Cheltenham Girls
High School

Student number .....

Teacher .....

2009
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 – 17
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 – 28
- Allow about 1 hour and 45 minutes for this part

Section II Pages 18 – 21
25 marks
- Attempt ONE question i.e. Question 29
- 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.

1 What is the weight of a 24 kg mass on Mars if its surface gravitational field = 3.5 Nkg^{-1}?

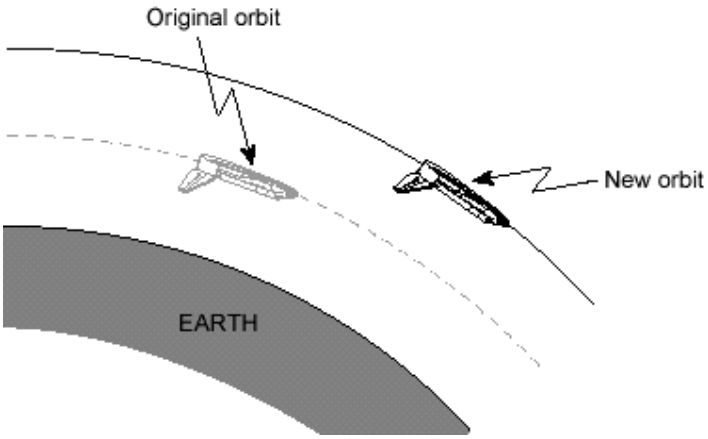
(A) 235.2 N

(B) 84 N

(C) 24 kg

(D) 6.86 kg

2



A space shuttle is placed in a circular orbit around the Earth. It then thrusts its engine and moves to a new orbit, as shown above. Which statement is true about the shuttle's speed in this new higher orbit, if the new orbit is also circular?

(A) The speed will have to be greater than in the lower orbit

(B) The speed will have to be less than in the lower orbit

(C) The speed will have to be the same as in the lower orbit

(D) The speed will have to increase continuously in the new orbit

3 Which of these statements best represents the concept of Escape Velocity?

(A) V_{esc} is the speed necessary to go into orbit

(B) V_{esc} is the speed necessary to escape from the surface of a planet

(C) V_{esc} is the speed necessary to become gravitationally unbound from a planet

(D) V_{esc} is the speed of the gravitational force

4 Which statement below was *not* one of Einstein's findings in the theory of relativity?

(A) The aether is unnecessary

(B) The speed of light in a vacuum is constant for all observers

(C) The laws of physics are the same in all inertial frames of reference

(D) Measurements of distance and time are the same for any two observers

5 What changes occur to the mass and acceleration of a rocket during a launch?

(A) The mass decreases and the acceleration decreases

(B) The mass decreases and the acceleration increases

(C) The mass decreases and the acceleration remains constant

(D) The mass remains constant and the acceleration increases

6 What type of motor includes a rotor which contains no coils of wire?

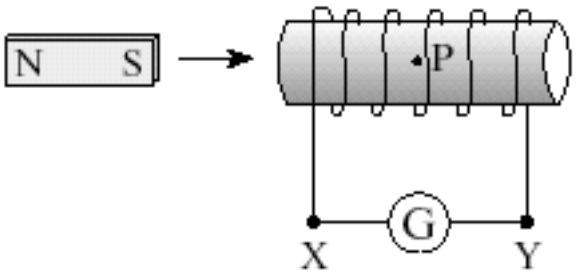
(A) An AC induction motor

(B) An AC coil motor

(C) A DC induction motor

(D) A DC coil motor

7 A student moves a bar magnet toward a solenoid which has a galvanometer attached to the ends of the coil windings. Point P is inside the centre of the iron core/coil.



(A) The current in the galvanometer flows from X to Y, the B field at P is to the right.

(B) The current in the galvanometer flows from X to Y, the B field at P is to the left.

(C) The current in the galvanometer flows from Y to X, the B field at P is to the right.

(D) The current in the galvanometer flows from Y to X, the B field at P is to the left.

8 What is the function of the stator coil in a DC coil motor?

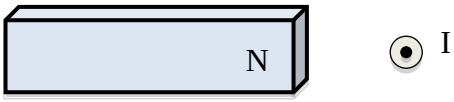
(A) It spins around in the centre of the motor

(B) It allows the current to the coils to change direction

(C) It provides a low friction contact with the external load

(D) It provides the magnetic field within which the rotor coil rotates

9 The diagram shows a stationary conductor carrying current I amperes out of the page near to a magnet. In what direction will a magnetic force act on the conductor?



(A) Up the page

(B) Down the page

(C) To the left of the page

(D) To the right of the page

10 A simple hand-driven A.C. generator is made of a single coil turning within a uniform magnetic field. It is turned at a rate of 4 rotations per second. How does the direction of the output current change as the generator is turned?

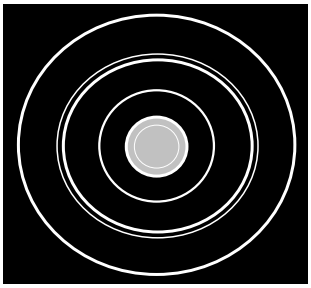
(A) The direction of the current flow does not change

(B) The direction of the current flow changes four times every second

(C) The direction of the current flow changes eight times every second

(D) The direction of the current flow changes two times every second

11



This diagram shows an interference pattern produced when a stream of X-rays is scattered from the surface of a metal such as aluminium.

Which of the following physicists would have found patterns such as this significant in the experiments they were carrying out?

(A) J.J. Thomson in his experiments with cathode-rays to find the *q/m* ratio of electrons

(B) William and Lawrence Bragg in their experiments to determine crystal structures

(C) Wilhelm Hertz in his experiments to determine the velocity of electromagnetic rays

(D) Bardeen, Cooper and Schrieffer in their experiments to explain superconductivity

12 Green light from a small laser is shone onto the surface of a certain metal X, but tests show that no photoelectrons are emitted from it. When blue light from a different laser illuminates the surface of metal X, tests show that now photoelectrons *are* released. Which of the following is most likely explanation for these experimental results?

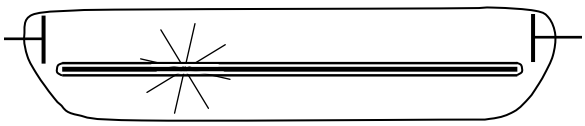
(A) The frequency of the green light was below the critical frequency for metal X

(B) The intensity of the green light was below the critical intensity for metal X

(C) The blue light had a greater intensity and power than the green light

(D) Two of the above answers are correct

13 The diagram below shows one of the evacuated glass tubes that were originally invented by Sir William Crookes to determine the properties of what were called cathode rays.



Which of the following properties of cathode rays was this tube designed to show?

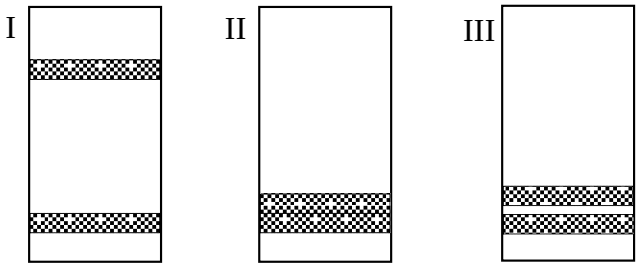
(A) Cathode rays are actually streams of electrons

(B) Cathode rays move in straight lines towards the cathode

(C) Cathode rays carry a negative charge.

(D) Cathode rays possess kinetic energy

14 These diagrams represent the band-theory structures for three distinct types of solid.



Of the following groups of solids, which would be most correctly represented by these diagrams, in the order given above?

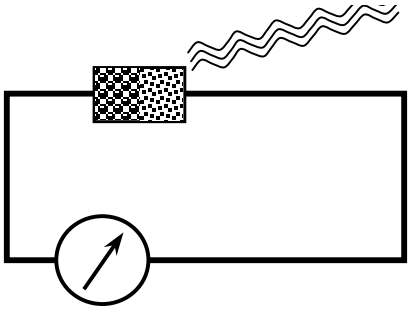
(A) Magnesium; plastic; iron

(B) Calcium; sulfur; graphite

(C) Glass; copper; germanium

(D) Quartz; doped silicon; undoped silicon

15 Consider the following simplified electric circuit.



Of the following, which could represent the p-n-junction device shown in the above circuit diagram?

(A) A valve

(B) A transistor

(C) A solar cell

(D) A light-emitting diode

Part B – 60 marks
Attempt Questions 16–28
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.

Question 16 (4 marks)

Marks

The power source of the space shuttle is its rocket engines.

(a) Describe how the gravitational potential energy changes as a shuttle takes off from the launch pad. **1**

(b) Explain the consequences for the craft and its occupants if the shuttle is undergoing re-entry, and the angle of re-entry is significantly greater (steeper) than optimal. **3**

Question 17 (4 marks)

Marks

A student spins a 1.2 kg rock on a string around above her head horizontally in an experiment which aims to model how satellites orbit the Earth. The student counts 3 orbits per second when the string produces an orbit radius of 35 cm.

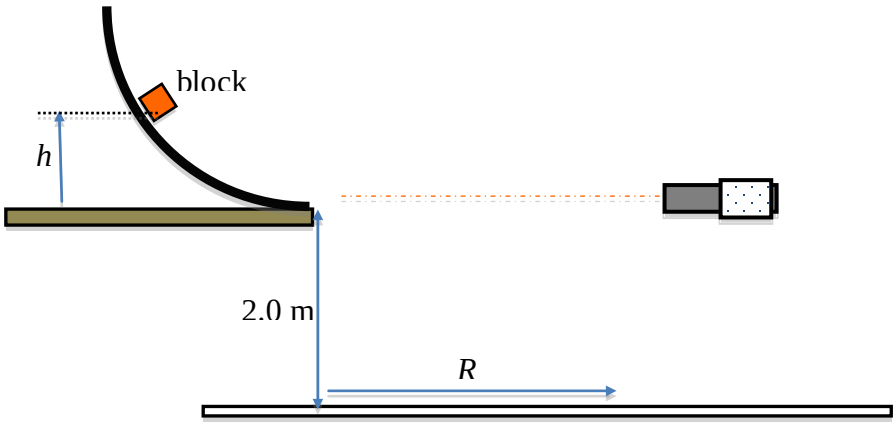
(a) Calculate the centripetal force acting on the rock. **2**

(b) Identify two forces acting on the rock, and describe their effects on the revolving rock in this situation. **2**

Question 18 (8 marks)

Marks

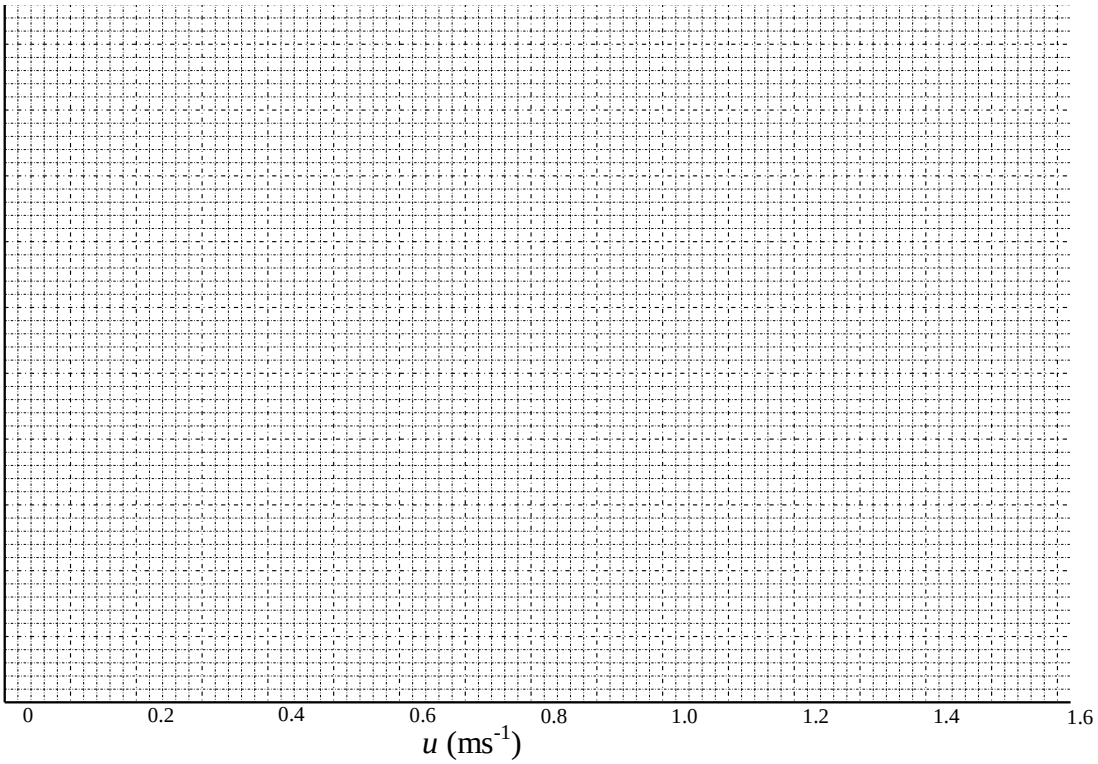
A small block was released from rest at a certain height "*h*" m above a platform and slid down a curved track. It shot off horizontally from the track, which was 2.0 m above the floor level, with an initial speed u m s^{-1}. The block then hit the ground after achieving range "*R*" m. The height "*h*" was changed and the effect on "*u*" and "*R*" was measured.



The data table below shows how *R* changed as the speed *u* was altered.

Speed u (m s^{-1})	0.80	1.00	1.20	1.40	1.60
Range R (m)	0.49	0.67	0.75	0.92	1.04

(a) On the graph paper below plot a graph of *u* versus *R*, and draw in the line of best fit. **3**



Question 18 is continued on the next page

(b) **Question 18 (continued)**

Marks

Given that $R = \frac{2u}{\sqrt{g}}$ is the equation for the line on the graph above, what does its gradient represent? **1**

(c) Calculate the value of *g*, the acceleration due to gravity, using the gradient of the line on the graph. **2**

(d) Explain why *u* is proportional to *R* in this experiment. **2**

Question 19 (4 marks)

A very important experiment was carried out at the end of the 1800's involving testing for the speed of the Earth through the aether.

(a) Identify the scientists who conducted this experiment. **1**

(b) Describe how the two light beams become perpendicular to each other at one stage of the experiment. You may use a diagram. **2**

Question 19 (continued) **Marks**

(c) Describe the expected observations if a *positive* result occurred in this experiment? **1**

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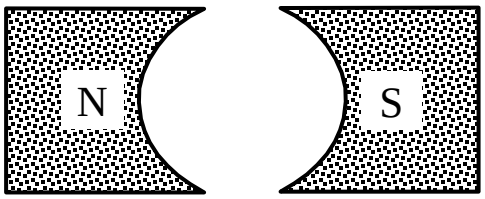
Question 20 (2 marks)

(a) In the diagram below, sketch a radial magnetic field between the two pole pieces. **1**



(b) Identify the reason for using a radial magnetic field in a DC motor. **1**

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Question 21 (6 marks)

A DC electric motor found in the lab was being examined by a student. It was connected to a power supply and it was not attached to any load.

(a) The student stated, 'When the motor is switched on, the electrical energy input should cause the motor to start rotating, and the rotation rate should increase without limit since there is no load.'
Assess the validity of this statement, mentioning the principles involved. **4**

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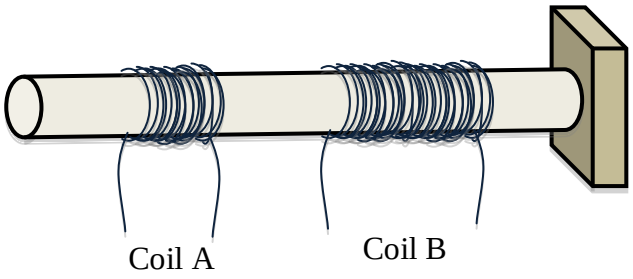
Question 21 (continued) **Marks**

(b) Calculate the current flowing in a motor having 210 turns of coil in the armature, which is a 3.0 × 3.0 cm square coil within a magnetic field of 0.023 T, when it is providing a maximum torque of 2.7×10^{-2} Nm. **1**

(c) For the motor used in part (b), calculate the angle the coil is making with the magnetic field when the torque is only one half of its maximum value. **1**

Question 22 (5 marks)

A student builds a model using insulated wire and a long steel bolt. Coil A is a coil of wire wound tightly around one end of the bolt. Coil B is another coil a little further down, with more turns of wire wound tightly around the steel bolt. The ends of coil A are connected to a 24 Volt, 50 Hz AC source. Coil B is attached to a multimeter.



(a) Identify the device studied in the Motors and Generators Module that this model represents. **1**

(b) Compare the voltage and the current in coil A with the voltage and the current in coil B when the device is connected to an appropriate circuit. **2**

Question 22 (continued) **Marks**

(c) Describe one way of increasing the voltage reading across coil B by changing a structural variable in the above set-up, and justify your reasoning. **2**

Question 23 (4 marks)

Marks

Complete the **part** and **function** table for an AC generator using the spaces below.

PART	FUNCTION
Many coil windings	*(a)*
(b)	*Makes eddy currents very small to reduce heat losses.*
Slip rings	*(c)*
(d)	*Provides a magnetic field from a current*

(a) **1**

(b) **1**

(c) **1**

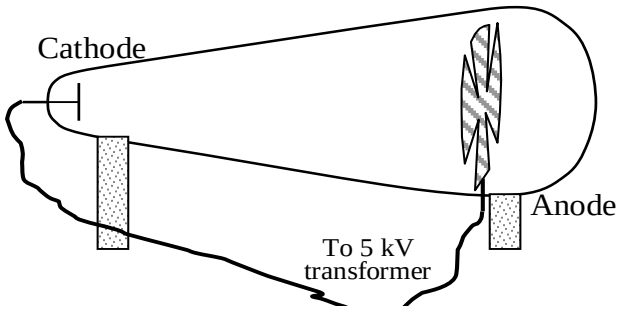
(d) **1**

Question 24 (3 marks)

Explain how a galvanometer functions, using electromagnetic principles. **3**

Question 25 (5 marks)

Marks



In the latter part of the 19th century, Sir William Crookes designed a special cathode-ray tube that looked similar to this in order to identify certain properties of cathode-rays.

(a) Describe how this tube can show that cathode-rays are emitted from the *cathode*. **2**

(b) Prior to 1895, the general opinion of German scientists was that cathode-rays are a form of electromagnetic radiation. Describe one observation from this experiment that might reasonably support such a view, rather than the general British opinion. **2**

(c) Identify one potential hazard in using this apparatus, and suggest an appropriate course of action to reduce the risk posed by using it in a classroom. **1**

Question 26 (7 marks)

Marks

Heinrich Hertz used apparatus resembling what is shown in this diagram to test for the existence of a new type of radiation.

(a) Identify the type of E.M.R. Hertz discovered. **1**

(b) Explain the physics of why Hertz was able to detect sparking in the small detector coil when the detector was located in the position shown on the diagram above. **3**

(c) Describe one test Hertz carried out to show that the radiation he had discovered resembles light. **2**

Marks

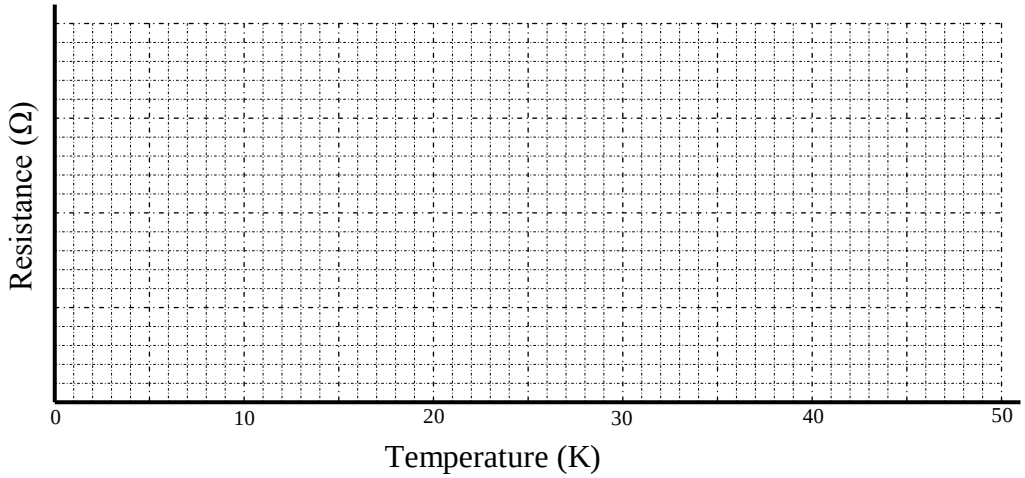
Question 26 (continued)

(d) How did Hertz discover the photoelectric effect using this apparatus? **1**

Question 27 (6 marks)

In 1908 Dutch scientist Heike Onnes discovered a phenomenon called superconductivity, and found that the element mercury has a critical temperature of 4.15 Kelvin.

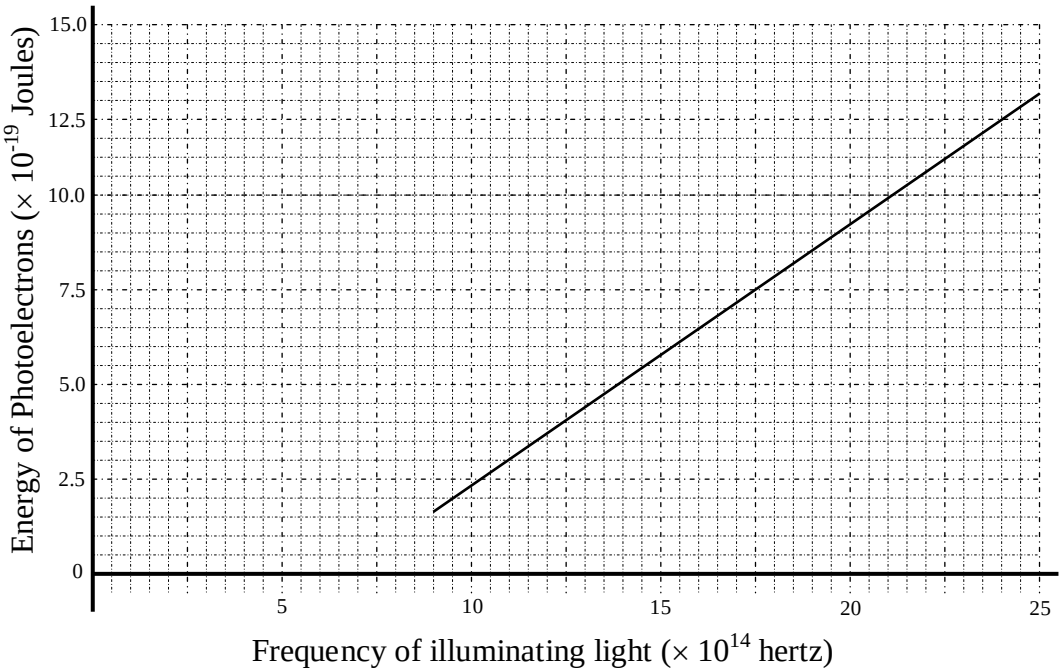
(a) On the graph paper sketch the resistance of mercury as temperature decreases. **1**



(b) John Bardeen, Leon Cooper and Robert Schrieffer gave a theoretical explanation for this phenomenon in 1957. Discuss the BCS theory, using at least one diagram. **5**

Question 28 (2 marks)

Marks



The graph above plots the kinetic energy of photoelectrons released from a certain metal when it is illuminated by monochromatic light of different frequencies (including U-V).

(a) From the graph estimate the threshold frequency of the light required to release photoelectrons from this metal. **1**

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(b) Hence, or otherwise, determine the work function of the metal. **1**

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End of Section I

Section II

25 marks
Attempt question 29 from this section.
Allow about 45 minutes for this section

Answer the question in the writing space provided.

Show all relevant working in questions involving calculations.

Marks

Question 29 – From Quanta to Quarks (25 marks)

(a) The Paschen series of spectral lines for excited hydrogen atoms includes all the wavelengths released for which $n_f = 3$.

(i) Find the wavelength of the light emitted in the Paschen series if an electron drops from the $n_i = 5$ energy shell. **1**

(ii) Is this light visible to the naked eye? – justify your answer. **1**

(iii) How was Bohr's atomic model able to explain the *spectral lines* of hydrogen? **1**

(b) Consider the famous gold-foil experiment devised by Ernest Rutherford to investigate the nature of the atom, which was first carried out by Geiger and Marsden. **2**
Relate one of the unexpected results of this investigation to Rutherford's proposal for a revised model of the atom.

(c) Bohr's atomic model was very successful but it could not fully explain the Hydrogen atom. Discuss some shortcomings of Bohr's model. **5**

(d) Assess Planck's contribution to quantum physics **4**

(e) (i) State the de Broglie hypothesis which he used to explain the stability of the orbits in a Bohr atom. **1**

(ii) Calculate the de Broglie wavelength of a proton moving at a velocity of 3×10^5 ms^{-1}. **2**

(f) (i) Identify an example of a non-inertial frame of reference. **1**

(ii) An observer on Earth measures the mass of a UFO flying past her as 1000.0 kg. If the UFO is travelling at 0.900c relative to Earth calculate the mass of the UFO as measured by an alien scientist travelling on the UFO. **2**

(g) (i) Determine the period of a geostationary satellite orbiting the Earth? **1**

(ii) Given the mass of the Earth is 5.9×10^{24} kg, and its radius is 6380 km, determine the height above the Earth's surface of a geostationary satellite. **2**

(iii) Compare geostationary and low Earth orbits. **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

$$v = f\lambda$$

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

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\Sigma F = ma$$

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

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

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

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

$$F = mg$$

$$v_x^2 = u_x^2$$

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

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

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

$$E = mc^2$$

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

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

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

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
Atomic Weight
79 Au 197.0 Gold
Symbol of element
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
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Marking guidelines

Section I – Part A

Question	Correct Response
1	B
2	B
3	C
4	D
5	B
6	A
7	A
8	D
9	A
10	C
11	B
12	A
13	D
14	C
15	C

Section I – Part B

Question 16

16 (a) (1 mark)

Criteria	Mark
• Correctly states the variation in the G.P.E. of the shuttle	1

Sample answer

As the altitude of the shuttle increases, its gravitational potential energy increases.

16 (b) (3 marks)

Criteria	Marks
• Identifies excess deceleration of the craft, and two consequences of this	3
• Identifies two consequences, or excess deceleration and one consequence **OR** • Incorrectly identifies insufficient deceleration and a consequence of that	2
• Identifies a correct consequence about an incorrect re-entry angle	1

Sample answer

If the craft re-enters at too steep an angle the air resistance will increase at too great a rate. This causes a large deceleration which results in a rate of conversion of the kinetic energy of the shuttle into heat that is too large, so the temperature of the craft exceeds the rate that heat can be dispelled, so it may partially melt, or 'burn up'. In addition, the consequent 'g-forces' acting on the astronauts due to the excess deceleration may become extremely painful – or worse!

Question 17

17 (a) (2 marks)

Criteria	Marks
• Correctly substituting into the correct formula to get an answer	2
• Incorrectly substituting into the correct equation	1

Sample answer

$$F_C = \frac{mv^2}{r} = \frac{1.2}{0.35} \times \left(\frac{2\pi \times 0.35}{1/3} \right)^2 = 149 \text{ newtons}$$

17 (b) (2 marks)

Criteria	Marks
• Identifies two forces acting, and describes their effect	2
• Identifies one of the forces acting on the rock	1

Sample answer

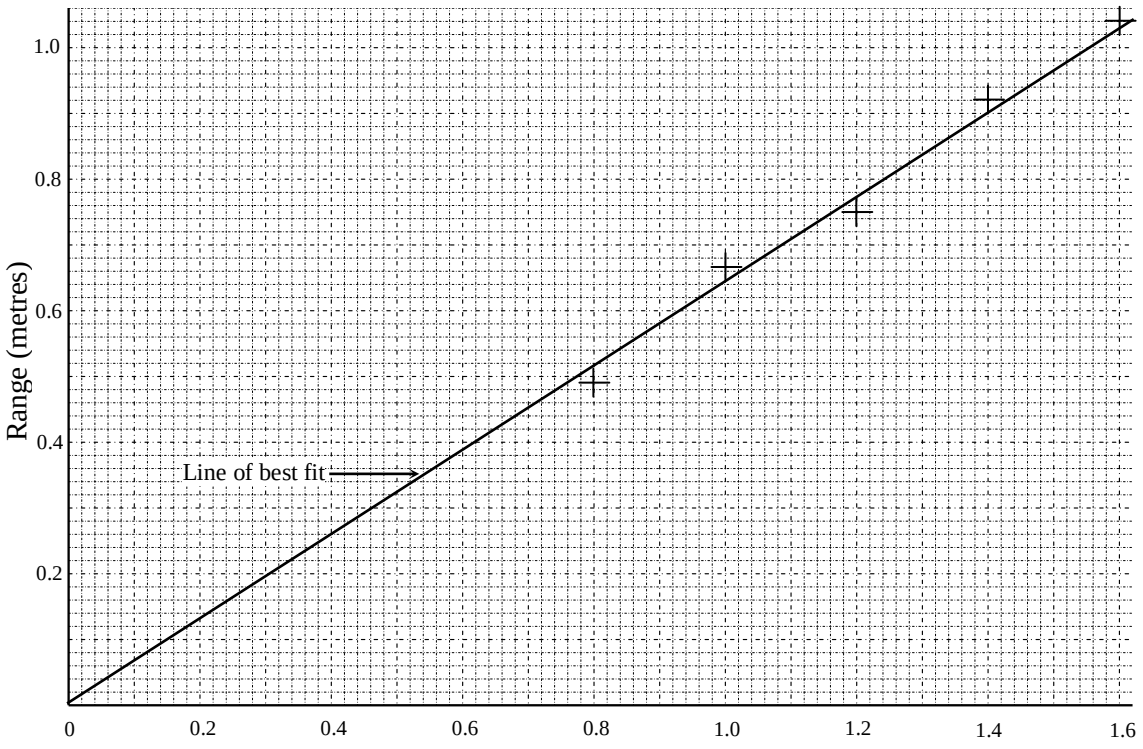
The weight force continually acts upon the rotating mass, pulling it down, so the cord always hangs at an angle, which affects the actual rotational radius. Air resistance slows down the moving mass, so the stone continually needs to experience a force to maintain its speed.

Question 18

18 (a) (3 marks)

Criteria	Marks
• Correctly naming vertical axis of graph and appropriate scale • Placing all five points accurately • Drawing a reasonable *straight* line of best fit	3
• Two of the above	2
• One of the above	1

Sample answer



Question 18 (continued)

18 (b) (1 mark)

Criteria	Mark
• Correctly identifies what the slope represents	1

Sample answer
The gradient of the line of best fit is $\frac{R}{u}$, which is equal to $\frac{2}{\sqrt{g}}$

18 (c) (2 marks)

Criteria	Marks
• Correctly assessing slope of their line of best fit • Correctly equating this slope with the formula given in part (b)	2
• One of the above	1

Sample answer
From the graph the slope of the line of best fit is approximately 1/1.55 = 0.645

Since $\frac{1}{1.55} = \frac{2}{\sqrt{g}} \therefore g = 3.1^2 = 9.61\, m\,s^{-2}$

18 (d) (2 marks)

Criteria	Marks
• Identifies that there is zero horizontal acceleration • Relates *u* to *R*	2
• Identifies that there is zero horizontal acceleration **OR** • An attempt to relate *u* to *R* by a different method	1

Sample answer
Because the block is initially travelling *horizontally* at *u* $\mathrm{m\,s^{-1}}$, and its horizontal acceleration is *zero*, the range *R* it covers depends simply upon *u* and the time it takes to fall 2.0 metres

Question 19

19 (a) (1 mark)

Criteria	Mark
• Correctly identifying Michelson and Morley	1

Sample answer
This is the Michelson-Morley experiment

19 (b) (2 marks)

Criteria	Marks
• Stating that reflecting light is deflected at 90° • Stating that the unreflected light passes straight through	2
• Identifying only one of these	1

Sample answer
The single light beam enters the device and strikes a beam-splitter inclined at 45° to its path. This causes half the light to reflect towards a mirror M_2, changing its path by an angle of 90°. Meanwhile, the rest of the light passes straight through the beam-splitter without deflection. OR appropriate diagram.

19 (c) (1 mark)

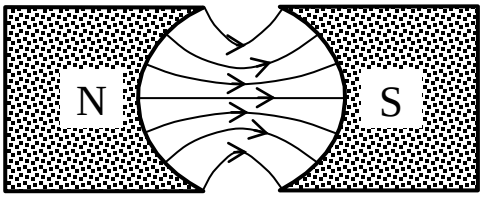
Criteria	Mark
• Identifying a variation in the observed diffraction pattern	1

Sample answer
Had this experiment shown a positive result, the diffraction pattern observed through the eyepiece of the device would have shown a variation in position when the whole experiment was changed through 90°.

Question 20
20 (a) (1 mark)

Criteria	Mark
• Correctly sketching in at least three lines	1

Sample answer



20 (b) (1 mark)

Criteria	Mark
• Identifying that the torque is maximised (cos 90=1)	1

Sample answer
Where the edges of the motor coils move (these are the only parts to which torque is applied), the magnetic field is perpendicular to the face of the pole-piece at that point, which makes the plane of the coil effectively parallel to the magnetic field lines there, maximizing the torque.

Question 21
21 (a) (4 marks)

Criteria	Marks
• Identifying back-emf (or self-induction) • Relating this to Lenz's law • Accepting the validity of the student's correct proposition about energy • Adding an assessment that the statement as a whole is not valid	4
• Identifying back-emf (or self-induction) • Assessing that the statement as a whole is not valid	3
• Identifying one reason why the student's statement is not valid • Assessing that the student's statement is not valid	1 – 2

Sample answer
The student is certainly correct in the statement that electrical energy input should cause the motor to start rotating, however, the supposition that the rotation rate should increase without limit since there is no load ignores the existence both of friction in the motor's bearings, and more significantly, that increasing speed of the motor will induce greater back-emf in the coils of the motor, in accordance with Lenz's law. This back-emf builds up, opposing the input voltage, and with friction removing energy from the device, at a certain speed there comes a balance between energy in and out.

21 (b) (1 mark)

Criteria	Mark
• Substituting correctly into the correct equation to get an answer	1

Sample answer

$\tau_{MAX} = BAnI \quad \therefore\ 2.7\times10^{-2} = 0.023\times\left(3.0\times10^{-2}\right)^2\times210\times I \quad \therefore\ I = 6.2$ Amperes

Question 21 (continued)

21 (c) (1 mark)

Criteria	Mark
• Recognising that the torque is halved when $\cos\theta = 0.5$	1

Sample answer

Since $\tau = BAnI\cos\theta$ and $\tau_{MAX} = BAnI$ (as above) $\therefore \cos\theta = 0.5$, so $\theta = 60°$.

Question 22

22 (a) (1 mark)

Criteria	Mark
• Identifying what the device is	1

Sample answer

This device is a simple transformer.

22 (b) (2 marks)

Criteria	Marks
• Correctly comparing both the voltage and the current in the coils	2
• Correctly comparing either the voltage or the current	1

Sample answer

Since there are more coils in the secondary coil than the primary, this would be a step-up transformer, so the voltage in coil A would be lower than that in coil B, while the current in coil A should be higher than in coil B (unless coil B is not connected, so no current is drawn).

22 (c) (2 marks)

Criteria	Marks
• Stating the dependence of voltage on ratio of turns, and a correct change	2
• Correctly providing one of these	1

Sample answer

Since the ratio of voltages in coils A and B depends upon the ratio of their turns $\frac{V_P}{V_S} = \frac{n_P}{n_S}$ the voltage in the secondary could be increased by removing turns from coil A

Question 23

23 (a) (1 mark)

Criteria	Mark
• States that emf or voltage is generated (not current)	1

Sample answer

To generate emf (voltage), and maximise the amount of emf generated.

23 (b) (1 mark)

Criteria	Mark
• Identifies the laminations	1

Sample answer

Laminated iron core.

23 (c) (1 mark)

Criteria	Mark
• States that emf, voltage, or current can reach the outside	1

Sample answer

To allow the generated emf to the outside circuit through wires, without the wires twisting.

23 (d) (1 mark)

Criteria	Mark
• Identifies electromagnets	1

Sample answer

Electromagnets.

Question 24 (3 marks)

Criteria	Marks
• Describes the coil within a uniform or radial magnetic field • Describes the coiled spring and its function • Describes the motor effect when current flows through the coil	3
• Correctly describes two of the above features **OR** • Correctly identifies three features of a galvanometer	2
• Correctly identifies one feature of a galvanometer	1

Sample answer

[A correct diagram of the functioning part of a galvanometer, correctly labelled is sufficient for a student to gain the full three marks available for this question.] The key part of a galvanometer is a coil within an external magnetic field with curved pole-pieces. If a current passes through the coil, it will rotate within the external field – a consequence of the motor effect. A needle attached to the coil moves across a scale, allowing the amount of current to be measured. A coiled spring is attached to the coil, to provide a counter-torque on the coil, allowing the scale to be calibrated, and to force the coil back to zero when no current flows through the coil. Curved pole-pieces of the permanent magnet produce a radial magnetic field around the coil to eliminate the 'cos θ' factor, so the scale can be uniform.

Question 25 (5 marks)

25 (a) (2 marks)

Criteria	Marks
• Describes cathode → anode flow with a linked observable effect	2
• Describes one fact about the cathode rays here with insufficient reasoning	1

Sample answer

The cathode rays are observed to produce a shadow behind the Maltese cross (anode side) when flowing; this can only occur if they run from the cathode to the anode and come through around the obstacle (the metal cross).

25 (b) (2 marks)

Criteria	Marks
• Appropriate observation and reasoning to suggest wave-like property	2
• An appropriate observation	1

Sample answer

The cathode rays are observed to produce a sharp shadow behind the Maltese cross in a similar way to which light produces a shadow around an opaque obstacle. Since light was thought to be a wave, it suggested that cathode rays are also wave-like.

25 (c) (1 mark)

Criteria	Mark
• An appropriate observation	1

Sample answer

The experiment produces X-rays; stay at least 1.5 m back from the equipment to minimise exposure.

Question 26 (7 marks)

26 (a) (1 mark)

Criteria	Mark
• Correct statement	1

Sample answer

Hertz discovered radio waves.

26 (b) (3 marks)

Criteria	Marks
• Describes role of induction coil and role of detection coil and explains how the waves are produced.	3
• Describes role of induction coil and role of detection coil **OR** • Describes role of induction coil and explains how the waves are produced **OR** • Describes role of detection coil and explains how the waves are produced	2
• One fact about the electromagnetic waves produced here.	1

Sample answer
The induction coil produces sparks and the electromagnetic waves by putting a large voltage across the spark contacts. This accelerates the charges across the gap and between the aerial plates, producing the electromagnetic waves. These waves travelled off in straight lines. Upon reaching the detector coil the waves would induce a voltage across the ends of the gap in the coil and produce sparks.

26 (c) (2 marks)

Criteria	Marks
• Describes one test and relates the property tested to light	2
• Identifies one test but does not relate the property to light	1

Sample answer
Hertz showed that the e-m waves could be reflected from flat metal surfaces and concave metal surfaces in the same way that light waves reflect from flat mirrors and concave mirrors. Hertz showed that the e-m waves could be refracted when travelling through wax prisms in the same way light waves refract through glass prisms.

Question 26 (continued)
26 (d) (1 mark)

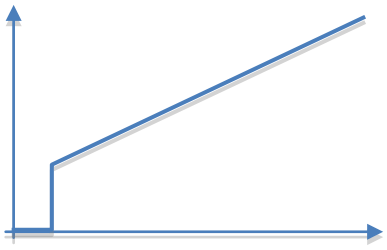
Criteria	Mark
• Correct statement	1

Sample answer
Hertz noticed that sparks occurred more easily when UV light was shining on the spark gap.

Question 27 (6 marks)
27 (a) (1 mark)

Criteria	Mark
• Correct graph showing drop at 4 K	1

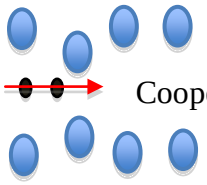
Sample answer



Question 27
27 (b) (5 marks)

Criteria	Marks
• Five factors covered (or an equivalently detailed discussion); appropriate diagram drawn, Cooper pairs outlined, zero resistance mentioned or critical temperature mentioned, limitation of BCS given.	5
• Four factors covered (or an equivalently detailed discussion)	4
• Three factors covered (or an equivalently detailed discussion)	3
• Two factors covered (or an equivalently detailed discussion)	2
• One correct statement (or an equivalently detailed discussion)	1

Sample answer
BCS theory states that the charge carriers in superconducting materials are Cooper pairs. These are actually two electrons which are linked in a special (quantum physics) way as they travel through the lattice, flowing with zero resistance. The linking comes about because there is an interaction with the electrons and the lattice, through phonons, below the critical temperature. The theory works well for type I materials but not for type II materials (the high temperature superconductors).



Question 28 (2 marks)
28 (a) (1 mark)

Criteria	Mark
• Correct answer	1

Sample answer

The line is produced down to the axis at 6.5×10^{14} Hz, which is the threshold frequency.

28 (b) (1 mark)

Criteria	Mark
• Correct answer	1

Sample answer

$E = hf$ gives the work function at the threshold frequency, so
$W = 6.626 \times 10^{-34} \times 6.5 \times 10^{14} = \underline{4.3 \times 10^{-19}\ J}$

Section II

Question 29 (25 marks)
29 (a) (i) (1 mark)

Criteria	Mark
• Correct calculation	1

Sample answer

$$\frac{1}{\lambda_R} = R\left[\frac{1}{n_f^{\,2}} - \frac{1}{n_i^{\,2}}\right] \quad \therefore \frac{1}{\lambda_R} = 1.097 \times 10^7 \left[\frac{1}{3^2} - \frac{1}{5^2}\right] = 780089 \quad \therefore \lambda_R = 1.28 \times 10^{-6}\ m$$

29 (a) (ii) (1 mark)

Criteria	Mark
• Correct statement which is justified	1

Sample answer
Visible light occupies 400 nm – 700 nm, so $\lambda = 1.28 \times 10^{-6}$ m = 1280 nm is outside this range and in the infra-red.

29 (a) (iii) (1 mark)

Criteria	Mark
• Correct statement	1

Sample answer
Bohr's theory was that electrons orbited in set energy levels, and spectral lines occurred whenever electrons jumped up or down energy levels, releasing or absorbing energy.

29 (b) (4 marks)

Criteria	Marks
• Describes one of the α-particle experiment results and links it with Rutherford's proposals	2
• Describes one of the α-particle experiment results but does not link this with Rutherford's proposal	1

Sample answer
Two of the unexpected results of this investigation were that most α-particles went straight through the atom and that there were a small number of α-particles which were deflected by a very large angle. This relates to Rutherford's proposal that most of the atom was made up of empty space, and that there was a small dense positive nucleus in the centre.

29 (c) (5 marks)

Criteria	Mark
• Mentions all three points and explains two	5
• Four of the above	4
• Three of the above	3
• Two of the above	2
• Mentions one point only	1

Sample answer
Bohr's model of the atom could not explain the hyperfine structure of spectral lines (lines consisted of two or three fine lines close together), the relative intensity of spectral lines (some were brighter than others), the Zeeman effect (lines split in a B field). It was also a mixture of classical and quantum ideas.

29 (d) (4 marks)

Criteria	Mark
• Mentions three facts and comes to an assessment	4
• Three of the above	3
• Two of the above	2
• One of the above	1

Sample answer
Planck proposed that, in Black Body Radiation, the atomic radiators could only radiate energy in discrete packets of energy called quanta. He derived the equation E=hf. This idea was later extended to all EMR by Einstein to explain the photoelectric effect and the equation was used by de Broglie. Thus Planck's ideas were the beginning of quantum physics and absolutely necessary for its development.

29 (e) (i) (1 mark)

Criteria	Mark
• States that wave/particle duality applies to electrons in atoms.	1

Sample answer

De Broglie proposed that electrons had a wave nature and could be considered as standing waves around the nucleus of an atom.

29 (e) (ii) (2 marks)

Criteria	Mark
• Uses correct equation to obtain correct answer.	2
• Uses correct equation but makes a substitution or calculation error	1

Sample answer

$\lambda = h/mv$ so $\lambda = 6.63 \times 10^{-34} / 1.27 \times 10^{27} \times 3 \times 10^{5}$ so $\lambda =$

29 (f) (i) (1 mark)

Criteria	Mark
• Correctly identifies a non-inertial frame	1

Sample answer

A train accelerating away from the station (or any accelerating frame).

29 (f) (ii) (2 marks)

Criteria	Mark
• Uses correct equation to obtain a correct answer	2
• Correct equation but wrong substitution	1

Sample answer

$M_o = m_v \sqrt{(1 - v^2/c^2)}$ so $m_o = 1000 \sqrt{(1 - 0.9^2)}$ so $m_o = 435.89$ kg

29 (g) (i) (1 mark)

Criteria	Mark
• Correctly determines 24 hours	1

Sample answer

24 hours

29 (g) (ii) (2 marks)

Criteria	Mark
• Correct equation and answer	2
• Substitution or calculation error	1

Sample answer

$R^3/T^2 = GM/4\Pi^2$ so $R^3 = GMT^2/4\Pi^2$ so $R^3 = 6.67 \times 10^{-11} \times 5.9 \times 10^{24} \times (24 \times 60 \times 60)^2 / 4\Pi^2$

$R = 4.21 \times 10^7$ m and Altitude $= R - R_E$ so Alt $= 3.6 \times 10^7$ m

29 (g) (iii) (2 marks)

Criteria	Mark
• Two valid comparisons	2
• One valid comparison	1

Sample answer

Geostationary orbits are at a higher altitude, have a longer period, have a lower velocity, must be located over the equator, etc compared to LEO satellites.