AQA

Icon

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Turning Points in Physics

Prep Work and Homework Pack

*Discovery of Electrons*

Name: …………………………………………………………

Teacher: ……………………………………………………..

|  |  |
| --- | --- |
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**How to use this Pack**

These packs are to be used alongside the topic ‘Turning Points in Physics’. The content within this topic is tested in Paper 3 of your A-Level Examinations.

The content in this topic is meant to be harder that what you have covered so far and will require you to make links between a variety of topics from Year 12 and 13.

These packs are designed to support your understanding throughout the topic. **Before class you should complete the tasks indicated in Sections A, B and C of that lesson.** These should take around an hour. Following the lesson you should consolidate your understanding using the resources provided in lesson and those linked in Section D.

The Assignments at the back of the pack are there to test the knowledge you have acquired in lessons.

The Textbook referenced in this pack can be found [here](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf).

**1.1 Cathode Rays**

**Section A: Pre-Requisite Knowledge**

*Please make sure you are confident with the following material before the lesson. Use the linked resources to review if you are unsure.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Topic** | **Kerboodle Textbook** | **CGP Textbook** | **Media** |
| History of the Atomic Model | 438-440 |  | [History of the Model of the Atom](https://www.youtube.com/watch?v=sG6QoLxwIw4) |
| Excitation and Ionisation | 34-36 |  | [Energy Levels](https://www.youtube.com/watch?v=31CW4axauxc&t=31s) |
| Fluorescence | 37-38 |  | [Fluorescent Lamps Explained](https://www.youtube.com/watch?v=aqXT2o9qcyE&t=263s) |

*Once you are happy with the above please move on to Section B.*

**Section B: Pre-Lesson Questions**

*Attempt, mark and correct the questions below to check your pre-requisite knowledge. This should be done before the lesson.*

**Q1.**

The diagram shows some energy levels of an atom.

Chart, box and whisker chart

Description automatically generated

The transition E3 to E1 corresponds to the emission of visible light.

A transition corresponding to the emission of infrared radiation could be

**A**       E1 to E0

**B**       E4 to E1

**C**       E1 to E2

**D**       E3 to E2

**(Total 1 mark)**

**Q2.**

In the Rutherford scattering experiment most α particles passed through the foil undeflected.

What is a correct deduction from this result?

|  |  |  |
| --- | --- | --- |
| **A** | Most of the mass of an atom is within the nucleus. |  |
| **B** | The diameter of the nucleus is much less than the diameter of the atom. |  |
| **C** | The nucleus has a positive charge. |  |
| **D** | The charge of the atom is neutral. |  |

**(Total 1 mark)**

**Q3.**

The diagram shows the path of an α particle deflected by the nucleus of an atom. Point P on the path is the point of closest approach of the α particle to the nucleus.

A picture containing fishing

Description automatically generated

Which of the following statements about the α particle on this path is correct?

|  |  |  |
| --- | --- | --- |
| **A** | Its acceleration is zero at P. |  |
| **B** | Its kinetic energy is greatest at P. |  |
| **C** | Its potential energy is least at P. |  |
| **D** | Its speed is least at P. |  |

**(Total 1 mark)**

**Q4.**

What is the best estimate for the order of magnitude for the diameter of an atom?

|  |  |  |
| --- | --- | --- |
| **A** | 10−14 m |  |
| **B** | 10−12 m |  |
| **C** | 10−11 m |  |
| **D** | 10−8 m |  |

**(Total 1 mark)**

**Q5.**

Which of the following classes of electromagnetic waves will **not** ionise neutral atoms?

What is the reason for this?

|  |  |  |
| --- | --- | --- |
| **A** | ultraviolet |  |
| **B** | X radiation |  |
| **C** | gamma radiation |  |
| **D** | microwave |  |

**(Total 1 mark)**

**Q6.**

An electron collides with a neutral atom and ionizes it. Which of the following describes the particles present after the collision?

|  |  |  |
| --- | --- | --- |
| **A** | An electron and an excited atom. |  |
| **B** | An excited atom containing an excess electron. |  |
| **C** | Two electrons and a positive ion. |  |
| **D** | Two electrons and a neutral atom in the ground state. |  |

**(Total 1 mark)**

**Q7.**

(a)     A fluorescent tube is filled with mercury vapour at low pressure. In order to emit light the mercury atoms must first be *excited*.

(i)      What is meant by an excited mercury atom?

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(ii)     Describe the process by which mercury atoms become excited in a fluorescent tube.

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**(3)**

(b)     What is the purpose of the coating on the inside surface of the glass in a fluorescent tube?

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**(2)**

(c)     The lowest energy levels of a mercury atom are shown below. The diagram is **not** to scale.

Diagram, schematic

Description automatically generated

(i)      Calculate the frequency of an emitted photon due to a transition, shown by an arrow, from level *n* = 4 to level *n* = 3.

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(ii)     Draw a line on the diagram to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level *n* = 4 to level *n* = 3.

**(3)**

**(Total 8 marks)**

**Q8.**

(a)     When free electrons collide with atoms in their *ground state*, the atoms can be excited or ionised.

(i)      State what is meant by ground state.

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**(1)**

(ii)     Explain the difference between excitation and ionisation.

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**(3)**

(b)     An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies cause excitation in a particular atom.

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**(4)**

(c)     The ionisation energy of hydrogen is 13.6 eV. Calculate the minimum frequency necessary for a photon to cause the ionisation of a hydrogen atom. Give your answer to an appropriate number of significant figures.

answer \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Hz

**(4)**

**(Total 12 marks)**

**Section C: Pre-Lesson Context**

*Research the prompts below in advance of the lesson (making notes on these in optional) to give you some context for the upcoming lesson.*

* What did Philipp von Lenard win his Nobel Prize for in 1905?
* What J.J. Thomson win his Nobel Prize for in 1906?
* What is an Induction Coil?
* What is the Mercury Vacuum Pump?

**Section D: Post Lesson Follow up tasks**

*Use the resources linked below to review, practice and go beyond the lesson.*

|  |  |  |  |
| --- | --- | --- | --- |
| Lesson | Lesson Title | [Specification](https://filestore.aqa.org.uk/resources/physics/specifications/AQA-7407-7408-SP-2015.PDF) | Resources  *Where resources are web-based they will be hyperlinked* |
| 1.1 | Cathode Rays | 3.12.1.1 Cathode Rays | ***Textbook page(s): 2-3***  Review:   * YouTube: [Cathode Ray Tube](https://www.youtube.com/watch?v=4QAzu6fe8rE)   Practice:   * Seneca Learning Section(s): 12.1.1 * Attempt Questions 1 and 2 on page 3 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Practice Question(s) 1 and 2 on pages 15-16 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf)   Go Beyond:   * Isaac Physics Question: [Cosmic Rays](https://isaacphysics.org/questions/maths_ch7_1_q4) * Podcast: [ASTROLOGY??? Heaven Help Us!](https://whattheif.com/episodes/2018/3/29/astrology-heaven-help-us?rq=rays) |

**1.2 Thermionic Emission**

**Section A: Pre-Requisite Knowledge**

*Please make sure you are confident with the following material before the lesson. Use the linked resources to review if you are unsure.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Topic** | **Kerboodle Textbook** | **CGP Textbook** | **Media** |
| The Work Function | 30-31 |  | [The Photoelectric Effect](https://www.youtube.com/watch?v=I_7ZfMlIKhk&t=241s) |
| Conduction and Metals | 202-203 |  | [Why do Metals Conduct Electricity?](https://www.youtube.com/watch?v=7RpyURBNZyU) |
| Current and Temperature | 205 |  | [Resistance and Temperature](https://www.youtube.com/watch?v=lgJ51xt191Q) |

*Once you are happy with the above please move on to Section B.*

**Section B: Pre-Lesson Questions**

*Attempt, mark and correct the questions below to check your pre-requisite knowledge. This should be done before the lesson.*

**Q1.**

A battery of negligible internal resistance and an emf of 12 V is connected in series with a heating element. The heating element has a resistance of 6.5 Ω when in operation.

What is the energy transferred by the heating element when operating for 5 minutes?

|  |  |  |
| --- | --- | --- |
| **A** | 111 J |  |
| **B** | 390 J |  |
| **C** | 6650 J |  |
| **D** | 23 400 J |  |

**(Total 1 mark)**

**Q2.**

Which graph shows how power dissipated *P* varies with current *I* in a component that obeys Ohm’s law?

Shape, polygon

Description automatically generated

|  |  |
| --- | --- |
| **A** |  |
| **B** |  |
| **C** |  |
| **D** |  |

**(Total 1 mark)**

**Q3.**

Which statement about superconductors is correct?

|  |  |  |
| --- | --- | --- |
| **A** | When a material becomes a superconductor, its resistivity is almost zero. |  |
| **B** | The temperature at which a material becomes a superconductor is called the critical temperature. |  |
| **C** | When current passes through a superconductor the pd across it becomes a maximum. |  |
| **D** | Copper is a superconductor at room temperature. |  |

**(Total 1 mark)**

**Q4.**

A circuit consists of a cell, a thermistor, a fixed resistor and two ammeters.

Diagram

Description automatically generated

The cell has a constant electromotive force and negligible internal resistance. Readings from the two ammeters are taken.

Which row describes what happens to the current in each ammeter when the temperature of the thermistor decreases?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Current in ammeter A1** | **Current in ammeter A2** |  |
| **A** | Decreases | Unchanged |  |
| **B** | Decreases | Increases |  |
| **C** | Increases | Decreases |  |
| **D** | Increases | Unchanged |  |

**(Total 1 mark)**

**Q5.**

Line **X** on the graphs below shows how the maximum kinetic energy of emitted photoelectrons varies with the frequency of incident radiation for a particular metal.

Which graph shows the results for a metal **Y** that has a higher work function than **X**?

Diagram

Description automatically generated

|  |  |
| --- | --- |
| **A** |  |
| **B** |  |
| **C** |  |
| **D** |  |

**(Total 1 mark)**

**Q6.**

(a)     Explain what is meant by the term *work* *function* of a metal.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(2)**

(b)     In an experiment on the photoelectric effect, the maximum kinetic energy of the emitted photoelectrons is measured over a range of incident light frequencies. The results obtained are shown in the figure below.

A picture containing diagram

Description automatically generated

(i)      A metal of work function *Φ*  is illuminated with light of frequency *f*. Write down the equation giving the maximum kinetic energy, *E*K, of the photoelectrons emitted in terms of *Φ* and *f*.

*E*K =

(ii)     Use the data in the figureto determine the work function of the metal.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(iii)     Determine the maximum kinetic energy of the photoelectrons when the frequency of the incident radiation is 2.5 × 1015 Hz.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(6)**

(c)     The experiment is repeated but with the light incident on a metal of lower work function. Draw a new line on the figurethat results from this change.

**(2)**

**(Total 10 marks)**

**Q7.**

When a filament lamp is switched on it takes 0.50 seconds for the filament to reach its normal operating temperature. The way in which the current changes during the first second after switching on is shown on the graph below.

Chart

Description automatically generated

(a)     Use the graph to determine the maximum current through the lamp.

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ A

**(1)**

(b)     Assuming that the lamp is connected to a 12V dc supply of a negligible internal resistance,

(i)      Calculate the resistance of the lamp when it has reached its normal operating temperature,

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ω

**(1)**

(ii)     Calculate the power of the lamp when it has reached its normal operating temperature.

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ W

**(1)**

(c)     Explain why the current through the lamp decreases between 0.05 s and 0.50 s.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(2)**

(d)     State and explain the change, if any, to the final current through the lamp if it is connected to the same supply with another similar lamp

(i)      in series,

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(2)**

(ii)     in parallel.

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**(2)**

(e)     State and explain why a filament lamp is most likely to fail as it is switched on.

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**(2)**

**(Total 11 marks)**

**Q8.**

In the apparatus shown, monochromatic ultraviolet radiation is incident on the surface of metal **X**. Photoelectrons are emitted from **X** and are collected at electrode **Y**.

Shape

Description automatically generated

(a)     Calculate the work function of **X**, given that each photon in the incident radiation has 3.2 × 10–19 J of energy.  
The maximum kinetic energy possessed by a single photoelectron is 2.1 × 10–19 J.

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**(3)**

(b)     The source of the incident radiation is replaced with a new source. The wavelength of the radiation from the new source is half the wavelength of the original radiation.

Calculate the maximum kinetic energy of the emitted photoelectrons.

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**(3)**

**(Total 6 marks)**

**Section C: Pre-Lesson Context**

*Research the prompts below in advance of the lesson (making notes on these in optional) to give you some context for the upcoming lesson.*

* What did Frederick Guthrie observe with regards to charged, hot conductors in 1873?
* What is a Thermionic Valve?
* How did a Thermionic Valve enable the creation of the first electronic computer?

**Section D: Post Lesson Follow up tasks**

*Use the resources linked below to review, practice and go beyond the lesson.*

|  |  |  |  |
| --- | --- | --- | --- |
| Lesson | Lesson Title | [Specification](https://filestore.aqa.org.uk/resources/physics/specifications/AQA-7407-7408-SP-2015.PDF) | Resources  *Where resources are web-based they will be hyperlinked* |
| 1.2 | Thermionic Emission | 3.12.1.2 Thermionic Emission of Electrons | ***Textbook page(s): 4-6***  Review:   * YouTube: [Thermionic Emission Explained](https://www.youtube.com/watch?v=qHPVGEY01qc) * YouTube: [How does an Electron Gun Work?](https://www.youtube.com/watch?v=tYCET6vYdYk)   Practice:   * Seneca Learning Section(s): 12.1.2 * Attempt Questions 3, 4 and 5 on page 5 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf)   Go Beyond:   * Isaac Physics: [Aiming an Oscilloscope Beam](https://isaacphysics.org/questions/an_oscilloscope_sym) * Isaac Physics: [Cool Coulomb Meters](https://isaacphysics.org/questions/coulometer) |

**1.3 The Specific Charge of the Electron**

**Section A: Pre-Requisite Knowledge**

*Please make sure you are confident with the following material before the lesson. Use the linked resources to review if you are unsure.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Topic** | **Kerboodle Textbook** | **CGP Textbook** | **Media** |
| Charged Particles in Electric and Magnetic Fields. | 400-405 |  | [Charged Particles in Magnetic Fields](https://www.youtube.com/watch?v=ZxZcnYFKUpc&t=49s)  [Charged Particles in Electric Fields](https://www.youtube.com/watch?v=1mi5_kh9cF4) |
| Specific Charge | 5 |  | [Specific Charge](https://www.youtube.com/watch?v=2ZPrUaW1kKg&t=17s) |
| Projectile Motion | 132-135 |  | [Projectile Motion and SUVAT](https://www.youtube.com/watch?v=p30tWWEElxU) |
| Cloud Chambers | 34 |  | [Bubble Chambers and Particle Detectors](https://www.youtube.com/watch?v=PQe7PHerKIw) |

*Once you are happy with the above please move on to Section B.*

**Section B: Pre-Lesson Questions**

*Attempt, mark and correct the questions below to check your pre-requisite knowledge. This should be done before the lesson.*

**Q1.**

Fluoride ions are produced by the addition of a single electron to an atom of fluorine  .

What is the magnitude of specific charge of the fluoride ion?

|  |  |  |
| --- | --- | --- |
| **A** | 3.2 × 10–26 C kg–1 |  |
| **B** | 8.4 × 10–21 C kg–1 |  |
| **C** | 5.0 × 106 C kg–1 |  |
| **D** | 4.5 × 107 C kg–1 |  |

**(Total 1 mark)**

**Q2.**

A beam of positive ions enters a region of uniform magnetic field, causing the beam to change direction as shown in the diagram.

A picture containing text, antenna

Description automatically generated

What is the direction of the magnetic field?

**A**        out of the page and perpendicular to it

**B**        into the page and perpendicular to it

**C**        in the direction indicated by +*y*

**D**        in the direction indicated by -*y*

**(Total 1 mark)**

**Q3.**

Two identical balls, **X** and **Y**, are at the same height and a horizontal distance of 25 cm apart.

**X** is projected horizontally with a velocity of 0.10 m s–1 towards **Y** at the same time that **Y** is released from rest. Both **X** and **Y** move freely in the absence of air resistance.

What is the distance between the balls 1.0 s later?

|  |  |  |
| --- | --- | --- |
| **A** | 0.15 m |  |
| **B** | 0.25 m |  |
| **C** | 2.4 m |  |
| **D** | 4.9 m |  |

**(Total 1 mark)**

**Q4.**

A particle of mass *m* and charge *q* is accelerated through a potential difference *V* over a distance *d*.

What is the average acceleration of the particle?

|  |  |  |
| --- | --- | --- |
| **A** |  |  |
| **B** |  |  |
| **C** |  |  |
| **D** |  |  |

**(Total 1 mark)**

**Q5.**

Which of the following nuclei has the smallest specific charge?

|  |  |  |
| --- | --- | --- |
| **A** |  |  |
| **B** |  |  |
| **C** |  |  |
| **D** |  |  |

**(Total 1 mark)**

**Q6.**

A projectile is launched some distance above the ground at an angle of 25° above the horizontal with a vertical component of velocity of 5.0 m s−1. **Figure 1** shows the flight path of the projectile. The flight takes 1.3 s.

Ignore the effects of air resistance throughout this question.

**Figure 1**

**Diagram, venn diagram

Description automatically generated**

(a)     (i)      Show that the initial speed of the projectile is about 12 m s−1.

**(2)**

(ii)    Calculate the horizontal component of velocity as the projectile hits the ground.

horizontal component of velocity = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m s−1

**(2)**

(b)     (i)      Calculate the maximum height above the starting point reached by the projectile.

Give your answer to an appropriate number of significant figures.

maximum height reached = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m

**(2)**

(ii)     Calculate the total horizontal distance travelled by the projectile from its starting point.

horizontal distance = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m

**(1)**

(c)     (i)      Mark with an **A** on the flight path in **Figure 1** the position where the speed of the projectile is greatest.

**(1)**

(ii)     Mark with a **B** on the flight path in **Figure 1** the position where the speed of the projectile is least.

**(1)**

(iii)    The projectile reaches its maximum height at time *t*H and finishes its flight at time *t*F. Draw on **Figure 2** a graph to show how the **magnitude** of the vertical component of velocity of the projectile varies with time. Numerical values are **not** required.

**Figure 2**

**A screenshot of a computer

Description automatically generated with medium confidence**

**(2)**

**(Total 11 marks)**

**Q7.**

A narrow beam of electrons is directed into a uniform electric field created by two oppositely-charged parallel metal plates at right angles to the field lines. A fluorescent screen is used to make the beam give a visible trace.

Diagram, engineering drawing

Description automatically generated

(a)     (i)      Explain why the beam curves towards the positive plate.

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(ii)     How does the trace show that, on entry to the electric field, all the electrons have the same speed?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(3)**

(b)     The beam is produced as a result of accelerating electrons between the filament and a metal anode.

(i)      Explain why the wire filament must be hot.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(ii)     Write down an equation relating the speed of the electrons, *υ*, to the potential difference, *VA*, between the anode and the filament.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(2)**

(c)     The deflection of the beam due to the electric field can be cancelled by applying a suitable uniform magnetic field *in* the same region as the electric field.

(i)      What direction should the magnetic field be in to do this?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(ii)     Write down an equation relating the speed of the electrons *υ* to the plate voltage *Vp*, the plate separation *d*, and the magnetic flux density *B* necessary to make the beam pass undeflected between the plates.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(iii)    The following measurements were made when the beam was undeflected.

*VA* = 3700 V      *Vp* = 4500 V      *d* = 50 mm      *B* = 2.5 mT

Use the two equations you have written down and the given data to calculate the specific charge, *e*/*m*, of the electron.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(5)**

**(Total 10 marks)**

**Section C: Pre-Lesson Context**

*Research the prompts below in advance of the lesson (making notes on these in optional) to give you some context for the upcoming lesson.*

* How did scientists use electrolysis to determine the specific charge on a hydrogen ion?
* What is a fine beam tube?
* Where is ‘[The Diamond Light Source’](https://www.diamond.ac.uk/Home.html;jsessionid=318AA3BE4E088D187291BD19D6C8E219) and what do they do there?

**Section D: Post Lesson Follow up tasks**

*Use the resources linked below to review, practice and go beyond the lesson.*

|  |  |  |  |
| --- | --- | --- | --- |
| Lesson | Lesson Title | [Specification](https://filestore.aqa.org.uk/resources/physics/specifications/AQA-7407-7408-SP-2015.PDF) | Resources  *Where resources are web-based they will be hyperlinked* |
| 1.3 | The Specific Charge of the Electron | 3.12.1.3 Specific charge of the electron | ***Textbook page(s): 6-11***  Review:   * YouTube: [Specific Charge of Electron](https://www.youtube.com/watch?v=JdPHmh6ZAj4)   Practice:   * Seneca Learning Section(s): 12.1.3 * Attempt Questions 6-11 on pages 7-9 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Complete Assignment 1 (page 33) * Practice Question(s) 3 and 4 on pages 15-16 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf)   Go Beyond:   * Attempt Questions 12 on page 9 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Practice Question 6 on page 16 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Isaac Physics: [A Charge in a Magnetic Field](https://isaacphysics.org/questions/charge_b_field_num) |

**1.4 Millikan’s Experiments**

**Section A: Pre-Requisite Knowledge**

*Please make sure you are confident with the following material before the lesson. Use the linked resources to review if you are unsure.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Topic** | **Kerboodle Textbook** | **CGP Textbook** | **Media** |
| Static Electricity | 358-361 |  | [Static Charge](https://www.youtube.com/watch?v=Vrh5FeGUTJA) |
| Terminal Velocity | 144-145 |  | [Terminal Velocity](https://www.youtube.com/watch?v=MNfANj2vkUU) |
| Forces and Acceleration | 138-143 |  | [F=ma](https://www.youtube.com/watch?v=HbNiwDFkgZM) |

*Once you are happy with the above please move on to Section B.*

**Section B: Pre-Lesson Questions**

*Attempt, mark and correct the questions below to check your pre-requisite knowledge. This should be done before the lesson.*

**Q1.**

Two parallel metal plates separated by a distance *d* have a potential difference V across them. What is the magnitude of the electrostatic force acting on a charge Q placed midway between the plates?

Diagram

Description automatically generated with medium confidence

**A**       

**B**       

**C**       

**D**       

**(Total 1 mark)**

**Q2.**

A rocket of mass 12 000 kg accelerates vertically upwards from the surface of the Earth at 1.4 m s−2.

What is the thrust of the rocket?

|  |  |  |
| --- | --- | --- |
| **A** | 1.7 × 104 N |  |
| **B** | 1.7 × 105 N |  |
| **C** | 1.3 × 105 N |  |
| **D** | 1.6 × 105 N |  |

**(Total 1 mark)**

**Q3.**

Two spheres, **P** and **Q**, have the same volume but **P** has a greater mass. The spheres fall in air at their terminal velocities *v*P and *v*Q respectively.

Which row states the relationship between *v*P and *v*Q and the reason?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Relationship between *v*P and *v*Q** | **Reason** |  |
| **A** | *v*P = *v*Q | Terminal velocity is unaffected by mass |  |
| **B** | *v*Q > *v*P | The mass of **Q** is less and it accelerates more |  |
| **C** | *v*Q > *v*P | **P** reaches equilibrium at a lower terminal velocity |  |
| **D** | *v*P > *v*Q | **Q** reaches equilibrium at a lower terminal velocity |  |

**(Total 1 mark)**

**Q4.**

The graph shows the variation in displacement with time for an object moving with simple harmonic motion.

Chart

Description automatically generated

What is the maximum acceleration of the object?

**A**      0.025 m s–2

**B**       0.99 m s–2

**C**        2.5 m s–2

**D**        9.8 m s–2

**(Total 1 mark)**

**Q5.**

A steel ball of weight *W* falls through oil. At a time **before** the ball reaches terminal velocity, the magnitude of the viscous resistance force on the ball is

|  |  |
| --- | --- |
| **A** | zero |
| **B** | between zero and *W* |
| **C** | equal to *W* |
| **D** | greater than *W* |

**(Total 1 mark)**

**Q6.**

A ball bearing is released into a tall cylinder of clear oil. The ball bearing initially accelerates but soon reaches terminal velocity.

(a)     By considering the forces acting on the ball bearing, explain its motion.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(3)**

(b)     How would you demonstrate that the ball bearing had reached terminal velocity?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(2)**

**(Total 5 marks)**

**Q7.**

An object of mass 3.2 kg is acted on by two forces which are at right angles to each other. The resultant force is 11.5 N.

(a)     Calculate the acceleration of the object.

**(2)**

(b)     One of the forces has a magnitude of 6.0 N.

Using a scale diagram or otherwise, find:

(i)      the magnitude of the other force;

**(2)**

(ii)     the angle between the resultant force and the 6.0 N force.

**(2)**

**(Total 6 marks)**

**Q8.**

A sprinter is shown before a race, stationary in the ‘set’ position, as shown in the figure below. Force **F** is the resultant force on the sprinter’s finger tips. The reaction force, **Y**, on her forward foot is 180 N and her weight, **W**, is 520 N. **X** is the vertical reaction force on her back foot.

Diagram

Description automatically generated

(a)     (i)      Calculate the moment of the sprinter’s weight, **W**, about her finger tips.  
Give an appropriate unit.

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ unit \_\_\_\_\_\_\_\_\_\_

**(2)**

(ii)     By taking moments about her finger tips, calculate the force on her back foot,  
marked **X**.

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_N

**(3)**

(iii)    Calculate the force **F**.

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_N

**(1)**

(b)     The sprinter starts running and reaches a horizontal velocity of 9.3 ms–1 in a distance  
of 35 m.

(i)      Calculate her average acceleration over this distance.

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_m s–2

**(2)**

(ii)     Calculate the resultant force necessary to produce this acceleration.

answer = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_N

**(2)**

**(Total 10 marks)**

**Section C: Pre-Lesson Context**

*Research the prompts below in advance of the lesson (making notes on these in optional) to give you some context for the upcoming lesson.*

* What did Robert Millikan win his Nobel Prize for in 1923?
* What is Viscous Force/Drag and what factors affect its’ size?
* What does ‘quantisation mean’?

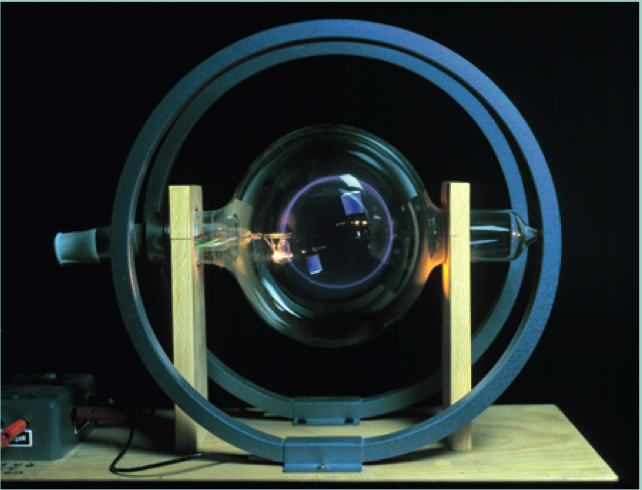
**Section D: Post Lesson Follow up tasks**

*Use the resources linked below to review, practice and go beyond the lesson.*

|  |  |  |  |
| --- | --- | --- | --- |
| Lesson | Lesson Title | [Specification](https://filestore.aqa.org.uk/resources/physics/specifications/AQA-7407-7408-SP-2015.PDF) | Resources  *Where resources are web-based they will be hyperlinked* |
| 1.4 | Millikan’s Experiments | 3.12.1.4 Principle of Millikan’s determination of the electronic charge, e | ***Textbook page(s): 11-13***  Review:   * YouTube: [Millikan’s Oil Drop Experiment](https://www.youtube.com/watch?v=JsHQvy-Y30g) * YouTube: [Discovery of the Electron and Oil Drop](https://www.youtube.com/watch?v=kXs8hUw8og0) (Full Section Overview!)   Practice:   * Seneca Learning Section(s): 12.1.4 * Attempt Question 13 on page 13 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Complete Assignment 2 (page 35) * Practice Question(s) 5 on pages 15-16 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf)   Go Beyond:   * Attempt Question 14 on page 13 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Isaac Physics: [Oil Drop Experiment](https://isaacphysics.org/questions/oil_drop_multiple_fields) * Podcast: [Live from the AAAS](https://titaniumphysicists.brachiolopemedia.com/2020/10/13/episode-86-live-from-the-aaas/) (Quantum Computers) |

**Assignment 1: Making Use of the Deflection of Particles by Magnetic Fields**

**Aim:** To understand how magnetic deflection in a fine beam tube enable the determination of a value of specific charge of an electron and to find out more about technologies that make use of the magnetic deflection of charged particles.

**Context:**The equation from which the specific charge of the electron can be determined in this apparatus is

where V is the anode–cathode potential difference, r is the radius of the circular path of the electron beam, and B is the magnetic flux density applied perpendicular to the beam path. This equation can be rearranged to give

If the radius r of the orbit is maintained at a specific value for various accelerating voltages V and magnetic flux densities B, a graph of V versus B2 should be a straight line with a gradient given by

Therefore, the electron’s specific charge can be determined from

The magnetic flux density B generated by Helmholtz coils of radius R and number of turns N can be calculated from the measurement of the current I flowing in the coils. The flux density between the coils in a Helmholtz coil arrangement is given by

Table

Description automatically generatedwhere is a constant called the permeability of free space, equal to 1.257 x 10-6 Hm-1. The unit K is the henry, and 1H = 1VA-1s.

The fine beam tube contains a scale, which enables the measurement of the diameter, 2r, of the circular electron beam.

In such an experiment, the accelerating voltage of the electron gun is gradually increased to 300V, and then the current supplied to the Helmholtz coils is gradually increased, until the electron beam forms a closed circle of diameter 10.0cm. The value of the current is recorded. The accelerating voltage is then reduced in steps of 20V down to 200V, and the Helmholtz coil current is adjusted to maintain the diameter of the circular path at 10.0 cm. The current value is recorded after each adjustment. Typical data are shown in Table A1.

**Activity:**

Using the data in Table A1, calculate the magnetic flux density B of the magnetic field for each corresponding value of accelerating voltage. Tabulate the values of B for each value of V and calculate B2 for each data set. Plot V versus B2 and determine the gradient.   
  
A value for the specific charge of the electron can now be calculated from

given that the radius r of the circular electron beam was kept constant at 0.050m.   
Determine the percentage difference between your value for the specific charge of an electron and the accepted value.  
*[I suggest using Excel!]*

**Go Beyond Activity *(optional)*:**

Find an article or piece of research detailing an application of cyclotron or synchrotron accelerator technology. You could select one of the examples cited here as your starting point, or you could choose an alternative accelerator application that you would like to investigate further. Write a report on your chosen application of accelerator technology, covering the following:

* the type of particles that are accelerated
* an outline of the processes involved in the application
* the advantages and implications of your chosen accelerator technology

**Assignment 2: Following in the Footsteps of Robert Millikan**

**Aim:** To consider some of the complications and practical difficulties that Millikan had to overcome in order to determine the charge on an electron, e.

**Context:**Issues to be considered:

1. There is an additional, albeit relatively small, upward force acting on the oil drop, called upthrust or buoyancy, which depends on the density of the air, which in turn depends on temperature and atmospheric pressure.
2. The coefficient of viscosity of air varies with temperature, so the air temperature in the chamber has to be monitored.
3. It is difficult to make a drop remain stationary.

The upthrust or upward buoyancy force on a charged oil droplet inside the chamber can be determined from Archimedes’ principle, which states that the upward force is equal to the weight of air displaced. Since the volume of the oil drop is given by , the upward buoyancy force is equal to . When the electric field is switched off and the drop is falling at its terminal speed v1, the balanced forces are the upward viscous force, the upward buoyancy force and the weight of the drop, which means that

**Activity 1:**

Rearrange the previous equation to make the radius of the drop r the subject, and determine a value for r, given the data in Table A1, the ‘engineer’s formula’ for air density in the box, and the graph of viscosity against temperature in Figure A1. Remember that

Text

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**Activity 2 *(harder)*:**

It is easier to adjust the voltage between the plates to cause the charged drop to rise at a steady speed than it is to keep the drop stationary. Assume the voltage V across the plates is now adjusted so that the drop rises at a new steady terminal speed v2.

The upward forces acting on the drop are the buoyancy and the force due to the electric field , where d is the plate separation.

The downward forces on the drop are its weight and the viscous force .

Write an equation showing the balance of the four forces when an electric field is applied and the droplet rises at constant speed.

Rearrange the equation to make the charge Q on the droplet the subject.

Table

Description automatically generatedUse the data supplied for Activity 1 and the data in Table A2 to determine Q.   
The air pressure remains at 101.3 kPa and the chamber temperature is still at 18.6°C.