OCR
Oxford Cambridge and RSA

Accredited

A Level Physics A
H556/02 Exploring physics
Sample Question Paper

Date – Morning/Afternoon
Version 2.0

Time allowed: 2 hours 15 minutes

You must have:
• the Data, Formulae and Relationships Booklet

You may use:
• a scientific or graphical calculator

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First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided.
- Additional paper may be used if required but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **32** pages.

SECTION A

You should spend a maximum of 20 minutes on this section.

Answer **all** the questions.

1 To find the density ρ of a metal wire, a student makes the following measurements:

length l = 100 ± 1 mm
diameter d = 2.50 ± 0.05 mm
mass m = 4.00 ± 0.02 g

The equation $\rho = \frac{4m}{\pi d^2 l}$ is used to calculate the density of the metal.

What is the percentage uncertainty in the answer?

A ± 2.5%

B ± 3.5%

C ± 4.5%

D ± 5.5%

Your answer ☐

[1]

2 A copper wire is connected across a cell. The conduction electrons within the copper wire move.

Which statement is correct about these electrons?

A They drift towards the negative end of the cell.

B They have random speeds because of collisions with other electrons.

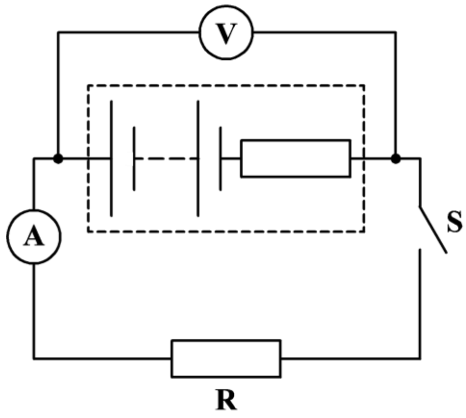
C They travel through the wire at the speed of light.

D They collide with vibrating copper ions.

Your answer ☐

[1]

3 A resistor **R**, an ammeter and a switch are connected in series to a battery.



The switch **S** is open. The voltmeter reading is 9.0 V and the ammeter reading is zero.
With **S** closed, the voltmeter reading is 6.0 V and ammeter reading is 2.0 A.

What is the internal resistance of the battery?

A 1.5 Ω

B 3.0 Ω

C 4.5 Ω

D 6.0 Ω

Your answer ☐

[1]

4 Which of the following statements is/are true about photons?

1 All photons travel at the same speed in a vacuum.

2 Photons have no charge.

3 The energy of a photon depends only on its frequency.

A 1, 2 and 3

B Only 2 and 3

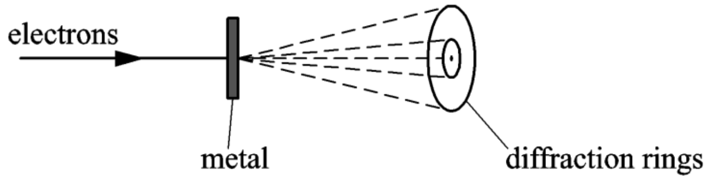
C Only 1 and 2

D Only 2

Your answer ☐

[1]

5 Electrons travelling through a thin layer of polycrystalline metal are diffracted.



Which statement is correct about these electrons?

A The electrons travel as photons through the metal.

B The electrons have a wavelength of about 10^{-10} m.

C The electrons are diffracted by holes in the metal.

D The electrons repel each other to produce the diffraction.

Your answer ☐

[1]

6 A sodium lamp is rated at 40 W. About 12% of the power is emitted as yellow light of wavelength 5.9×10^{-7} m.

How many photons of yellow light are emitted per second from this lamp?

A 1.4×10^{19} s^{-1}

B 1.2×10^{20} s^{-1}

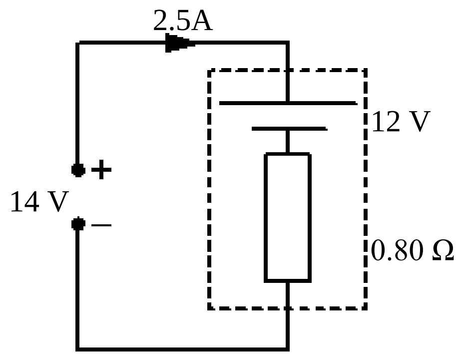
C 3.6×10^{27} s^{-1}

D 1.0×10^{40} s^{-1}

Your answer ☐

[1]

7 A 14 V d.c. supply is used to charge a 12 V car battery of internal resistance 0.80 Ω for 6.0 hours. The current in the circuit is 2.5 A.



How much electrical energy is provided by the charging supply?

A 13 kJ

B 110 kJ

C 650 kJ

D 760 kJ

Your answer

[1]

8 The electric potential is -1.2×10^{-4} J C^{-1} at a point 1.2×10^{-5} m from an isolated electron. An α-particle $^{4}_{2}He$ passes through this point.

What is the magnitude of the electric potential at the mid-point between the α-particle and the electron at this instant?

A -7.2×10^{-4} J C^{-1}

B $+2.4 \times 10^{-4}$ J C^{-1}

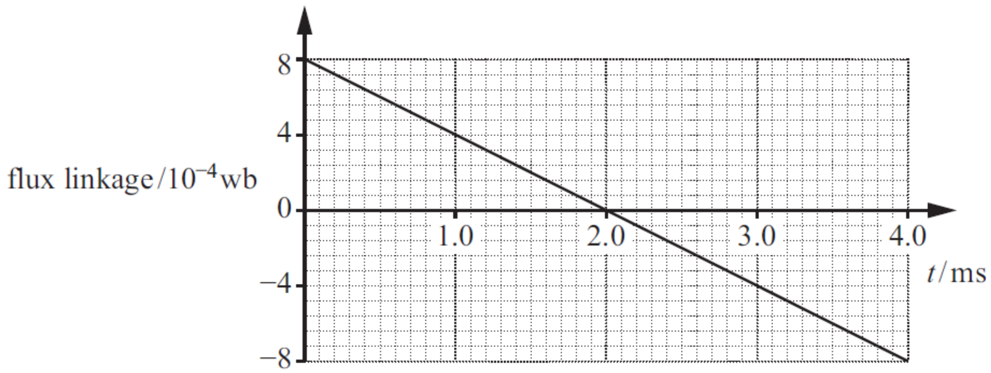
C $+4.8 \times 10^{-4}$ J C^{-1}

D $+7.2 \times 10^{-4}$ J C^{-1}

Your answer

[1]

9 A coil with three turns of wire is used in an experiment.
The graph shows the variation of magnetic flux linkage with time *t* for this coil.



What is the e.m.f. induced across the ends of the coil?

A 0 V

B 0.20 V

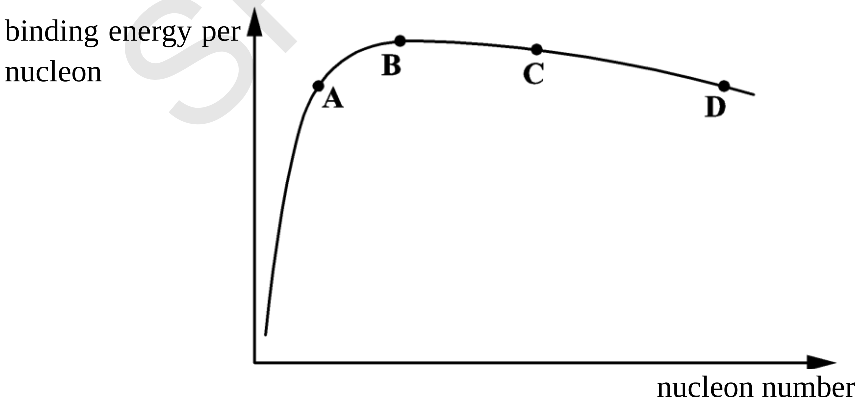
C 0.40 V

D 1.2 V

Your answer ☐

[1]

10 A graph of binding energy per nucleon against nucleon number is shown below.



Which nucleus, **A**, **B**, **C**, or **D**, shown on the graph has the largest magnitude of binding energy?

Your answer ☐

[1]

11 A radiographer in a hospital directs a parallel beam of X-rays at the leg bone of a patient. The attenuation (absorption) coefficient of bone is 0.7 cm^{-1}.

The answers below are given to one significant figure.
What is the percentage intensity of X-rays transmitted through bone of thickness 0.7 cm?

A 0 %

B 40 %

C 50 %

D 60 %

Your answer ☐

[1]

12 When a nucleus of uranium-238 absorbs a neutron, one combination of fission products can be tin-126 and a nucleus of element **X**. 13 neutrons are also emitted.

$$^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow \mathbf{X} + {}^{126}_{50}\text{Sn} + 13\,{}^{1}_{0}\text{n}$$

How many neutrons are there in the nucleus of element **X**?

A 30

B 42

C 58

D 100

Your answer ☐

[1]

13 The potential difference across the cathode and the anode of an X-ray tube is V. The minimum wavelength of the X-ray photons emitted from the tube is λ_o.

Which of the following statements is/are correct?

1 λ_o is halved when V is doubled.

2 λ_o is unchanged when the temperature of the cathode is increased.

3 λ_o is independent of the cathode material.

A 1, 2 and 3

B Only 2 and 3

C Only 1 and 2

D Only 2

Your answer ☐

[1]

14 Two leptons are emitted when a down quark decays into an up quark.

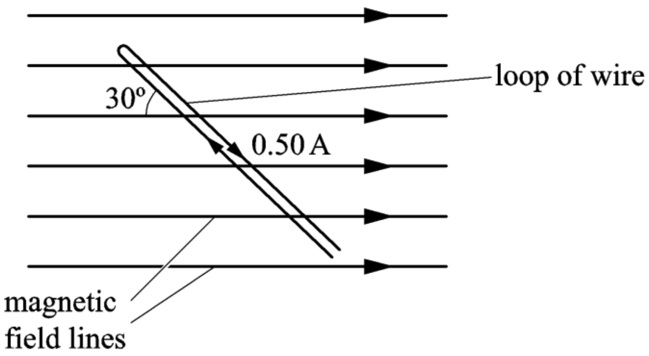
Which of the following is correct about this decay?

	force responsible for the decay	**leptons emitted**
A	strong nuclear	positron and antineutrino
B	weak nuclear	positron and neutrino
C	strong nuclear	electron and neutrino
D	weak nuclear	electron and antineutrino

Your answer ☐

[1]

15 A rigid loop of insulated wire is placed in a uniform magnetic field of flux density 80 mT. The current in this loop is 0.50 A and the angle between the wire and the direction of the magnetic field is 30°.



What is the magnitude of the force experienced by a 1.0 cm section of the loop?

A 0 N

B 2.0×10^{-4} N

C 3.5×10^{-4} N

D 4.0×10^{-4} N

Your answer ☐

[1]

SECTION B

Answer **all** the questions.

16 A student uses the circuit shown in **Fig. 16.1** to determine the resistivity of a metal in the form of a wire.

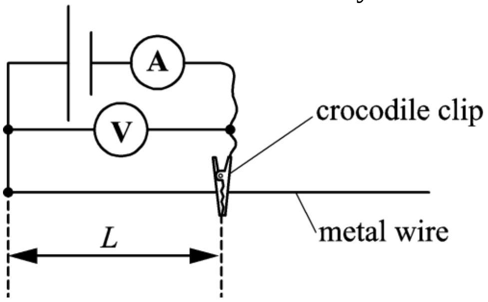


Fig. 16.1

The length L of the wire is changed with the help of a crocodile clip. The current in the wire is I, the p.d. across the wire is V and the wire has resistance R.
The table in **Fig. 16.2** shows the results recorded by the student from the experiment.

***L* / m**	***V* / V**	***I* / A**	***R* / Ω**
0.050	0.40	0.160	2.50
0.200	0.40	0.140	2.86
0.400	0.40	0.072	
0.800	0.40	0.036	11.1
1.000	0.40	0.029	13.8

Fig. 16.2

Fig. 16.3 shows the graph of R against L for this wire.

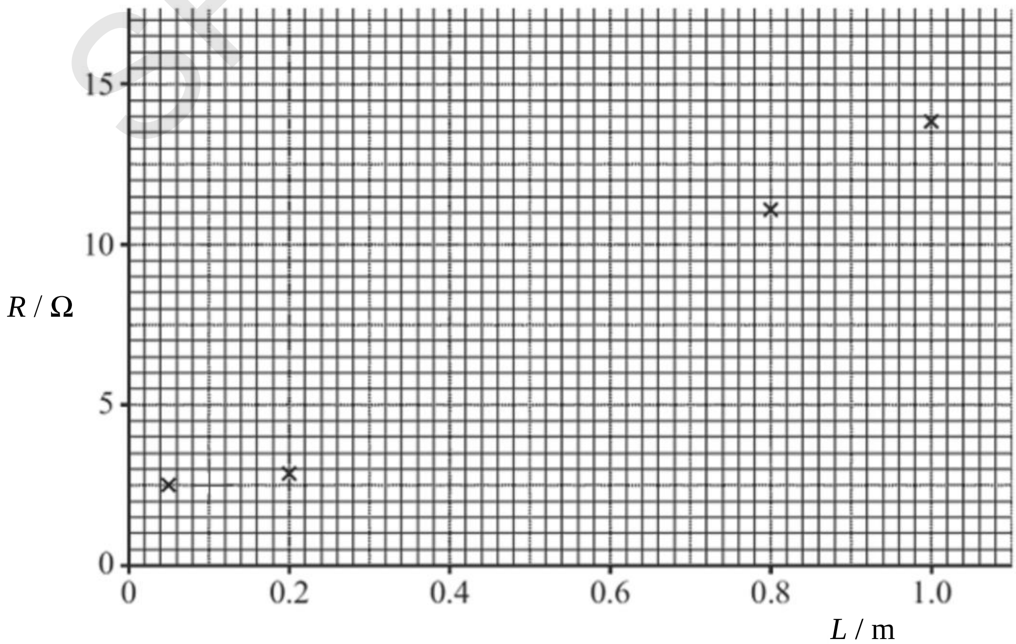


Fig. 16.3

(a) Complete the table by calculating the resistance of the wire of length 0.400 m. On **Fig. 16.3** plot the data point corresponding to this length.

[1]

(b) The student observed that the wire was significantly hotter when the shortest length L = 0.050 m was used.
The cross-sectional area of the wire is $8.0 \times 10^{-8}\,\text{m}^2$.

Use **Fig. 16.3** to determine the resistivity of the metal.

resistivity = **....................................** Ω m **[3]**

(c) The voltmeter used in the experiment had a zero error. The potential difference recorded in the experiment was larger than it should have been.

Discuss how the actual value of the resistivity of the metal would differ from the value calculated in **(b)**.

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.... **[3]**

17 (a) **Fig. 17.1** shows a resistor and a diode connected in series to a cell.

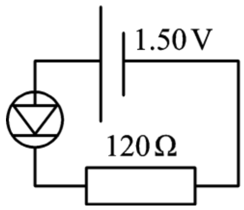

Fig. 17.1

The resistor has resistance 120 Ω. The cell has e.m.f. 1.50 V and negligible internal resistance. The potential difference across the diode is 0.62 V.

Calculate the total power dissipated in the circuit.

power = ……………….. W **[3]**

(b) A student designs a circuit to vary the brightness of a filament lamp. The circuit is shown in **Fig. 17.2**.

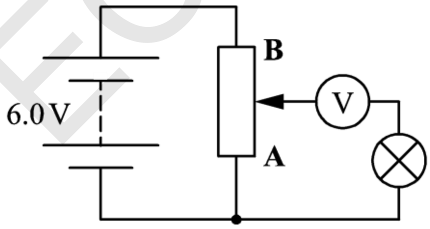

Fig. 17.2

The circuit is set up. Moving the slider from **A** to **B** changes the voltmeter reading from 0 V to 6.0 V but the lamp stays off. The lamp is not faulty.

Explain the observations above and refine the circuit design so that the brightness of the lamp can be varied as the slider is moved from **A** to **B**.

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…………………………………………………………………………………………… **[3]**

(c)* **Fig. 17.3** shows how the resistance of a thermistor varies with temperature.

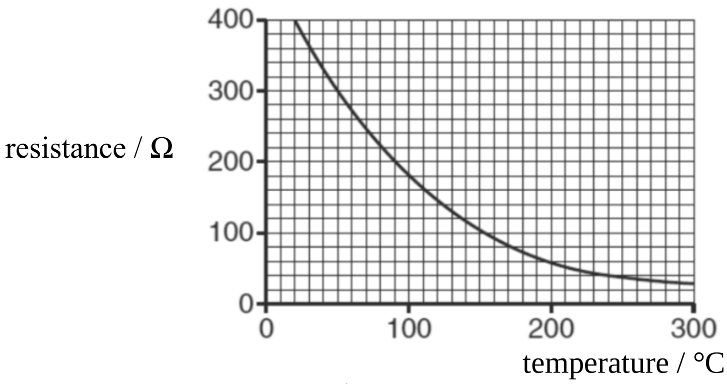

Fig. 17.3

Fig. 17.4 shows a potential divider circuit which uses this thermistor. The circuit is designed to monitor the changes in the temperature of an oven in the range 200 °C to 300 °C.

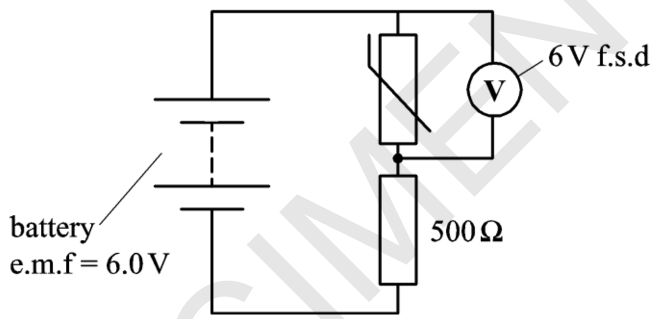

Fig. 17.4

The voltmeter has very high resistance and has a full scale deflection (f.s.d.) of 6.0 V.

Explain how the circuit works and use calculations to discuss a significant limitation of this design. **[6]**

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Question 18 begins on page 16

18 A guitar manufacturer wants to investigate the quality of sound produced from a new uniform polymer string. **Fig. 18.1** shows the string which is kept in tension between a clamp and a pulley. The frequency of the mechanical oscillator close to one end is varied so that a stationary wave is set up on the string.

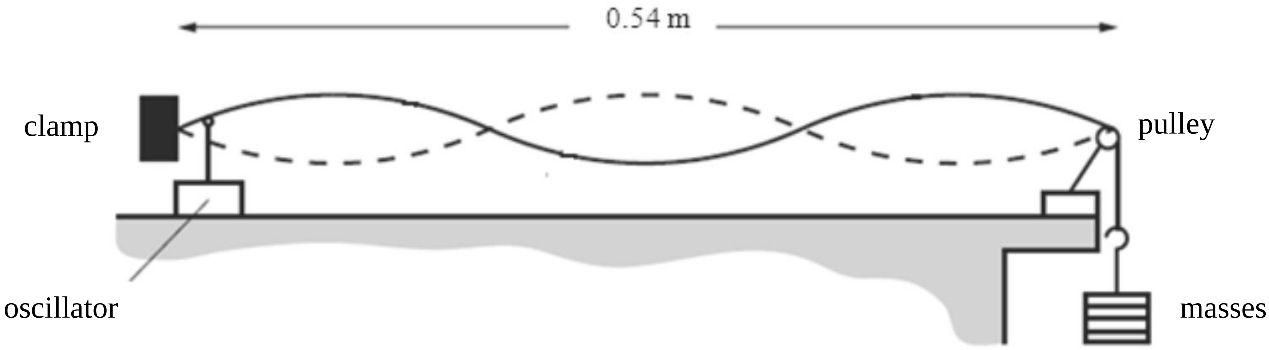

Fig. 18.1

(a) Explain how the stationary wave is formed on this stretched string.

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…………………………………………………………………………………………… **[2]**

(b) The frequency of the oscillator is 60 Hz.

Use Fig. **18.1** to calculate the speed of the transverse waves on the string.

speed = ………………….. m s^{-1} **[3]**

(c) The speed v of the transverse waves on the string is directly proportional to $\sqrt{T}$, where T is the tension in the string.
The tension T in the string is increased by 14 %. The frequency f of the oscillator is adjusted to get the same stationary wave pattern as **Fig. 18.1**.

Calculate the percentage increase in the frequency f.

increase = **......................** % **[2]**

19 **(a)** State what is meant by the *photoelectric effect*.

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.... **[1]**

(b) The photoelectric effect cannot be explained in terms of the wave-model of electromagnetic waves. Discuss how the new knowledge of the particulate nature of radiation was used by physicists to validate the photon model.

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.... **[3]**

(c) A metal plate is placed in an evacuated chamber. Electromagnetic radiation of wavelength 380 nm is incident on the plate. The work function of the metal is 1.1 eV.

(i) Calculate the maximum speed of the photoelectrons emitted from the plate.

speed = ... m s^{-1} **[3]**

(ii) State the change, if any, to the maximum speed of the emitted photoelectrons when the intensity of the incident electromagnetic radiation on the metal plate is doubled.

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.... **[1]**

20 **(a)** **Fig. 20.1** shows a capacitor and a switch connected in series to a cell.

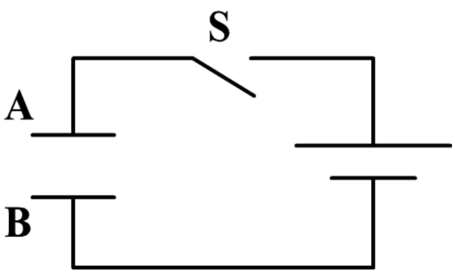

Fig. 20.1

The switch **S** is closed.

Describe and explain how the capacitor plates **A** and **B** acquire opposite charges.

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.... **[2]**

(b) **Fig. 20.2** shows an arrangement of capacitors connected to a battery.

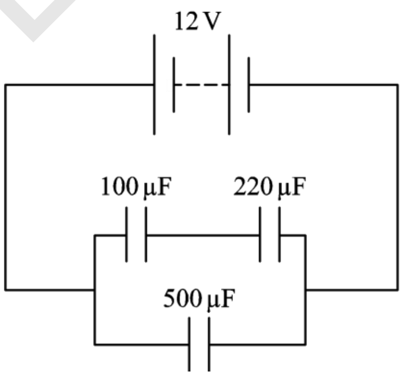

Fig. 20.2

The e.m.f. of the battery is 12 V.

Calculate the total energy E stored by the capacitors in this circuit.

E = ... J **[4]**

(c) Fig. 20.3 shows a capacitor-resistor circuit.

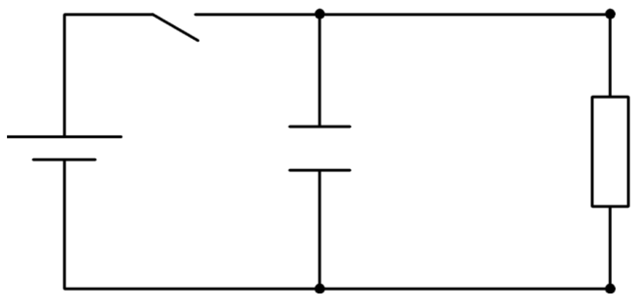

Fig. 20.3

Describe how the time constant of this circuit can be determined experimentally in the laboratory.

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21 (a) Describe the similarities and the differences between the gravitational field of a point mass and the electric field of a point charge.

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(b) **Fig. 21.1** shows two identical negatively charged conducting spheres.

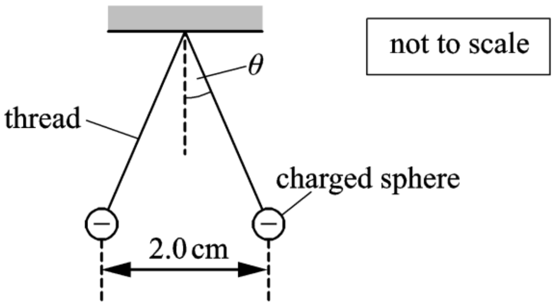

Fig. 21.1

The spheres are tiny and each is suspended from a nylon thread. Each sphere has mass 6.0×10^{-5} kg and charge -4.0×10^{-9} C. The separation between the centres of the spheres is 2.0 cm.

(i) Explain why the spheres are separated as shown in **Fig. 21.1**.

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.... **[2]**

(ii) Calculate the angle θ made by each thread with the vertical.

θ = ... ° **[4]**

(c) **Fig. 21.2** shows two parallel vertical metal plates connected to a battery.

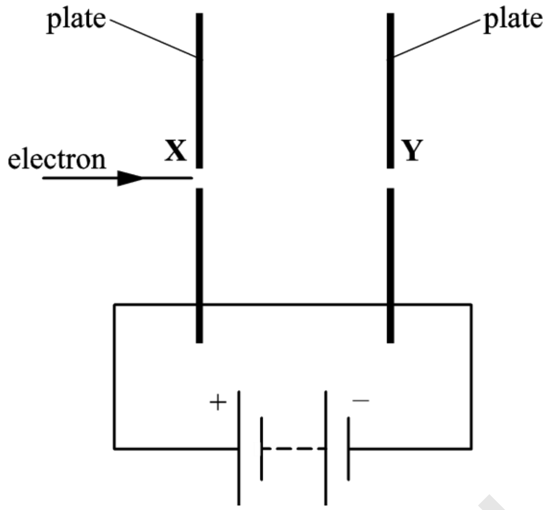

Fig. 21.2

The plates are placed in a vacuum and have a separation of 1.2 cm. The uniform electric field strength between the plates is 1500 V m^{-1}. An electron travels through holes **X** and **Y** in the plates. The electron has a horizontal velocity of 5.0×10^6 m s^{-1} when it enters hole **X**.

(i) Draw five lines on **Fig. 21.2** to represent the electric field between the parallel plates. **[2]**

(ii) Calculate the final speed of the electron as it leaves hole **Y**.

speed = ... m s^{-1} **[3]**

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Question 22 begins on page 22

22 **Fig. 22.1** shows the circular track of a positron moving in a uniform magnetic field.

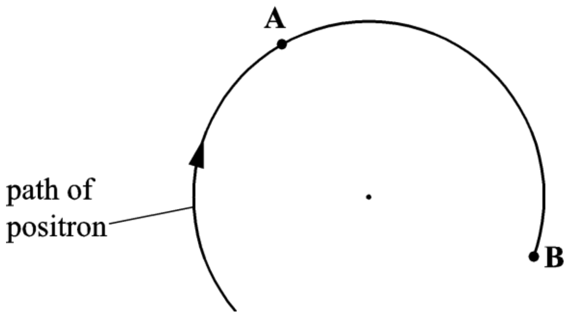

Fig. 22.1

The magnetic field is perpendicular to the plane of **Fig. 22.1**.
The speed of the positron is 5.0×10^{7} m s^{-1} and the radius of the track is 0.018 m.

(a) State the direction of the force acting on the positron when at point **A** and explain why this force does **not** change the speed of the positron.

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.... **[2]**

(b) Calculate the magnitude of the magnetic flux density of the magnetic field.

magnetic flux density = ... T **[3]**

(c) At point **B** the positron interacts with a stationary electron and they annihilate each other. The annihilation process produces two identical gamma photons travelling in opposite directions.

Calculate the wavelength of the gamma photons. Assume the kinetic energy of the positron is negligible.

wavelength = **................................** m **[3]**

23 (a)* Lead of different thicknesses can be used to investigate the absorption of gamma photons from a radioactive source.
Fig. 23.1 shows a graph of gamma photon energy against the half-thickness of lead. Half-thickness of lead is the thickness of lead which will reduce the original count-rate by half.

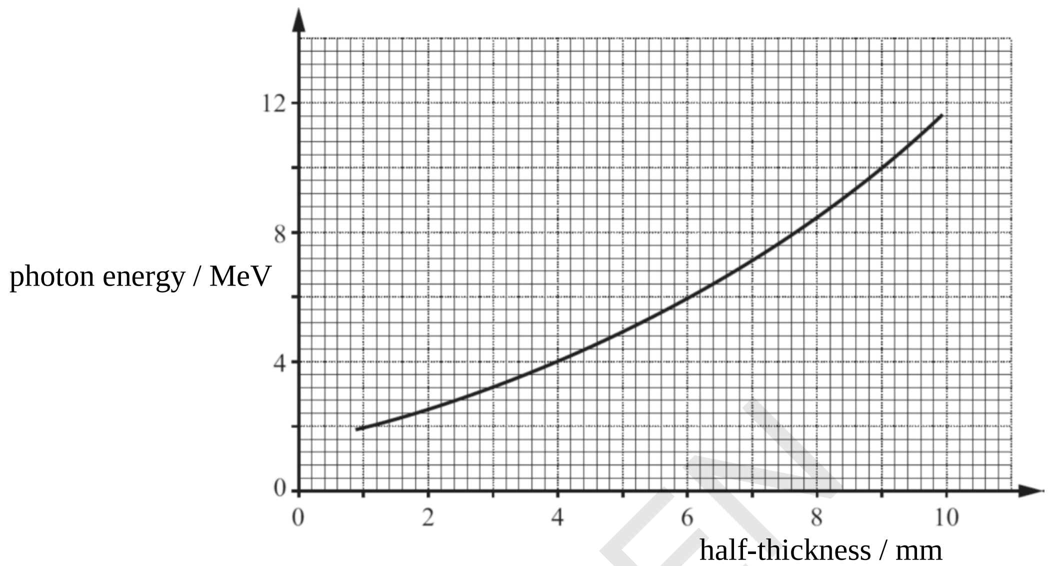

Fig. 23.1

Describe an experiment that can be carried out to determine the half-thickness of lead and how you would use your results with **Fig. 23.1** to determine the energy of a gamma photon from a radioactive gamma source in your laboratory.

Include the equipment used, any safety precautions necessary and how the quality of the results may be improved. **[6]**

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Additional answer space if required.

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(b) Fluorodeoxyglucose (FDG) is a radioactive tracer often used for PET scans. It contains radioactive fluorine-18, which is a positron-emitter. Some information about FDG and fluorine-18 is given below.

- 9.9% of the mass of FDG is fluorine-18.
- The half-life of fluorine-18 is 6600 s.
- The molar mass of fluorine-18 is 0.018 kg mol^{-1}.

A patient is injected with FDG. The initial activity of FDG is 400 MBq.

Use the information given to calculate the initial mass of FDG given to the patient.

mass = **........................** kg **[4]**

(c) PET scanners are expensive because they require a near-by or on-site particle accelerator that produces fluorine-18. Discuss the ethical issues this raises in the treatment of patients.

[2]

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Question 24 begins on page 30

24 **(a)** State what is meant by the *piezoelectric effect*.

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.... **[1]**

(b) In an experiment, a beam of ultrasound is directed at the boundary between two materials **A** and **B**. **Fig. 24.1** shows the beam incident at right angles to the boundary between these two materials.

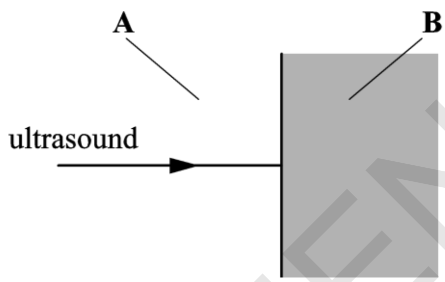

Fig. 24.1

The material **A** is unchanged. The acoustic impedance of material **A** is 2.5×10^6 kg m^{-2} s^{-1}. The material **B** is varied. The acoustic impedance of **B** is *Z*.
Fig. 24.2 shows the variation with *Z* of the percentage of reflected intensity of the ultrasound at the boundary.

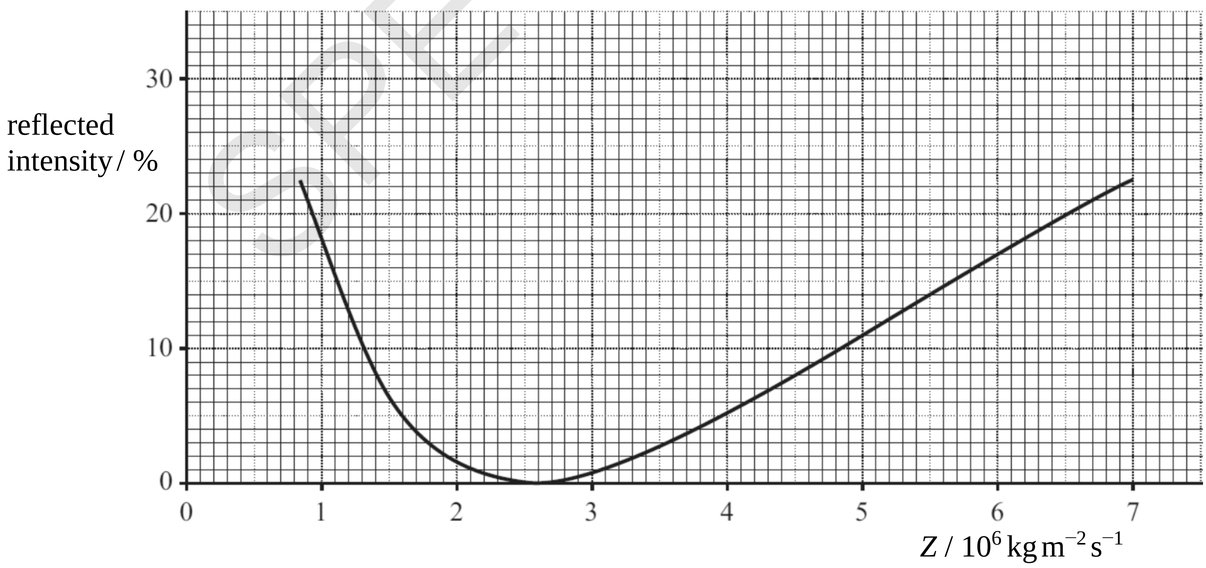

Fig. 24.2

Explain why the curve shown in **Fig. 24.2** has a dip.

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.... **[3]**

(c) Describe and explain a method using ultrasound to determine the speed of blood in an artery in an arm. State one major advantage of this technique for the patient.

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…… **[4]**

END OF QUESTION PAPER

…day June 20XX–Morning/Afternoon

A Level Physics A

H556/02 Exploring physics

SAMPLE MARK SCHEME

Duration: 2 hour 15 minutes

MAXIMUM MARK 100

This document consists of 20 pages

MARKING INSTRUCTIONS

PREPARATION FOR MARKING

SCORIS

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *scoris assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to scoris and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the scoris 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the scoris messaging system.

5. Work crossed out:

   a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks

   b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. There is a NR (No Response) option. Award NR (No Response)

   - if there is nothing written at all in the answer space

   - OR if there is a comment which does not in any way relate to the question (e.g. ‘can’t do’, ‘don’t know’)

   - OR if there is a mark (e.g. a dash, a question mark) which isn’t an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The scoris **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

   If you have any questions or comments for your Team Leader, use the phone, the scoris messaging system, or email.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:

- Read through the whole answer from start to finish.

- Decide the level that **best fits** the answer – match the quality of the answer to the closest level descriptor.

- To select a mark within the level, consider the following:

  Higher mark: A good match to main point, including communication statement (in italics), award the higher mark in the level
  Lower mark: Some aspects of level matches but key omissions in main point or communication statement (in italics), award lower mark in the level.

  Level of response questions on this paper are **17(c)** and **23(a)**.

11. **Annotations**

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12. **Subject-specific Marking Instructions**

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures:

If the data given in a question is to 2 sf, then allow to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Additional Guidance.

SECTION A

Question	Answer	Marks	Guidance
1	D	**1**	
2	D	**1**	
3	A	**1**	
4	A	**1**	
5	B	**1**	
6	A	**1**	
7	D	**1**	
8	B	**1**	
9	C	**1**	
10	D	**1**	
11	D	**1**	
12	C	**1**	
13	A	**1**	
14	D	**1**	
15	A	**1**	
	Total	**15**	

SECTION B

Question			Answer	Marks	Guidance
16	(a)		5.56 (V) and data point plotted correctly to ± ½ small square.	B1	
	(b)		Best fit straight line drawn through the last 4 data points. Gradient of the line determined. ρ = gradient × A, hence resistivity = (1.1± 0.1) × 10^{-6} (Ω m)	B1 B1 B1	**Allow** a maximum of 2 marks if the line of best fit is drawn through all 5 data points.
	(c)		The actual resistance values will be smaller. The gradient of the graph will be lower. Hence resistivity of the metal will be smaller than the value in **(b)**.	B1 B1 B1	
			Total	**7**	

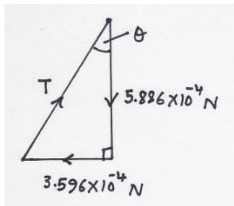
Question			Answer	Marks	Guidance
17	(a)		p.d. across resistor = 1.50 – 0.62 = 0.88 (V) current = 0.88/120 = 7.33... $\times 10^{-3}$ (A) power = VI = 1.50 $\times$ 7.33 $\times 10^{-3}$ = 1.1 $\times 10^{-2}$ (W)	C1 C1 A1	
	(b)		The voltmeter has large or infinite resistance. Hence the p.d across the lamp or current in the lamp is small or zero (and the lamp is not lit). Refining design: remove voltmeter from the circuit or place the voltmeter across the lamp.	B1 B1 B1	
	(c)*		**Level 3 (5–6 marks)** Explanation is complete with E1, 2 and 3 For calculation expect C3 At least two limitations mentioned. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect two points from E1, 2 and 3 Expect either C1 or C2 for the calculations Expect at least one limitation Limitation identified but calculations are inappropriate. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*	B1 ×6	**Explanation (E)** 1. Total resistance decreases as temperature increases (allow reverse argument) 2. Current in circuit increases as temperature increases or p.d. is in the ratio of the resistance values 3. Therefore, the p.d. across resistor increases or p.d. across thermistor decreases. **Calculations (C)** 1. $I = V/R$ used to show current increases as temperature increases 2. Potential divider equation (or $I = V/R$ and $R = R_1 + R_2$) used to calculate the voltmeter reading at either 200°C or 300°C • V_{300} = 6.0 $\times$ 25/(25+500) = 0.29 V • V_{200} = 6.0 $\times$ 60/(60+500) = 0.64 V) 3. Potential divider equation used to calculate the voltmeter reading at **both** 200°C and 300°C

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) Expect at least one point from explanation Expect C1 and an attempt at C2 Limitations given are inappropriate. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		**Limitation (L)** 1. The change in resistance is small when resistance of thermistor changes from 200 °C to 300 °C 2. Change in voltmeter reading is too small over this range 3. Non-linear change of resistance with temperature.
			Total	**12**	

Question			Answer	Marks	Guidance
18	(a)		Waves are reflected at the pulley end. This produces nodes and antinodes on the string.	B1 B1	
	(b)		$\lambda/2 = 0.54/3 = 0.18$ m $\lambda = 0.18 \times 2 = 0.36$ (m) $v = 60 \times 0.36$; speed = 21.6 m s^{-1} $\approx$ 22 (m s^{-1})	C1 C1 A1	
	(c)		$v \propto f$ and since $v \propto \sqrt{T}$, therefore $f \propto \sqrt{T}$ frequency will increase by a factor of $\sqrt{1.14} = 1.068$, therefore increase = 6.8 %	C1 A1	
			Total	**7**	

Question			Answer	Marks	Guidance
19	(a)		The emission of electrons from the surface of a metal when electromagnetic waves (of frequency greater than the threshold frequency) are incident on the metal.	B1	
	(b)		The wave model cannot explain why there is a threshold frequency for metals. The new model / photon model proposed one-to-one interaction between photons and electrons and this successfully explained why threshold frequency exists. Any further one from: Energy of photon (hf) must be greater than or equal to work function of metal. The kinetic energy of emitted electrons was independent of the incident intensity. Correct reference to hf = Φ + KEmax	B1 B1 B1	
	(c)	(i)	$E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{380\times10^{-9}}$ or $\phi = 1.1\times1.6\times10^{-19}$ $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{380\times10^{-9}} = 1.1\times1.6\times10^{-19} + \frac{1}{2}\times9.11\times10^{-31}v^{2}$ speed = 8.7×10^{5} (m s^{-1})	C1 C1 A1	This is substituting values into $\frac{hc}{\lambda} = \phi + \frac{1}{2}mv^{2}$
		(ii)	The energy of a photon depends only on wavelength or frequency, so intensity does not change the maximum speed of the photoelectrons.	B1	
			Total	**8**	

Question			Answer	Marks	Guidance
20	(a)		Electrons in the circuit move in a clockwise direction **and e**lectrons are deposited on plate **B.** (An equal number of) electrons are removed from plate **A** giving it a positive charge (of equal magnitude).	**B1** **B1**	**Allow**: Conventional current is in anticlockwise direction.
	(b)		series capacitors: $C = (100^{-1} + 220^{-1})^{-1} = 68.75$ (μF) total capacitance = 500 + 68.75 = 568.75 (μF) $E = ½ \times 12^2 \times 568.75 \times 10^{-6}$ $E = 4.1 \times 10^{-2}$ (J)	**C1** **C1** **C1** **A1**	
	(c)		Connect a voltmeter or data-logger or oscilloscope across the resistor (or capacitor) or an ammeter in series with the resistor. A stopwatch is started when the switch is opened and stopped when the p.d. or the current to decreases to 37% of its initial value. The time constant is the time taken for the p.d. or the current to decreases to 37% of its initial value.	**B1** **B1** **B1**	
			Total	**9**	

Question			Answer	Marks	Guidance
21	(a)		**Similarity** The field strength or force $\propto$ 1/separation^2 or both produce a radial field. **Differences** Gravitational field is linked to mass and electric field is linked to charge. Gravitational field is always attractive whereas electric field can be either attractive or repulsive.	B1 B1 B1	
	(b)	(i)	The charges repel each other (because they have like charges). Each charge is in equilibrium under the action of the three forces: downward weight, a horizontal electrical force and an upwardly inclined force due to the tension in the string.	B1 B1	
		(ii)	$F = \dfrac{(4.0\times10^{-9})^2}{4\pi\varepsilon_0\times0.02^2} = 3.596\ldots\times10^{-4}$ (N) weight $W = 6.0 \times 10^{-5} \times 9.81 = 5.886 \times 10^{-4}$ (N) $\tan\theta = \dfrac{3.596\times10^{-4}}{5.886\times10^{-4}}$ angle $\theta = 31°$	C1 C1 C1 A1	Correct use of $F = \dfrac{Qq}{4\pi\varepsilon_0 r^2}$ 
	(c)	(i)	Parallel and equidistant field lines. Field direction is correct (from left to right).	B1 B1	**Note**: Field lines must be right angle to the plates.

Question			Answer	Marks	Guidance
		(ii)	work done = 1500 × 1.6 × 10^{-19} × 1.2 × 10^{-2} = 2.88 × 10^{-18} (J)	C1	
			$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = \frac{1}{2} \times 9.11 \times 10^{-31} \times (5.0 \times 10^6)^2 - 2.88 \times 10^{-18}$	C1	Correct use of: final KE = initial KE – work done.
			speed = 4.3 × 10^6 (m s^{-1})	A1	
			Total	**14**	

Question			Answer	Marks	Guidance
22	(a)		The force is towards the centre of the circle. The force is perpendicular to the motion or no component of force in direction of motion; hence no work is done on the particle.	B1 B1	
	(b)		centripetal force provided by BQv; hence $\frac{mv^2}{r} = BQv$ $B = \frac{mv}{Qr} = \frac{9.11 \times 10^{-31} \times 5.0 \times 10^{7}}{1.6 \times 10^{-19} \times 0.018}$ B = 1.6 × 10^{-2} (T)	C1 C1 A1	
	(c)		energy of <u>two</u> photons = 2 × mc^2 or $2 \times \frac{hc}{\lambda} = 2 \times mc^2$ $\lambda = \frac{h}{mc} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3.0 \times 10^{8}}$ wavelength = 2.4 × 10^{-12} (m)	C1 C1 A1	Correct use of $\frac{hc}{\lambda} = mc^2$
			Total	**8**	

Question			Answer	Marks	Guidance
23	(a)*		**Level 3 (5–6 marks)** For equipment expect both E1 and E2 Descriptions has all the points At least two safety precautions mentioned Both Q1 and Q2 mentioned for the quality of results. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect at least E1 for equipment For description expect D1 and D2 and an attempt at either D3 or D4 At least one safety point mentioned Expect either Q1 or Q2 for quality of results. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect at least E1 for equipment For description expect D1 and D2 At least one safety point mentioned Statements for quality are not relevant. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	**B1 ×6**	**Equipment (E)** 1. GM tube, counter or rate-meter and lead plates used 2. Micrometer or vernier calliper (to measure thickness of plates). **Description (D)** 1. Measure counts for a specific time and hence the count-rate for each thickness of lead 2. Vary the thickness of lead and record the count-rates 3. Plot a graph of count-rate against thickness and determine the half thickness of lead 4. Fig. 23.1 is used to determine the photon energy. **Safety (S)** 1. Do not point source at person 2. Keep safe distance between you and source 3. Use tongs to handle source. **Quality of results (Q)** 1. The counts are recorded over a long period of time 2. Background radiation taken into account.

Question			Answer	Marks	Guidance
	(b)		$\lambda = \frac{\ln 2}{6600} = 1.050 \times 10^{-4}$ (s^{-1})	C1	Correct use of $A = \lambda N$
			$N = \frac{400 \times 10^{6}}{1.050 \times 10^{-4}} = 3.809 \times 10^{12}$	C1	
			mass of FDG = $\frac{3.809 \times 10^{12}}{6.02 \times 10^{23}} \times 0.018 \div 0.099$	C1	
			mass of FDG = 1.15×10^{-12} (kg) or 1.2×10^{-12} (kg)	A1	
	(c)		Doctors have to make difficult decisions about who can and cannot have a PET scan.	B1	
			Some patients will miss out on PET scans because of their location / not all patients will have access to the scans.	B1	
			Total	**12**	

Question			Answer	Marks	Guidance
24	(a)		The material expands or contracts when a p.d. is applied across its opposite faces.	B1	**Allow**: When a p.d. is applied across its opposite faces the material expands or contracts.
	(b)		The fraction *f* of the incident intensity of ultrasound reflected at the boundary is given $f = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$ There is reflection when $Z \neq 2.5 \times 10^6$ (kg m^{-2} s^{-1}) At $Z = 2.5 \times 10^6$ (kg m^{-2} s^{-1}) there is impedance (acoustic) matching and hence no reflection of ultrasound.	B1 B1 B1	
	(c)		The transducer is placed at an angle to the arm or artery **and** ultrasound is reflected by the moving blood cells. The wavelength or the frequency of the reflected ultrasound is altered. Since $\Delta f = \frac{2vf\cos\theta}{c}$, the change in frequency $\propto$ speed of the blood. The technique is non-invasive/no incision needed/minimises risk of infection.	B1 B1 B1 B1	
			Total	**8**	

Summary of updates

Date	Version	Change
January 2019	2.0	Minor accessibility changes to the paper: i) Additional answer lines linked to Level of Response questions ii) One addition to the rubric clarifying the general rule that working should be shown for any calculation questions Question paper Q16(c) Amendment to wording Mark scheme - Q11 mcq response correction