)

Criteria	Marks
Any two reasonable factors eg – strength of magnet - speed of movement - distance of movement from coil - presence of iron core (?)	2

b)

Criteria	Marks
Clear description of method for each factor (2) Statement of results obtained (2)	4

Question 24 Outcomes assessed: H9, H13, H14

Criteria	Marks
• mass at X causes that end to move down (optional) • current through YZ is adjusted until insulator is horizontal (½) • current is measured (½) • force on wire can then be calculated (½) • This force is equal to the weight of the mass (½)	2

Question 25 Outcomes assessed: H7, H9, H13

a)

Criteria	Marks
State caused by eddy currents or induced currents	1

b)

Criteria	Marks
• Core consists of thin layers (½) • insulated from each other (½) • This reduces the size of the currents (½) • and therefore the heating loss (½)	2

Question 26 Outcomes assessed: H9, H13

a)

Criteria	Marks
To maintain electrical connection with the coil in the rotor	1

b)

Criteria	Marks
• Rotor does not have a coil with current flowing (½) Therefore it is not necessary to supply electricity to the core (½)	1

Question 27 Outcomes assessed: H2, H10

(a)

Criteria	Marks
• Mentions energy gaps. (0.5) • Diagrams or descriptions of relative size of energy gaps between conduction and valence bands for all three types. (1.5) • Description of effects on conductivity on at least 2 types of material. (1.0)	3

(b)

Criteria	Marks
• Group 3 elements e.g. Ga, produce holes (p-type) so that holes are the majority charge carrier. • Donor level in n-type semiconductors just below conduction band reduces energy gap, producing improved electrical conduction at room temperature. • Group 5 elements e.g. As, produce unbonded electrons (n-type) so that electrons are the majority charge carrier. • Acceptor level in p-type semiconductors just above valence band reduces energy gap, producing improved electrical conduction at room temperature. Some of these points may be illustrated in a diagram. Any 2 points for 2 marks.	2

Question 28 Outcomes assessed: H1, H2, H10

(a)

Criteria	Marks
• Photons have a fixed amount of energy, dependent on their frequency (E=hf) • Photons give all (or none) of their energy to an electron in the metal • Electrons need to 'expend' some energy to escape the metal lattice (the minimum amount being called the Work Function being fixed for a given metal); thus frequency needs to be above a threshold frequency.. • Excess electron energy is observed as the E_K of the electron when it leaves the metal surface. E_K depends only on frequency of light, not on intensity because energy depends on frequency, not intensity. • Increased intensity increases photocurrent (if f above threshold frequency) because there are more photons hitting electrons. Any 3 points for 3 marks	3

(b)

Criteria	Marks
• Einstein had used Planck's idea that radiation was emitted from a black body in discrete packets called quanta. • Einstein reasoned that by the Law of Conservation of Energy, if energy is radiated in quanta, then it must be propagated through space in quanta (or photons as he called them). 1 mark for a reference to Planck's work.	1

(c)

Criteria	Marks
$\therefore \lambda = hc/E = (6.626 \times 10^{-34})(3.00 \times 10^{8}) / (0.15)(1.602 \times 10^{-19})$ m $\therefore \lambda = 8.27 \times 10^{-6}$ m 1 mark for correct substitution 1 mark for correct answer with units (- 0.5 for incorrect units)	

Question 29 Outcomes assessed: H3, H10

Criteria	Marks
• An electric field is produced across the junction of the diode due to the diffusion of electrons from the n-type to p-type semiconductors, and holes in the opposite direction. Diffusion stops as n-type semicond. becomes positively charged and p-type semiconductor becomes negatively charged. Electric field in direction from n-type to p-type semiconductors. • If shine light onto p-type side, electrons (the minority carrier) will be excited and pass across the junction to the n-type side (due to the electric field in the opposite direction). • If the n- and p-type sides are connected externally, the electrons in the n-type side will move through the conducting wire towards the p-type side, doing work in any load that is connected. Some of these points may be illustrated in a diagram. 3 points for 3 marks	3

Question 30 Outcomes assessed: H1, H2, H3, H9, H10

(a)

Criteria	Marks
Bragg's experiment: • Shone x-rays of known λ onto a crystal lattice. • Measured angles θ at which x-ray scattering maxima and minima occurred using an x-ray detector. • Used a formula ($n\lambda = 2d\sin\theta$ for maxima) to calculate d the separation between the planes. • Several different planes can be envisaged (at different angles throughout the lattice), but in principle the separations in all directions can be calculated from the scattering pattern. Some of these points may be illustrated in a diagram. 3 points for 3 marks.	3

(b)

Criteria	Marks
BCS model: • BCS realised that superconductivity was produced by the interaction of electrons with the vibrations of the atomic lattice. • Current is carried by pairs of electrons (Cooper pairs) and not by single electrons. • The attractive force between the electrons (which repel one another due to having the same charge) is caused by phonons (phonon-mediated attraction) – packets of	3

acoustic energy emitted by the vibrating lattice (the 'electron-lattice-electron' interaction). Normally, vibrations of atoms in a lattice cause and increase in resistance, but with superconductors, lattice vibrations reduce resistance and help move the Cooper pairs. • When the first of the electron pair passes through the positively charged lattice, the lattice distorts towards the electron and this positive charge draws the second electron forward, overcoming the repulsive force. Thus, the electron pair passes through the lattice in unison. • The 'Cooper pair' behaves like a single particle (a boson) that is at a lower energy state than the individual electrons – need quantum mechanics to explain. • The electron pair moves through the lattice without any collisions with the lattice and so the electrons do not lose any E_K. The total momentum of the Cooper pair is unchanged by the interaction of one of the electrons with the lattice, and the flow of electrons continues indefinitely. • Normally vibrations in the lattice cause an increase in resistance, but with superconductors, vibrations reduce resistance and help move the Cooper pairs. • Cooper pairs break up above the critical temperature. • BCS model is able to explain superconductivity in metals, but unable to explain 'high-temperature' (ceramic) superconductivity. 3 points for 3 marks.	

Section II

Question 31 – From Quanta to Quarks (25 marks)

Question 31 Outcomes assessed: H1, H2, H7, H8, H9, H10,

(a)

Criteria	Marks
Rutherford model: • Central nucleus – very small (~10^{-14} m); atom diameter ~10^{-10} m, so most of the atom is empty space • Nucleus positively charged. • Nucleus has most of the mass of the atom. • Electrons 'orbiting' outside the nucleus 2 points about nucleus for 2 marks. 1 point about electrons for 1 mark.	3

(b)

Criteria	Marks
Bohr's postulates: • Electrons can exist in particular energy states called stationary states without radiating e.m. energy. • Electrons only emit energy by 'quantum jumps' from one stationary state to another (producing discrete spectral lines) • The Law of Conservation of Energy applies at atomic scale, so the energy of a radiated photon is equal to the difference in energy between one stationary state and the next ($E = hf$). • Angular momentum of atomic electrons is quantised and can only take values of L = $nh/2\pi$, where n is an integer called a quantum number. 2 points for 2 marks	2

(c)(i)

Criteria	Marks
$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097 \times 10^7 (1/2^2 - 1/4^2) = 2.057 \times 10^6$ m-1 $\therefore \lambda = 1 / 2.057$ m $= 4.86 \times 10^{-7}$ m 1 mark for correct substitution. 1 mark for correct answer with units (-1/2 for incorrect units)	2

(c)(ii)

Criteria	Marks
$f = c/\lambda = (3 \times 10^8) / (4.86 \times 10^{-7}) = 6.17 \times 10^{14}$ Hz $E = hf = (6.626 \times 10^{-34}) . (6.17 \times 10^{14}) = 4.11 \times 10^{-19}$ J. 1 mark for frequency (units not required for mark). 1 mark for E with correct units (-1/2 for incorrect units)	2

(d)

Criteria	Marks
Difficulties with Rutherford-Bohr model: • the spectra of larger atoms • relative intensity of spectral lines • existence of hyperfine spectral lines • Zeeman effect 1 mark for each above (or other correct) point	4

(e)

Criteria	Marks
Davisson & Germer: • D&G directed a beam of low energy electrons (to avoid producing x-rays) onto a Ni crystal and used a detector to measure the scattering intensity of the electrons by the crystal at different angles. • They found that the scattering was not uniform as was expected, but had maxima at certain angles, e.g. 50°, i.e. the electrons were demonstrating wave properties of interference. • From x-ray diffraction, the separation D of the layers of the Ni crystal was known and this was substituted into $\lambda = D\sin\theta$ to calculate the wavelength of the electron. • The E_K of the electrons and thus the speed of the electrons could be calculated from the known accelerating voltage. This was used to calculate de Broglie's prediction of the wavelength ($\lambda = h/mv$), and the value was found to match that calculated from the interference equation above.	4

4 marks for 4 points.	

2 marks for 2 points	

(f)

Criteria	Marks
de Broglie & Bohr: (Bohr had postulated the 'stationary states' for his model without any theoretical basis). • de Broglie used his idea of matter waves to propose that the matter wave of an orbiting electron could be considered to be a circular standing wave. • If a whole number of wavelength fits into the circumference of the orbit, then the standing wave is maintained (an 'allowed' orbit); If a whole number of wavelength does not fit, then destructive interference will occur and the orbit will not be allowed. 2 marks for 2 points.	2

(g)(i)

Criteria	Marks
$\lambda = h/mv = (6.626 \times 10^{-34}) / (9.109 \times 10^{-31})(1.68 \times 10^{5}) = 4.33 \times 10^{-12}$ m 1 mark for correct substitution. 1 mark for correct answer with units (-1/2 for incorrect units)	2

(g)(ii)

Criteria	Marks
Resolving power: • the ability to distinguish clearly between two very close objects (limited by diffraction of light etc. & therefore by the wavelength. • the distance between two points that can be just resolved.	1

(g)(iii)

Criteria	Marks
Resolving power of a microscope is of the order of the wavelength used. Because the matter wavelength of electrons in an electron microscope are typically shorter than the wavelength of visible light, the resolving power of an e.m. is better.	1

(h)

Criteria	Marks
Heisenberg: • developed a mathematical analysis using matrix mechanics to determine the possible states of electrons in an atom; obtained similar results to those of Schrodinger & hence provided greater confidence to the understanding of the atom. • Uncertainty Principle: Showed that (particularly at atomic level) there was a theoretical (and not just practical) limit to the ability to measure: - (1) position & momentum together. Thus, the idea of a 'localised' electron etc became less meaningful, and leant weight to other 'probabilistic' or 'wave' models. - (2) energy and time interval together. This has significance for understanding quantum processes in atoms, and 'virtual particles' where energy may not be 'conserved' over extremely short time intervals.	2