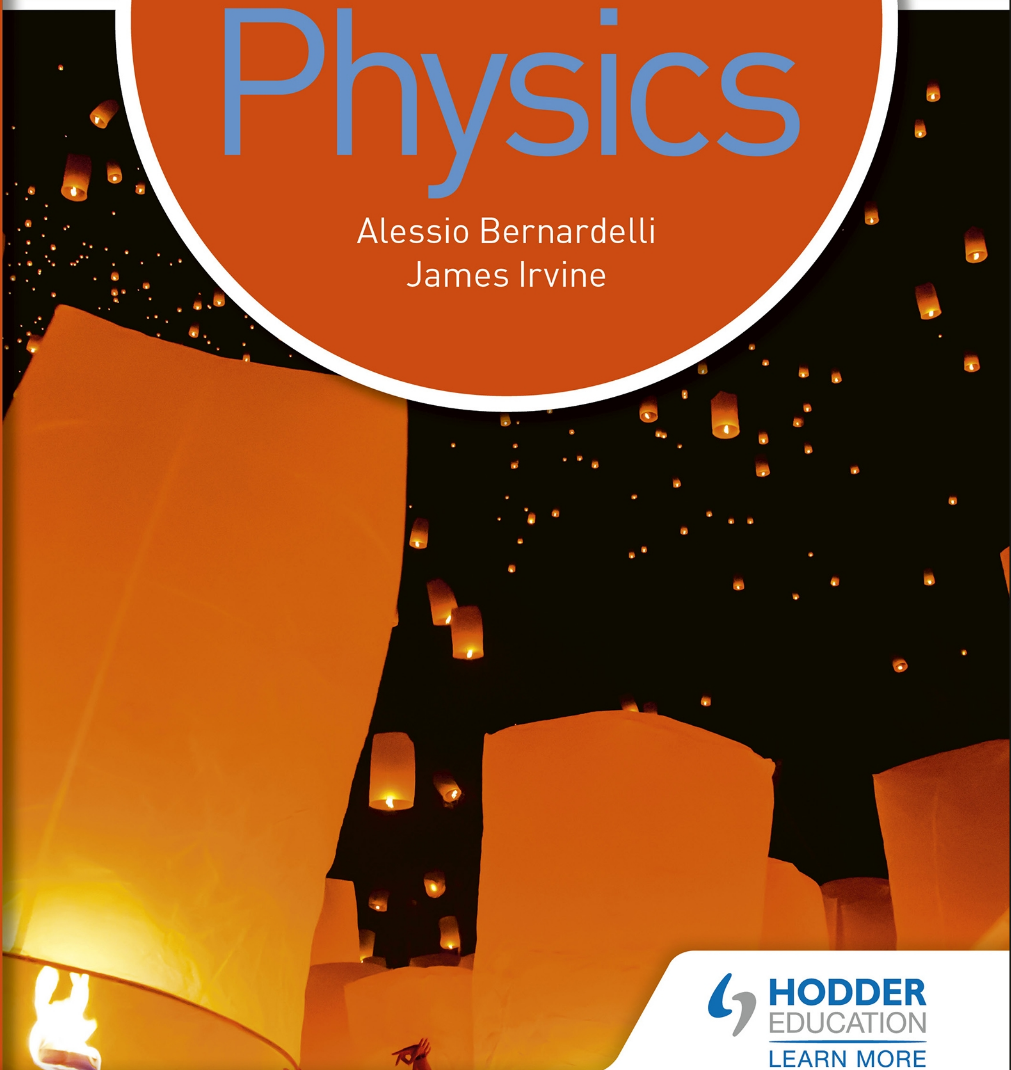
PRACTICE MAKES PERMANENT

450+ questions

AQA A-level Physics

Alessio Bernardelli
James Irvine



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Contents

Introduction

Practice Makes Permanent is a series that advocates the benefits of answering lots and lots of questions. The more you practise, the more likely you are to remember key concepts; practice does make permanent. The aim is to provide you with a strong base of knowledge that you can automatically recall and apply when approaching more difficult ideas and contexts.

This book is designed to be a versatile resource that can be used in class, as homework, or as a revision tool. The questions may be used in assessments, as extra practice, or as part of a SLOP (Shed Loads of Practice) teaching approach.

How to use this book

This book is suitable for the AQA A-level Physics course. It covers all the content that you will be expected to know for the final examination. For Paper B Section 3, the option covered is Astrophysics.

The content is arranged topic-by-topic in the order of the AQA specification, so areas can be practised as needed. Within each topic there are:

- **Quick questions** – short questions designed to introduce the topic
- **Exam-style questions** – questions that replicate the types, wording and structure of real exam questions, but highly targeted to each specification point
- **Topic reviews** – sections of exam-style questions that test content from across the entirety of the topic in a more synoptic way.

These topic questions are tagged with the following:

- Page references to the accompanying Hodder Education student books, for example **SB1 p3** refers you to page 3 of *AQA A-level Physics Student Book 1* (ISBN 978 1471 80773 2) and **SB2 p8** refers to page 8 of *AQA A-level Physics Student Book 2* (ISBN 978 1471 80776 3)
- AQA specification references such as **3.2.1.4**, which can be used if you want to select questions to practise a specific area of the specification
- **MS** indicates questions that test maths skills
- **AT** indicates questions that ask you to use practical knowledge of apparatus and techniques
- **PS** indicates questions that ask you to use knowledge of practical skills
- **RP** indicates questions that test understanding of the required practicals.

At the end of the book there is a full set of practice exam papers. These have been carefully assembled to resemble typical AQA question papers in terms of coverage, marks and skills tested. We have also constructed each one to represent the typical range of demand in the A-level Physics papers as closely as possible.

Full worked answers are included at the end of the book for quick reference, with awarded marks indicated where appropriate.

If you are using a different textbook

Some students will be using a different Hodder Education student book for their course: *AQA A-level Physics (Year 1 and Year 2)*, ISBN 978 1510 46983 9. If you have this book, there is a mapping grid available at https://tinyurl.com/qmbn6u8 to show how each question in *Practice Makes Permanent* links to the content of your student book.

1 Particles and radiation

Particles

Quick questions

SB1 p4 3.2.1.1 — 1 Describe what is meant by two isotopes of the same element.

SB1 p21 3.2.1.2 — 2 Name the **four** fundamental interactions.

SB1 p12 3.2.1.3 — 3 What happens when a particle and its antiparticle collide?

SB1 p22 3.2.1.4 — 4 What exchange particles mediate electromagnetic (EM) forces?

SB1 p27 3.2.1.5 — 5 Name the **two** classes of hadrons and describe their structure.

SB1 p31 3.2.1.4 — 6 Describe the change of quark character in a β^+ decay.

Exam-style questions

7 **Figure 1** represents the decay of particle X into particle Y and two other particles.

The diagram shows the quark structure of particles X and Y.

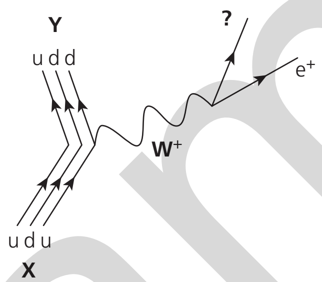

Figure 1

SB1 p31 3.2.1.4 — 7–1 Deduce the names of particles X and Y. *[2]*

SB1 p19 3.2.1.4 — 7–2 State what class of particles W^+ belongs to and what type of interaction this decay is. *[2]*

SB1 p19 3.2.1.4 — 7–3 Deduce the name of the particle represented by the question mark (?) in **Figure 1**. *[1]*

SB1 p30 3.2.1.5 — 7–4 Explain how charge and baryon number are conserved in this interaction. Make reference to all the particles involved. *[2]*

SB1 p30 3.2.1.5 — 7–5 Explain why the particle represented by the question mark (?) in **Figure 1** is formed in this interaction. *[2]*

SB1 p30 3.2.1.5 — 7–6 Describe what eventually happens to all unstable baryons. *[1]*

Total: 10

SB1 p13 3.2.1.3 — 8 In a pair production event, a photon is converted to an electron (e^-) and a positron (e^+).

Both particles generated have an energy of 3.512 MeV.

8–1 Calculate the wavelength of the photon in this process. *[3]*

8–2 State **two** quantities that are conserved in pair production processes. *[2]*

8–3 Explain why a photon of the same wavelength you calculated in **Question 8–1** could not produce a muon–antimuon pair. *[2]*

8–4 Calculate the minimum frequency needed for a photon to produce a muon and an antimuon through pair production. *[3]*

Total: 10

9 Carbon-14 is an unstable isotope of carbon.

SB1 p4 | 3.2.1.1

9–1 State what the term isotope means of carbon. *[2]*

SB1 p4 | 3.2.1.1

9–2 A carbon atom has 6 electrons orbiting its nucleus. Identify how many nucleons a carbon-14 atom has. *[1]*

SB1 p4 | 3.2.1.1

9–3 State how many neutrons a nucleus of carbon-14 contains. *[1]*

SB1 p31 | 3.2.1.4

9–4 Carbon-14 eventually decays into another element through beta decay. Copy and complete the nuclear equation below by filling in the gaps for the proton and nucleon numbers. *[3]*

$${}^{14}_{\_}C \rightarrow {}^{\_}_{\_}X + {}^{\_\_}_{-1}e + \bar{\nu}_e$$

SB1 p31 | 3.2.1.4

9–5 State the name of the particle $\bar{\nu}_e$ and explain why it is emitted in a beta decay. *[3]*

Total: 10

SB1 p24–5 | 3.2.1.4

10 **Figure 2** shows a β-decay event.

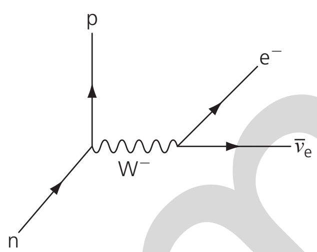

Figure 2

10–1 Add the exchange particle that mediates this interaction on **Figure 2**. *[1]*

10–2 Name the type of fundamental force that mediates β-decays. *[1]*

10–3 Name another nuclear decay that is **not** mediated by this type of interaction. *[1]*

10–4 Give a reason for the charge you chose in the exchange particle you added in **Figure 2**. *[1]*

10–5 Identify the range of action in metres of the fundamental force mediating the interaction in **Figure 2**. *[1]*

Total: 5

SB1 p30–2 | 3.2.1.7

11 Look at the following interactions and show whether they are possible or not.

11–1 $p + p \rightarrow p + p + K^- + K^+$ *[3]*

11–2 $K^- \rightarrow \pi^- + \pi^- + \pi^+$ *[3]*

11–3 $p \rightarrow n + \beta^- + \nu_e$ *[3]*

11–4 $n + e^+ \rightarrow e^- + \Sigma^+ + K^+$ (Σ^+ has quark structure *uus*) *[3]*

Total: 12

12 **Figure 3** represents the decay of a Λ^0 particle into particle X and particle Y.

The diagram shows the quark structure of particles X and Y.

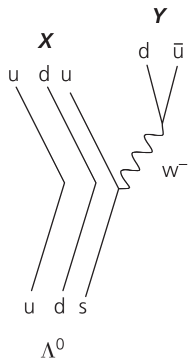

Figure 3

SB1 p31 | 3.2.1.4

12–1 Deduce the names of particles X and Y. *[2]*

SB1 p30–2 | 3.2.1.7

12–2 By considering the conservation of charge, baryon number and strangeness, explain why this interaction is possible. *[3]*

SB1 p22–4 | 3.2.1.4

12–3 The distribution of charge in the quarks that make up particle X is uneven. Explain how particle X is held together despite its uneven distribution of charge. *[3]*

Total: 8

13 **Figure 4** shows the traces left by α-particles in a cloud chamber.

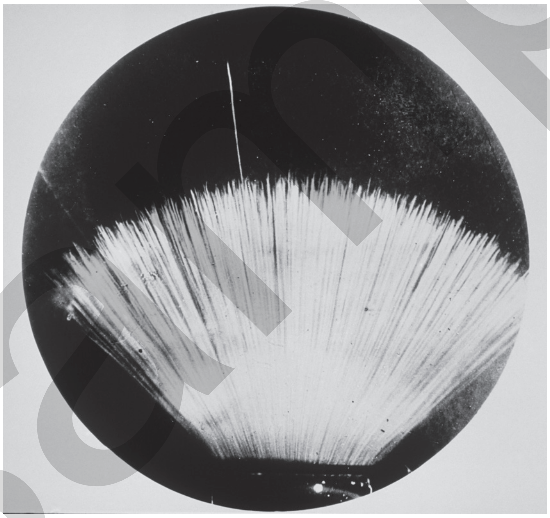

Figure 4

SB1 p8 | 3.2.1.2 | AT i

13–1 Suggest a method that would allow you to accurately measure the range of α-particles in the cloud chamber.

In your method include a description of how you would determine the uncertainty in your results. *[6]*

SB1 p6–7 | 3.2.1.2

13–2 Describe how the traces left by α-particles would change if the cloud chamber were immersed in a perpendicular magnetic field 'entering' the page. *[3]*

SB1 p9 | 3.2.1.1

13–3 Radon is often used as an alpha source for small cloud chambers like the one in **Figure 4**. Copy and complete the nuclear equation below by filling in the gaps. *[2]*

$${}^{\_\_}_{88}Ra \rightarrow {}^{222}_{\_\_}Rn + {}^{\_\_}_{\_\_}He$$

Total: 11

SB1 p12 3.2.1.3

14 In a PET scanner, the gamma photons used for imaging are produced when a positron meets an electron inside a patient's body.

14–1 Name the process by which these gamma rays are produced. *[1]*

14–2 Describe what happens to a positron and an electron when they meet inside the patient's body. *[2]*

14–3 Calculate the frequency and wavelength of the gamma photons produced by the process you described above, when the electron and positron are at rest. *[4]*

14–4 Explain why PET scans should be avoided unless they are necessary. *[2]*

Total: 9

SB1 p22 3.2.1.4

15 In a β-decay, a u quark of a neutron changes character to a d quark and this interaction generates a proton, a β-particle and an antineutrino.

15–1 Describe the nature of the β-particle. *[2]*

15–2 This interaction is mediated by the exchange particle W^-. Name the type of interaction responsible for this nuclear decay. *[1]*

15–3 Describe how the W^- particle is responsible for the force between the nucleus of the decaying atom, the β-particle and the antineutrino. In your answer consider the properties of all particles involved to explain their behaviour in this interaction. *[6]*

Total: 9

SB1 p27–32 3.2.1.5–7

16 The nuclear interaction below shows the production of a K^0 and Σ^+ (sigma) particle.

$\pi^0 + p \rightarrow K^0 + \Sigma^+$

16–1 The Σ^+ particle is made up of a strange quark and two other quarks. Use the conservation laws to show that this interaction is possible. *[3]*

16–2 Name the type of interaction in **Question 16–1**. Justify your answer. *[2]*

16–3 Deduce the quark structure of Σ^+ and show that its relative charge is +1. *[3]*

16–4 Explain why the interaction below would not be possible. *[2]*

$\pi^0 + p \rightarrow \pi^0 + \Sigma^+$

16–5 Σ^+ can decay into a proton and a pion in the interaction shown below.

$\Sigma^+ \rightarrow \pi^0 + p$

Explain why this can only be a weak interaction. *[2]*

Total: 12

Electromagnetic radiation and quantum phenomena

Quick questions

SB1 p61 3.2.2.1 **1** Define the work function of a metal.

SB1 p43 3.2.2.1 **2** What is a photon?

SB1 p45 3.2.2.2 **3** Give the definition of electron volt (eV).

SB1 p47 3.2.2.2 **4** What is the ionisation energy of an atom?

SB1 p49 3.2.2.3 **5** Describe how the emission spectrum for an element is formed.

SB1 p51 3.2.2.2 **6** Describe how thermionic emission of electrons occurs.

Exam-style questions

SB1 p60–1 3.2.2.1 MS 1.1, 2.3 **7** A TV manufacturer is testing a range of metals to use in their TV phototransistor as a receiver for the remote control infrared signals. **Figure 5** shows a graph of the maximum energy $E_{k(max)}$ of the photoelectrons emitted by the phototransistor for different frequencies of incident photons.

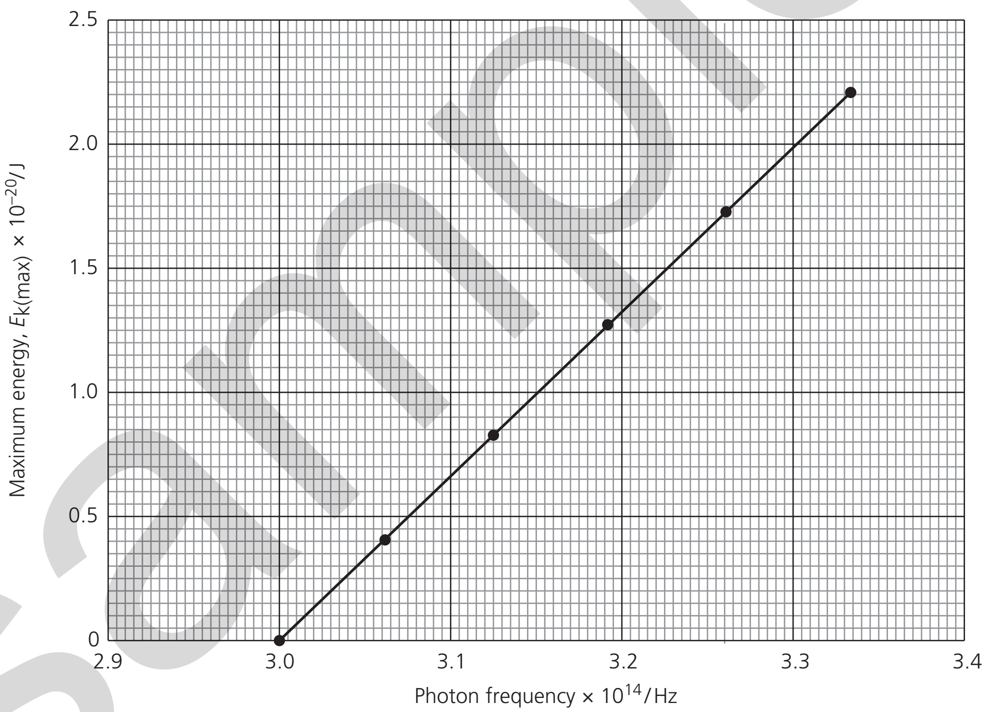

Figure 5

7–1 The infrared LED in the remote control emits photons with wavelength of 940 nm. Show whether the metal from the graph in **Figure 5** is suitable to use with this wavelength. *[3]*

7–2 Calculate the Planck constant using the graph. You must show your calculations. *[3]*

7–3 State the threshold frequency for this metal. *[1]*

7–4 Calculate the work function φ for this metal. *[2]*

7–5 Copy the graph in **Figure 5** and draw a line on it to show a metal with a greater work function. *[2]*

Total: 11

8 **Figure 6** shows a photoelectric cell connected to a variable power source and a high sensitivity ammeter. A voltmeter is connected in parallel to the photocell to measure the p.d. across it.

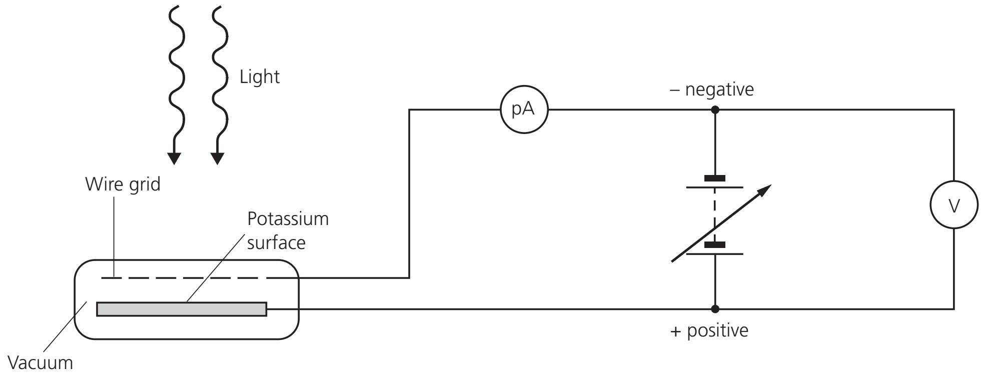

Figure 6

SB1 p57–61 | 3.2.2.1 | PS 3.2 | MS 2.3

8–1 When white light is shone on the potassium surface, a small current is registered by the picoammeter. Explain how this process happens. *[3]*

SB1 p57–61 | 3.2.2.1 | PS 3.2 | MS 2.3

8–2 Explain why the photoelectrons emitted by the potassium plate can have a range of kinetic energy up to a maximum kinetic energy $E_{k(max)}$. *[3]*

SB1 p57–61 | 3.2.2.1 | PS 3.2 | MS 2.3

8–3 The apparatus in **Figure 6** was calibrated using different frequencies of light to find the stopping potential V_s for each frequency. The graph in **Figure 7** shows the relationship between V_s and different frequencies of electromagnetic radiation.

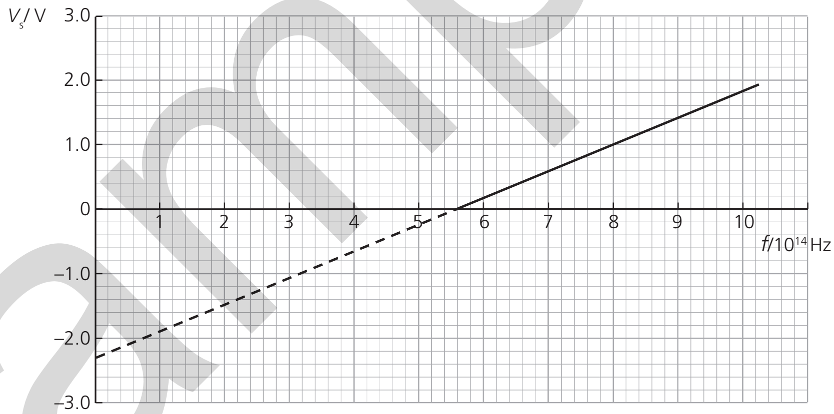

Figure 7

State what is meant by stopping potential. *[1]*

SB1 p57–61 | 3.2.2.1 | PS 3.2 | MS 2.3

8–4 Suggest a method to use the apparatus in **Figure 6** and the data in **Figure 7** to measure the frequencies of visible light emitted by a gas lamp. *[6]*

SB1 p49 | 3.2.2.3 | MS 0.1, 0.2

8–5 **Figure 8** shows the emission spectrum of hydrogen.

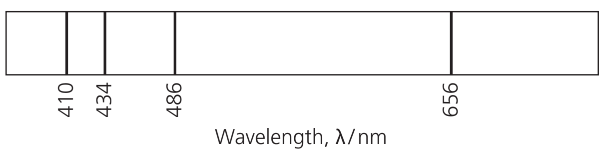

Figure 8

Identify the wavelength(s) of the hydrogen spectrum that could be detected with the apparatus in **Figure 6.** Use calculations to support your answer. *[4]*

SB1 p49 | 3.2.2.3 | MS 0.1, 0.2

8–6 Suggest how the apparatus in **Figure 6** could be adapted to be able to detect the wavelengths emitted by hydrogen that could not be detected before. *[2]*

Total: 19

SB1 p61 3.2.2.1 PS 3.2 MS 2.3

9 A calcium surface is hit by light emitted by a violet LED of wavelength 410 nm. The threshold frequency of calcium is 6.5×10^{14} Hz.

9–1 Calculate the maximum kinetic energy of the photoelectrons emitted by the calcium plate in eV. *[6]*

9–2 Calculate the maximum velocity of the photoelectrons emitted by the calcium plate. *[3]*

Total: 9

10 **Figure 9** represents the kinetic energy levels in a hydrogen atom.

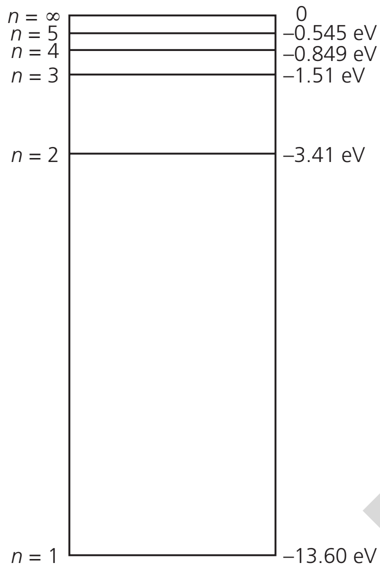

Figure 9

SB1 p48–50 3.2.2.3 MS 0.1, 0.2

10–1 Calculate the wavelength of the photon the atom would need to absorb to excite an electron from the ground state to the 3rd energy level. *[4]*

SB1 p48–50 3.2.2.3 MS 0.1, 0.2

10–2 The electron that was excited to the 3rd energy level eventually drops to the 2nd energy level and then back to the 1st energy level. Calculate the frequencies of the two photons emitted in this process and state in what region of the electromagnetic spectrum they can be found. *[5]*

SB1 p47 3.2.2.2

10–3 State the definition of ionisation energy. *[2]*

SB1 p47 3.2.2.2

10–4 Give the ionisation energy of the hydrogen atom in joules. *[2]*

Total: 13

11 **Figure 10** shows the emission spectrum of a sodium lamp.

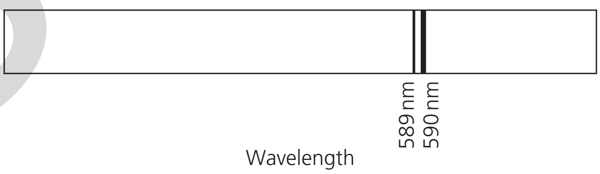

Figure 10

SB1 p49 3.2.2.3

11–1 Explain how the lines in the emission spectrum of sodium support the energy level model of atomic electrons. *[6]*

SB1 p47–50 3.2.2.3 MS 0.1, 0.2

11–2 The ionisation energy of sodium is 5.14 eV and the 3rd energy level of a sodium atom has an energy of -3.10×10^{-19} J. Calculate the wavelength of a photon emitted by an electron in transiting from energy level 3 to energy level 1. *[4]*

SB1 p47–50 3.2.2.3 MS 0.1, 0.2

11–3 State the region of the electromagnetic spectrum in which the photon emitted in **Question 11–2** is found. *[1]*

SB1 p47–50 | 3.2.2.3 | MS 0.1, 0.2

11–4 The two emission wavelengths shown in **Figure 10** are so close to each other that they need to be represented as a single line in an energy levels diagram.

Draw a diagram of energy levels 1, 2 and 3 for an atom of sodium. Use the information in **Figure 10** and in **Question 11–2.**

Indicate the energy of each level in eV on your diagram. *[5]*

Total: 16

SB1 p51 | 3.2.2.2

12 A fluorescent tube is a glass tube coated with phosphor and filled with mercury gas. A cathode and an anode are at either end of the tube and a p.d. of 500 V is applied between them.

12–1 Describe how the atoms in the mercury vapour become excited. *[3]*

12–2 Describe what happens after an atom of mercury becomes excited. *[2]*

12–3 Explain what happens to an atom of mercury after ionisation. *[3]*

12–4 Explain why the phosphor coating is essential for the fluorescent tube to emit visible light. *[3]*

Total: 11

SB1 p64–5 | 3.2.2.4 | MS 1.1, 2.3

13 Electron crystallography can complement X-ray crystallography when studying the structure of very small crystals. In this method, beams of electrons are shot through the crystal we want to study and electrons will be diffracted on screen. The diffraction pattern formed by the scattered electrons helps scientists to understand the structure of the crystal.

13–1 The distance between the atoms of a sample crystal is 0.025 μm. Calculate the velocity the electron beam will need in order to study this sample crystal. *[3]*

13–2 Explain why the velocity you calculated is a good choice for achieving electron diffraction through the sample crystal. *[2]*

13–3 Calculate the kinetic energy of the electrons shot at the sample crystal in eV. *[2]*

13–4 Explain how the wavelength of the electrons would change, if their kinetic energy is halved. Ignore relativistic effects on the mass of the electron. *[3]*

Total: 10

SB1 p64–5 | 3.2.2.4 | MS 1.1, 2.3

14 A radioactive source emits α-particles with energy of about 5 MeV. In Rutherford's experiment, α-particles were directed at a foil of gold. When the α-particles hit the gold foil, some were scattered, but did not undergo diffraction.

14–1 Calculate the velocity of an α-particle emitted by this radioactive source. *[4]*

14–2 Calculate the de Broglie wavelength of one of these α-particles. *[2]*

14–3 The distance between nuclei in the gold foil is roughly 2×10^{-10} m. Explain why the α-particles from this radioactive source do not undergo diffraction. *[2]*

14–4 Show that the units of the de Broglie wavelength are metres. Use the de Broglie equation. *[2]*

Total: 10

Topic review: particles and radiation

1 A 'slow' positron and a 'slow' electron collide with each other, generating a photon pair.

SB1 p12 | 3.2.1.3

1–1 Name this phenomenon **and** the region of the electromagnetic spectrum the photon pair belongs to. *[2]*

SB1 p12 | 3.2.1.3

1–2 Explain why a pair of photons is produced. *[1]*

SB1 p47 3.2.2.2

1–3 One of the photons produced is absorbed by an electron in the ground state of a helium atom. The ionisation energy of helium is 24.6 eV. The total energy of the electron–positron pair before the collision is approximately 1.6×10^{-13} J. Show whether the helium atom will be ionised by absorbing the photon. *[3]*

SB1 p49–50 3.2.2.3

1–4 The same helium atom absorbs a photon that causes an electron in its ground state to transition to the 3rd energy level. **Figure 11** shows a diagram of this event.

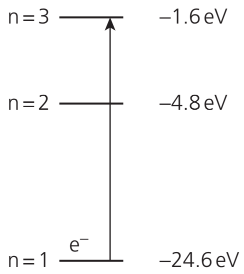

Figure 11

Calculate the wavelength of the photon absorbed by the electron. *[4]*

SB1 p49–50 3.2.2.3

1–5 After a short time, the electron in **Figure 11** 'drops' from the 3rd to the 2nd energy level. Calculate the wavelength of the photon emitted during this transition and use **Table 1** to suggest which colour it is. *[4]*

Colour	**Wavelength interval**
red	~ 625–740 nm
orange	~ 590–625 nm
yellow	~ 565–590 nm
green	~ 500–565 nm
cyan	~ 485–500 nm
blue	~ 440–485 nm
violet	~ 380–440 nm

Table 1

SB1 p30–1 3.2.1.2

1–6 The nucleus of a helium atom is composed of two protons and two neutrons. Describe the sub-atomic composition of a neutron and a proton. *[4]*

SB1 p30–1 3.2.1.2

1–7 Explain how the helium nucleus is held together despite the electrostatic repulsion between the protons. *[3]*

Total: 21

2 An electric current passes through a mercury gas to excite electrons in mercury atoms to their fifth energy state.

SB1 p49 3.2.2.3

2–1 When an electron in the fifth energy state de-excites to the ground state, it emits a photon of wavelength 184.9 nm. Calculate the energy of the emitted photon. *[1]*

SB1 p43 3.2.1.3

2–2 State in what region of the electromagnetic spectrum the photons emitted by the mercury gas are. *[1]*

SB1 p47 3.2.2.2

2–3 The photons emitted by the mercury gas hit a zinc plate, which emits photoelectrons as a result. Describe the difference between photoelectrons emitted from the surface of the zinc plate and photoelectrons emitted from deeper in the zinc plate. *[3]*

2–4 The work function of zinc is 4.33 eV. Calculate the maximum energy of the electrons emitted by the zinc plate in joules. *[3]*

2–5 Explain what would happen if green light was incident to the zinc plate, instead of the light emitted by the mercury gas. *[2]*

Total: 10

Practice exam papers

Paper 1

Section A

1 An isotope of carbon undergoes β⁺ decay.

1–1 State what an isotope of an element is. *[1 mark]*

1–2 Copy and complete the nuclear equation below that describes the β⁺ decay of carbon-10.

$^{10}_{6}\text{C} \rightarrow {}^{\_\_}_{\_\_}\text{B} + {}^{\_\_}_{\;1}e^{+} + \_\_\_\_\_\_$ *[2 marks]*

1–3 Draw a diagram of this nuclear decay showing the correct change of quarks in the nucleon involved in the interaction. *[3 marks]*

1–4 State which type of nuclear interaction the β⁺ decay of carbon-10 is. *[1 mark]*

Total: 7

2 A thin block of potassium is connected to the metal plate of an electroscope charged positively. When green light hits the potassium plate, the electroscope discharges quickly.

2–1 Explain why this phenomenon shows particle-like behaviour of light. *[2 marks]*

2–2 The wavelength of the light hitting the potassium block is 520 nm and the electrons escaping the metal show kinetic energy ranging from 0 to 0.078 eV.

Calculate the work function of potassium.

Work function = __ J *[4 marks]*

2–3 Explain why not all photoelectrons escape the potassium block with an energy of 0.078 eV. *[2 marks]*

2–4 The potassium block is now connected to the circuit in **Figure 1**. Suggest what could be done to increase the current through the resistor. *[1 mark]*

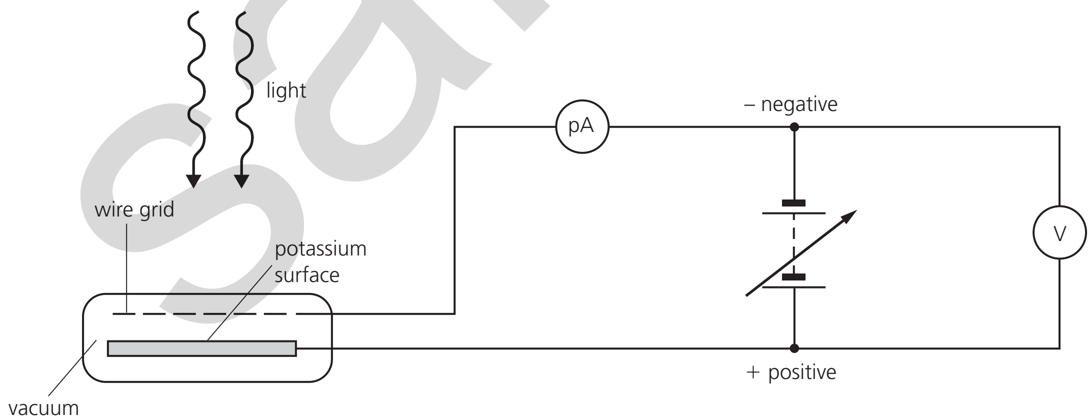

Figure 1

2–5 The metal of the block in the circuit from **Question 2–4** is changed to a zinc plate. Suggest why a current is not detected by the ammeter. *[2 marks]*

Total: 11

3 A red and violet beam of light are incident on a block of borosilicate glass. Both beams of light hit the surface of the glass at the same point and at an angle of 55° to the normal, as shown in **Figure 2**.

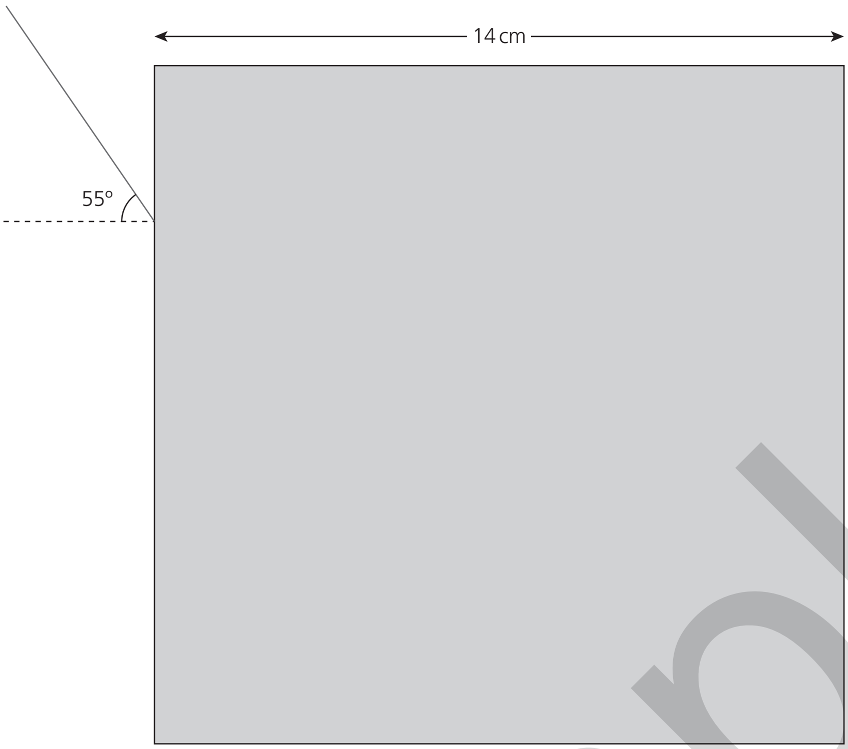

Figure 2

3–1 The borosilicate glass manufacturer gives the information in **Table 1**.

Colour of light	Wavelength / nm	Refractive index
Red	640	1.50917
Yellow	589	1.51124
Green	509	1.51534
Blue	486	1.51690
Violet	434	1.52136

Table 1

Deduce the angles of refraction for the red and violet beams of light to 4 s.f. using the information in **Table 1** and in **Figure 2**. *[3 marks]*

3–2 Calculate separation between the red and violet beam when they come out of the borosilicate block. *[2 marks]*

3–3 On a copy of **Figure 2**, draw a **single** line to show the path of the light beams inside the borosilicate glass. *[1 mark]*

3–4 Explain the potential effects of using pulses of light of different wavelengths in optical fibres. *[2 marks]*

3–5 Describe an experiment that could be used to find a suitable material to use for cladding to make an optical fibre that has borosilicate glass at its core. *[4 marks]*

Total: 12