AQA

Icon

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Turning Points in Physics

Prep Work and Homework

*Wave-Particle Duality*

Name: …………………………………………………………

Teacher: ……………………………………………………..

|  |  |
| --- | --- |
| **CONTENT** | **PAGE** |
| 2.1 Newton’s Corpuscular Theory of Light | **3** |
| 2.2 Determining the Speed of Light | **10** |
| 2.3 Electromagnetic Waves | **19** |
| 2.4 The Concept of Quanta | **29** |
| 2.5 Wave-Particle Duality | **33** |
| 2.6 Electron Microscopes | **41** |
| Assignment 1. Looking at the ‘Speed of Light’ Timeline | **49** |
| Assignment 2. Use Electron Diffraction to Determine Crystal Lattice Spacing | **50** |

**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 you’re 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).

**2.1 Newton’s Corpuscular Theory of Light**

**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** |
| Refraction and Snell’s Law | 70-72 |  | [Refraction and Snell’s Law](https://www.youtube.com/watch?v=k8oK67nlm3M&t=1s) |
| Wave Diffraction | 57 |  | [Wave Diffraction](https://www.youtube.com/watch?v=1bHipDSHVG4) |
| Young Double Slit | 76-78 |  | [Young Double Slit Experiment](https://www.youtube.com/watch?v=8GIwQ_QQ9uA&t=10s) |

*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.**

White light passes through a single narrow slit and illuminates a screen.

What is observed on the screen?

|  |  |  |
| --- | --- | --- |
| **A** | a set of equally spaced white fringes |  |
| **B** | a central maximum made up of a spectrum surrounded by white fringes |  |
| **C** | a white central maximum surrounded by coloured fringes |  |
| **D** | a single narrow white line |  |

**(Total 1 mark)**

**Q2.**

When a parallel beam of monochromatic light is directed at two narrow slits, S1 and S2, interference fringes are observed on a screen.

A picture containing text, antenna

Description automatically generated

Which line in the table gives the changes that will increase the spacing of the fringes?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Slit spacing** | **Distance from slits to screen** |  |
| **A** | halved | halved |  |
| **B** | halved | doubled |  |
| **C** | doubled | halved |  |
| **D** | doubled | doubled |  |

**(Total 1 mark)**

**Q3.**

A ray of light is incident on a glass–air boundary of a rectangular block as shown.

Diagram

Description automatically generated

The refractive index of this glass is 1.5

The refractive index of air is 1.0

The angle of incidence of the light at the first glass–air boundary is 44°

What is the path of the ray of light?

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

**(Total 1 mark)**

**Q4.**

A layer of liquid of refractive index 1.6 covers the horizontal flat surface of a glass block of refractive index 1.5. A ray of light strikes the boundary between them at an angle such that it travels along the boundary afterwards.

How does the ray strike the boundary?

|  |  |  |
| --- | --- | --- |
| **A** | it travels in glass at an angle of 70° to the boundary |  |
| **B** | it travels in glass at an angle of 20° to the boundary |  |
| **C** | it travels in the liquid at an angle of 70° to the boundary |  |
| **D** | it travels in the liquid at an angle of 20° to the boundary |  |

**(Total 1 mark)**

**Q5.**

When a monochromatic light source is incident on two slits of the same width an interference pattern is produced.

One slit is then covered with opaque black paper.

What is the effect of covering one slit on the resulting interference pattern?

|  |  |  |
| --- | --- | --- |
| **A** | The intensity of the central maximum will increase |  |
| **B** | The width of the central maximum decreases |  |
| **C** | Fewer maxima are observed |  |
| **D** | The outer maxima become wider |  |

**(Total 1 mark)**

**Q6.**

The diagram below shows an arrangement used to demonstrate the interference of sound waves. The two loudspeakers act as *coherent sources* of sound.

Shape

Description automatically generated with medium confidence

(a)     Explain what is meant by the term coherent sources.

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

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**(2)**

(b)     In the diagram, the loudspeakers are separated by 8.5 m and are emitting sound of wavelength 0.77 m. When a sound engineer walks along the line **AB**, 65 m from the loudspeakers, he observes a regular rise and fall in the sound intensity.

(i)      Explain this observation.

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

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**(2)**

(ii)     Calculate the distance moved along **AB** between two consecutive maxima of sound.

Distance moved \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**(2)**

**(Total 6 marks)**

**Q7.**

The figure belowshows a ray of light passing from air into glass at the top face of glass block 1 and emerging along the bottom face of glass block 2.

refractive index of the glass in block 1 = 1.45

Diagram

Description automatically generated

(a)     Calculate

(i)      the incident angle *θ*1,

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

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(ii)     the refractive index of the glass in block 2,

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

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(iii)     the angle *θ*3 by considering the refraction at point **A**.

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

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**(7)**

(b)     In which of the two blocks of glass will the speed of light be greater?

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

Explain your reasoning.

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**(2)**

(c)     Using a ruler, draw the path of a ray partially reflected at **A** on the figure above. Continue the ray to show it emerging into the air. No calculations are expected.

**(2)**

**(Total 11 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 experiments was Newton’s reporting on in his 1672 paper called ‘New Theory about Light and Colour’?
* Who was Christiaan Huygens and what was his theory of light?
* Who was Thomas Young and what were his specialist fields in Physics in 1801?

**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* |
| 2.1 | Newton’s Corpuscular Theory of Light | 3.12.2.1 Newton’s corpuscular theory of light  3.12.2.2 Significance of Young’s double slits experiment | ***Textbook page(s): 17-19***  Review:   * YouTube: [Newton vs. Huygens](https://www.youtube.com/watch?v=OQ6kWit51fA&t=353s) * Article: [The History of Light](https://www.visionlearning.com/en/library/Physics/24/Light-I/132)   Practice:   * Attempt Questions 1-4 on page 19 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Attempt Questions 5-7 on page 20 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Seneca Learning Section(s): 12.2.1 * Practice Question(s) 1 on page 37 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 Problem: [Prism Deviations](https://isaacphysics.org/questions/prism_deviations_sym) * Isaac Physics Problem: [The Lifeguard](https://isaacphysics.org/questions/lifeguard_num) * Article: [Newton and the Colour of Light](https://www.college-optometrists.org/the-college/museum/online-exhibitions/virtual-observatory-gallery/newton-and-the-colour-of-light.html) |

**2.2 Determining the Speed of Light**

**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** |
| Circular Motion | 274-277 |  | [Circular Motion](https://www.youtube.com/watch?v=a2o2mzBvWbU) |
| Equations of Motion | 122-124 |  | [SUVAT – Newton’s Equations of Motion](https://www.youtube.com/watch?v=NJRsGRNCqkQ&t=2s) |

*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.**

What is the angular speed of a car wheel of diameter 0.400 m when the speed of the car is 108 km h–1?

**A**        75 rad s–1

**B**       150 rad s–1

**C**       270 rad s–1

**D**       540 rad s–1

**(Total 1 mark)**

**Q2.**

A wave motion has period *T*, frequency *f*, wavelength *λ* and speed *ʋ*. Which one of the following equations is **incorrect**?

**A**       1 = *Tf*

**B**       *T* =  

**C**       *λ* =  

**D**       *Tʋ* = *λ*

**(Total 1 mark)**

**Q3.**

Shape

Description automatically generated

A simple pendulum consists of a bob of mass *m* on the end of a light string of length *l*.  
The bob is released from rest at X when the string is horizontal. When the bob passes through Y its velocity is *ʋ* and the tension in the string is *T*. Which one of the following equations gives the correct value of *T*?

**A**       *T* = *mg*

**B**       *T* =  

**C**       *T* + *mg* =  

**D**       *T* − *mg* =  

**(Total 1 mark)**

**Q4.**

A revolving mountain top restaurant turns slowly, completing a full rotation in 50 minutes. A man is sitting in the restaurant 15 m from the axis of rotation. What is the speed of the man relative to a stationary point outside the restaurant?

**A**     

**B**      

**C**      

**D**      

**(Total 1 mark)**

**Q5.**

The graph shows how the displacement of a particle performing simple harmonic motion varies with time.

Diagram, venn diagram

Description automatically generated

Which statement is **not** correct?

|  |  |  |
| --- | --- | --- |
| **A** | The speed of the particle is a maximum at time |  |
| **B** | The potential energy of the particle is zero at time |  |
| **C** | The acceleration of the particle is a maximum at time |  |
| **D** | The restoring force acting on the particle is zero at time *T* |  |

**(Total 1 mark)**

**Q6.**

**Figure 1** shows a fairground ride called a Rotor. Riders stand on a wooden floor and lean against the cylindrical wall.

**Figure 1**

**Diagram

Description automatically generated**

The fairground ride is then rotated. When the ride is rotating sufficiently quickly the wooden floor is lowered. The riders remain pinned to the wall by the effects of the motion. When the speed of rotation is reduced, the riders slide down the wall and land on the floor.

(a)     (i)      At the instant shown in **Figure 2** the ride is rotating quickly enough to hold a rider at a constant height when the floor has been lowered.

**Figure 2**

**Diagram

Description automatically generated**

Draw onto **Figure 2** arrows representing all the forces on the rider when held in this position relative to the wall.

Label the arrows clearly to identify all of the forces.

**(3)**

(ii)     Explain why the riders slide down the wall as the ride slows down.

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**(2)**

A Rotor has a diameter of 4.5 m. It accelerates uniformly from rest to maximum angular velocity in 20 s.

The total moment of inertia of the Rotor and the riders is 2.1 × 105 kg m2.

(b)     (i)      At the maximum speed the centripetal acceleration is 29 m s–2.

Show that the maximum angular velocity of a rider is 3.6 rad s–1.

**(2)**

(ii)     Calculate the torque exerted on the Rotor so that it accelerates uniformly to its maximum angular velocity in 20 s.

State the appropriate SI unit for torque.

torque \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ SI unit for torque \_\_\_\_\_\_\_\_\_\_

**(3)**

(iii)     Calculate the centripetal force acting on a rider of mass 75 kg when the ride is moving at its maximum angular velocity.

Give your answer to an appropriate number of significant figures.

centripetal force \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N

**(1)**

(c)     **Figure 3** shows the final section of a roller coaster which ends in a vertical loop. The roller coaster is designed to give the occupants a maximum acceleration of 3*g*. Cars on the roller coaster descend to the start of the loop and then travel around it, as shown.

**Figure 3**

**Diagram

Description automatically generated**

(i)      At which one of the positions marked **A**, **B** and **C** on **Figure 3** would the passengers experience the maximum reaction force exerted by their seat?

Circle your answer below.

**A**                      **B**                         **C**

**(1)**

(iii)     Explain why the maximum acceleration is experienced at the position you have chosen.

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

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**(2)**

**(Total 14 marks)**

**Q7.**

**Figure 1** shows an acrobat swinging on a trapeze.

**Figure 1**

**Diagram

Description automatically generated**

(a)     (i)      State and explain how the tension in the ropes of the trapeze varies as the acrobat swings on the trapeze.

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

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**(3)**

(ii)     The period of the oscillation of the acrobat on the trapeze is 3.8 s.

Calculate the distance between the point of suspension of the trapeze and the centre of mass of the acrobat.

Assume that the acrobat is a point mass and that the system behaves as a simple pendulum.

distance \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m

**(2)**

(b)     At one instant the amplitude of the swing is 1.8 m. The acrobat lets go of the bar of the trapeze at the lowest point of the swing. He lands in a safety net when his centre of mass has fallen 6.0 m.

(i)      Calculate the speed of the acrobat when he lets go of the bar.

speed \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m s−1

**(3)**

(ii)     Calculate the horizontal distance between the point of suspension of the trapeze and the point at which the acrobat lands on the safety net.

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

**(3)**

(c)     **Figure 2** shows the displacement−time (*s–t*) graph for the bar of the trapeze after the acrobat has let go of the bar.

**Figure 2**

**Chart

Description automatically generated**

(i)      Show that the amplitude of the oscillations decreases exponentially.

**(3)**

(ii)     Explain why the period of the trapeze changes when the acrobat lets go of the bar.

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

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**(2)**

**(Total 16 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.*

* Who was Hippolyte Fizeau?
* Who was Leon Foucault?
* Why did it take so long for Scientists to neglect Newton’s Corpuscular Theory of Light?

**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* |
| 2.2 | Determining the Speed of Light | 3.12.2.3 Electromagnetic waves | ***Textbook page(s): 20-21***  Review:   * YouTube: [Fizeau Experiment](https://www.youtube.com/watch?v=a6gl8KZM0PM) (3D model) * YouTube: [Replicating the Fizeau Apparatus](https://www.youtube.com/watch?v=YMO9uUsjXaI)   Practice:   * Attempt Question 8 on page 21 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Attempt Assignment 1 (page X)   Go Beyond:   * Isaac Physics Problem: [Light up a Mirror](https://isaacphysics.org/questions/lighting_up_a_mirror) * Isaac Physics Problem: [Patch of Light](https://isaacphysics.org/questions/light_circ_mirror) |

**2.3 Electromagnetic Waves**

**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** |
| Polarisation | 53 |  | [Polarisation](https://www.youtube.com/watch?v=JWy0QsBZgbk&t=20s) |
| Electromagnetic Waves | 8 |  | [Electromagnetic Waves](https://www.youtube.com/watch?v=X4f7au1VCgM)  [Electromagnetic Spectrum](https://www.youtube.com/watch?v=R6I7Fh3hN3M) |
| Stationary Waves | 60-63 |  | [Stationary Waves and Phase](https://www.youtube.com/watch?v=TAGlpuMYdk4&t=541s) |
| Electromagnetic Induction | 410-419 |  | [Electromagnetic Induction](https://www.youtube.com/watch?v=OObvIrzIfbA&t=64s) |

*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.**

Stationary waves are set up on a length of rope fixed at both ends. Which one of the following statements is true?

**A**       Between adjacent nodes, particles of the rope vibrate in phase with each other.

**B**       The mid point of the rope is always stationary.

**C**       Nodes need not necessarily be present at each end of the rope.

**D**       Particles of the rope at adjacent antinodes always move in the same direction.

**(Total 1 mark)**

**Q2.**

A rectangular conducting loop is pulled horizontally through the gap between two vertical magnets as shown in the diagram.

Diagram

Description automatically generated

Which one of the graphs best represents the variation of loop current *I* with time *t* as the loop moves at a constant speed from **JKLM** to **J'K'L'M'**?

Diagram

Description automatically generated

**(Total 1 mark)**

**Q3.**

Which row correctly shows electromagnetic radiations in order of decreasing wavelength?

|  |  |  |
| --- | --- | --- |
| **A** | gamma > ultraviolet > microwave |  |
| **B** | ultraviolet > gamma > microwave |  |
| **C** | microwave > ultraviolet > gamma |  |
| **D** | gamma > microwave > ultraviolet |  |

**(Total 1 mark)**

**Q4.**

Diagram

Description automatically generated frequency of vibration = 50 Hz

The diagram above shows a stationary wave on a stretched string at a time *t* = 0. Which one of the diagrams, **A** to **D**, correctly shows the position of the string at a time *t* = 0.010 s?

**A**        Diagram

Description automatically generated

**B**        Diagram

Description automatically generated

**C**        Diagram

Description automatically generated

**D**        Diagram, shape

Description automatically generated

**(Total 1 mark)**

**Q5.**

Which statement is correct about the properties of an unpolarised electromagnetic wave as it passes through a polariser?

|  |  |  |
| --- | --- | --- |
| **A** | The wave remains unchanged. |  |
| **B** | The wave does not pass through the polariser. |  |
| **C** | The wave’s electric field oscillates along the direction of travel. |  |
| **D** | The intensity of the wave is reduced. |  |

**(Total 1 mark)**

**Q6.**

The figure belowshows the appearance of a stationary wave on a stretched string at one instant in time. In the position shown each part of the string has its maximum displacement. The arrow at **W** shows the direction in which the point **W** is about to move.

A picture containing text, computer, dark

Description automatically generated

(a)     (i)      Mark clearly on the diagram the directions in which points **X**, **Y** and **Z** are about to move.

(ii)     State the conditions necessary for a stationary wave to be produced on the string.

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**(4)**

(b)     In the figure above, the frequency of vibration is 120 Hz. Calculate the frequency of the fundamental vibration for this string.

frequency of the fundamental vibration \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**(2)**

**(Total 6 marks)**

**Q7.**

(a)     State the characteristic features of

(i)      longitudinal waves,

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(ii)     transverse waves.

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**(3)**

(b)     Daylight passes horizontally through a fixed polarising filter **P**. An observer views the light emerging through a second polarising filter **Q**, which may be rotated in a vertical plane about point **X** as shown in **Figure 1**.

Diagram

Description automatically generated with medium confidence

**Figure 1**

Describe what the observer would see as **Q** is rotated slowly through 360°.

You may be awarded marks for the quality of written communication provided in your answer.

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**(2)**

**(Total 5 marks)**

**Q8.**

A metal aircraft with a wing span of 42 m flies horizontally with a speed of 1000 km h–1 in a direction due east in a region where the vertical component of the flux density of the Earth’s magnetic field is 4.5 × 10–5 T.

(a)      Calculate the flux cut per second by the wings of the aircraft.

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(b)     Determine the magnitude of the potential difference between the wing tips, stating the law which you are applying in this calculation.

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(c)     What would be the change in the potential difference, if any, if the aircraft flew due west?

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

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**(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 is Icelandic Spar?
* What was the main premise of James Clerk Maxwell’s 1865 publication ‘A dynamical theory of the Electromagnetic Field’?
* What did Röntgen and Villard discover in 1895 and 1900 respectively?

**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* |
| 2.3 | Electromagnetic Waves | 3.12.2.3 Electromagnetic waves | ***Textbook page(s): 22-25***  Review:   * YouTube: [Hertz Experiment](https://www.youtube.com/watch?v=FWCN_uI5ygY) (first 60 seconds) * YouTube: [Electromagnetic Waves Lecture](https://www.youtube.com/watch?v=j2gOh39IyPM)   Practice:   * Attempt Questions 9 and 10 on page 25 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Practice Question(s) 2 on page 37 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Seneca Learning Section(s): 12.2.2   Go Beyond:   * Isaac Physics Problem: [Don’t Bragg](https://isaacphysics.org/questions/don't_bragg_sym) * Isaac Physics Problem: [Electromagnetic Induction in a Disc](https://isaacphysics.org/questions/em_induction_disc) * Video: [Maxwells Equations and the Speed of Light](https://www.youtube.com/watch?v=FSEJ4YLXtt8) |

**3.4 The Concept of Quanta**

**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 Photoelectric Effect | 30-33 |  | [The Photoelectric Effect](https://www.youtube.com/watch?v=6VqNz4oT0ng&t=322s) |
| Stopping Potential | 31 |  | [Photoelectric Effect](https://www.youtube.com/watch?v=I_7ZfMlIKhk&t=258s) (with stopping potential) |
| Photons | 8-9 |  | [The Photon](https://www.youtube.com/watch?v=j22nxWX4w9c&t=92s) |

*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.**

When light of a certain frequency greater than the threshold frequency of a metal is directed at the metal, photoelectrons are emitted from the surface.

The power of the light incident on the metal surface is doubled.

Which row shows the effect on the maximum kinetic energy and the number of photoelectrons emitted per second?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Maximum kinetic energy** | **Number of photoelectrons emitted per second** |  |
| **A** | remains unchanged | remains unchanged |  |
| **B** | doubles | remains unchanged |  |
| **C** | remains unchanged | doubles |  |
| **D** | doubles | doubles |  |

**(Total 1 mark)**

**Q2.**

Which one of the graphs best represents the relationship between the energy *W* of a photon and the frequency *f* of the radiation?

A picture containing clock

Description automatically generated

**(Total 1 mark)**

**Q3.**

What is the correct order of increasing photon energy in the electromagnetic spectrum?

1 is least energy, 4 is greatest energy.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Radio waves** | **γ rays** | **Visible light** | **Infrared** |  |
| **A** | 1 | 4 | 3 | 2 |  |
| **B** | 4 | 1 | 2 | 3 |  |
| **C** | 1 | 4 | 2 | 3 |  |
| **D** | 4 | 1 | 3 | 2 |  |

**(Total 1 mark)**

**Q4.**

Which graph best shows the relationship between photon energy *E* and wavelength *λ* of a photon of electromagnetic radiation?

Diagram, shape, engineering drawing

Description automatically generated

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

**(Total 1 mark)**

**Q5.**

Monochromatic radiation from a source of light (source A) is shone on to a metallic surface and electrons are emitted from the surface. When a second source (source B) is used no electrons are emitted from the metallic surface. Which property of the radiation from source A must be greater than that from source B?

**A**       amplitude        

**B**       frequency        

**C**       intensity          

**D**       wavelength     

**(Total 1 mark)**

**Q6.**

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

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**(1)**

(b)     Violet light of wavelength 380 nm is incident on a potassium surface.

(i)      Calculate the energy of a photon of this light.

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

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photon energy \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ J

**(3)**

(ii)     Show that this photon can cause the photoelectric effect when incident on the potassium surface.

work function of potassium = 2.3 eV

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

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**(2)**

(c)     The potassium surface is now given a positive charge.  
Explain why no photoelectric effect is observed.

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**(2)**

**(Total 8 marks)**

**Q7.**

**Figure 1** shows a photocell which uses the photoelectric effect to provide a current in an external circuit.

**Figure 1**

**Diagram

Description automatically generated**

(a)     Electromagnetic radiation is incident on the photoemissive surface.

Explain why there is a current only if the frequency of the electromagnetic radiation is above a certain value.

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

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**(3)**

(b)     State and explain the effect on the current when the intensity of the electromagnetic radiation is increased.

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**(2)**

(c)     A student investigates the properties of the photocell. The student uses a source of electromagnetic radiation of fixed frequency and observes that there is a current in the external circuit.

The student then connects a variable voltage supply so the positive terminal is connected to the electrode with a photoemissive surface and the negative terminal is connected to the wire electrode. As the student increases the supply voltage, the current decreases and eventually becomes zero. The minimum voltage at which this happens is called the stopping potential. The student’s new circuit is shown in **Figure 2**.

**Figure 2**

**Diagram

Description automatically generated**

The photoemissive surface has a work function of 2.1 eV. The frequency of the electromagnetic radiation the student uses is 7.23 × 1014 Hz.

Calculate the maximum kinetic energy, in J, of the electrons emitted from the photoemissive surface.

maximum kinetic energy = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ J

**(3)**

(d)     Use your answer from **part (c)** to calculate the stopping potential for the photoemissive surface.

stopping potential = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ V

**(1)**

(e)     The student increases the frequency of the electromagnetic radiation.

Explain the effect this has on the stopping potential.

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

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**(3)**

**(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 was Kirchhoff’s proposed idealised concept of a ‘black body’?
* What did Wilhelm Wein win his Nobel Prize for in 1911?
* What is ‘ultraviolet catastrophe’?   
  *[Hint: You may wish to search alongside the names Rayleigh and Jeans]*

**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* |
| 2.4 | The Concept of Quanta | 3.12.2.4  The discovery of photoelectricity | ***Textbook page(s): 26-29***  Review:   * YouTube: [Wien’s Displacement Law](https://www.youtube.com/watch?v=qjM73TlVkTo) * YouTube: [Blackbody Curve and Wien’s Law](https://www.youtube.com/watch?v=XdXAdwb7loE) * YouTube: [Stefan-Boltzmann Law](https://www.youtube.com/watch?v=AMwzCDTW82M) * YouTube: [Quantisation of Energy Part 1](https://www.youtube.com/watch?v=7BXvc9W97iU) * YouTube: [Quantisation of Energy Part 2](https://www.youtube.com/watch?v=eU6VqGIc-2Q)   Practice:   * Attempt Question 11 on page 27 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Attempt Questions 12-15 on page 30 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Practice Question(s) 3 on page 38 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Seneca Learning Section(s): 12.2.3   Go Beyond:   * Isaac Physics Problem: [The Photoelectric Effect](https://isaacphysics.org/questions/the_photoelectric_effect) * Video: [Neil deGrasse Tyson explains Why the Sky is Blue](https://www.youtube.com/watch?v=eU6VqGIc-2Q) |

**2.5 Wave-Particle Duality**

**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** |
| De Broglie Wavelength | 41-42 |  | [De-Broglie Wavelength](https://www.youtube.com/watch?v=gGmUEwc9B_U&t=24s) |
| Electron Diffraction | 42 |  | [Electron Diffraction](https://www.youtube.com/watch?v=q80rdZLspoc&t=36s) |
| Diffraction Patterns | 82-83 |  | [Diffraction of Light](https://www.a-levelphysicstutor.com/wav-light-diffr.php) |

*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 particle of mass *m* has a kinetic energy of *E*.

What is the de Broglie wavelength of this particle?

|  |  |  |
| --- | --- | --- |
| **A** |  |  |
| **B** |  |  |
| **C** | **A picture containing text  Description automatically generated** |  |
| **D** |  |  |

**(Total 1 mark)**

**Q2.**

When a monochromatic light source is incident on two slits of the same width an interference pattern is produced.

One slit is then covered with opaque black paper.

What is the effect of covering one slit on the resulting interference pattern?

|  |  |  |
| --- | --- | --- |
| **A** | The intensity of the central maximum will increase |  |
| **B** | The width of the central maximum decreases |  |
| **C** | Fewer maxima are observed |  |
| **D** | The outer maxima become wider |  |

**(Total 1 mark)**

**Q3.**

Electrons and protons in two beams are travelling at the same speed. The beams are diffracted by objects of the same size.

Which correctly compares the de Broglie wavelength *λ*e of the electrons with the de Broglie wavelength *λ*p of the protons and the width of the diffraction patterns that are produced by these beams?

|  |  |  |  |
| --- | --- | --- | --- |
|  | comparison of de  Broglie  wavelength | diffraction pattern |  |
| **A** | *λe > λp* | electron beam width > proton beam width |  |
| **B** | *λe < λp* | electron beam width > proton beam width |  |
| **C** | *λe > λp* | electron beam width < proton beam width |  |
| **D** | *λe < λp* | electron beam width < proton beam width |  |

**(Total 1 mark)**

**Q4.**

Electrons moving in a beam have the same de Broglie wavelength as protons in a separate beam moving at a speed of 2.8 × 104 m s–1.

What is the speed of the electrons?

|  |  |  |
| --- | --- | --- |
| **A** | 1.5 × 101 m s–1 |  |
| **B** | 2.8 × 104 m s–1 |  |
| **C** | 1.2 × 106 m s–1 |  |
| **D** | 5.1 × 107 m s–1 |  |

**(Total 1 mark)**

**Q5.**

Which graph shows how intensity *I* varies with angle *θ* when electrons are diffracted by a nucleus?

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A** | **A picture containing hanger  Description automatically generated** | | | |  | | | |
| **B** | **A picture containing white  Description automatically generated** | |  | | | |
| **C** | **A picture containing hanger  Description automatically generated** |  | | | |
| **D** | **A picture containing white  Description automatically generated** | | |  | | | |

**(Total 1 mark)**

**Q6.**

The table shows results of an experiment to investigate how the de Broglie wavelength *λ* of an electron varies with its velocity *v*.

|  |  |
| --- | --- |
| ***v* / 107 m s–1** | ***λ* / 10–11 m** |
| 1.5 | 4.9 |
| 2.5 | 2.9 |
| 3.5 | 2.1 |

(a)     Show that the data in the table are consistent with the relationship 

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

**(2)**

(b)     Calculate a value for the Planck constant suggested by the data in the table.

Planck constant = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ J s

**(2)**

(c)     **Figure 1** shows the side view of an electron diffraction tube used to demonstrate the wave properties of an electron.

**Figure 1**

**Diagram

Description automatically generated**

An electron beam is incident on a thin graphite target that behaves like the slits in a diffraction grating experiment. After passing through the graphite target the electrons strike a fluorescent screen.

**Figure 2** shows the appearance of the fluorescent screen when the electrons are incident on it.

**Figure 2**

**A picture containing electronics

Description automatically generated**

Explain how the pattern produced on the screen supports the idea that the electron beam is behaving as a wave rather than as a stream of particles.

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**(3)**

(d)     Explain how the emission of light from the fluorescent screen shows that the electrons incident on it are behaving as particles.

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**(3)**

**(Total 10 marks)**

**Q7.**

A single slit diffraction pattern is produced on a screen using a laser. The intensity of the central maximum is plotted on the axes in the figure below.

Diagram

Description automatically generated with medium confidence

(a)     On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

**(2)**

(b)     A laser is a source of *monochromatic*, *coherent* light. State what is meant by

monochromatic light \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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

coherent light \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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

**(2)**

(c)     Describe how the pattern would change if light of a longer wavelength was used.

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

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**(1)**

(d)     State **two** ways in which the appearance of the fringes would change if the slit was made narrower.

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

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**(2)**

(e)     The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

**(3)**

**(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 is the ‘Compton Effect’ and who discovered it?
* What do Clinton Davisson, Lester Germer and George Thomson have in common?
* What is ‘X-ray Crystallography’ and what is it used for? How is it linked to Rosalind Franklin?

**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* |
| 2.5 | Wave-Particle Duality | 3.12.2.5 Wave–particle duality | ***Textbook page(s): 30-32***  Review:   * YouTube: [Compton Scattering](https://www.youtube.com/watch?v=QsCmslcSlEs) * YouTube: [Potential Difference and de Broglie Wavelength](https://www.youtube.com/watch?v=evtyqXRSGlM) * YouTube: [The de Broglie Wavelength and Wave Particle Duality](https://www.youtube.com/watch?v=ZqspDsQSZuI&t=20s)   Practice:   * Attempt Questions 16 and 17 on page 32 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Attempt Assignment 2 (page X) * Practice Question(s) 4 on page 38 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Seneca Learning Section(s): 12.2.4   Go Beyond:   * Attempt Question 18 on page 32 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Video: [Structure Determination by Microcrystal Electron Diffraction](https://www.youtube.com/watch?v=JfGa-ohJHUc) |

**2.6 Electron Microscopes**

**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** |
| Electric Fields | 358-365 |  | [Electric Fields: Crash Course](https://www.youtube.com/watch?v=mdulzEfQXDE) |
| Current and Charge | 202-203 |  | [Electric Current](https://www.youtube.com/watch?v=9OchTQ4Qfik) |
| Capacitors | 380-387 |  | [Capacitors](https://www.youtube.com/watch?v=UG5TkLL4gYY&t=9s) |

*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.**

Four positive charges are fixed at the corners of a square as shown.

A picture containing scale, wire

Description automatically generated

The total potential at the centre of the square, a distance d from each charge, is 

Three of the charges have a charge of +Q

What is the magnitude of the fourth charge?

|  |  |  |
| --- | --- | --- |
| **A** |  |  |
| **B** | *Q* |  |
| **C** | √2*Q* |  |
| **D** | 2*Q* |  |

**(Total 1 mark)**

**Q2.**

A 1000 μF capacitor and a 10 μF capacitor are charged so that they store the same energy. The pd across the 1000 μF capacitor is V1 and the pd across the other capacitor is V2.

What is the value of the ratio ?

**A**       

**B**       

**C**       

**D**       10

**(Total 1 mark)**

**Q3.**

A conducting sphere holding a charge of +10 μC is placed centrally inside a second uncharged conducting sphere.

Which diagram shows the electric field lines for the system?

Engineering drawing

Description automatically generated with medium confidence

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

**(Total 1 mark)**

**Q4.**

The circuit shows a cell with negligible internal resistance connected in a circuit with three resistors, an ammeter and a voltmeter.

Diagram, schematic

Description automatically generated

Which row shows the readings on the ammeter and voltmeter?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Current / A** | **Voltage / V** |  |
| **A** | 0.075 | 0.75 |  |
| **B** | 0.075 | 1.50 |  |
| **C** | 0.150 | 0.75 |  |
| **D** | 0.150 | 1.50 |  |

**(Total 1 mark)**

**Q5.**

The graph shows the variation of potential difference *V* with time *t* across a 470 μF capacitor discharging through a resistor.

Chart, line chart

Description automatically generated

The resistance of the resistor is approximately

**A**       900 Ω

**B**       1300 Ω

**C**       1900 Ω

**D**       4700 Ω

**(Total 1 mark)**

**Q6.**

The graph shows how the charge *Q* stored by a capacitor varies with the potential difference (pd) *V* across it as *V* is increased from 9.0 V to 12.0 V.

Chart, line chart

Description automatically generated

(a)     (i)      Use the graph to determine an accurate value for the capacitance of the capacitor.

capacitance = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ μF

**(2)**

(ii)     Calculate the additional energy stored by the capacitor when *V* is increased from 9.0 V to 12.0 V.

additional energy = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ J

**(3)**

(b)     When a 470 μF capacitor is discharged through a fixed resistor R, the pd across it decreases by 80% in 45 s.

(i)      Calculate the time constant of the capacitor–resistor circuit.

time constant = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ s

**(3)**

(ii)     Determine the resistance of R.

resistance = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ω

**(2)**

(iii)     At which point during the discharging process is the capacitor losing charge at the smallest rate? Tick (✔) the correct answer.

|  |  |
| --- | --- |
|  | ✔ if correct |
| when the charge on the capacitor is greatest |  |
| when energy is dissipated at the greatest rate |  |
| when the current in the resistor is greatest |  |
| when the pd across R is least |  |

**(1)**

**(Total 11 marks)**

**Q7.**

The circuit diagram below shows a 6.0 V battery of negligible internal resistance connected in series to a light dependent resistor (LDR), a variable resistor and a fixed resistor, R.

Diagram, schematic

Description automatically generated

(a)     For a particular light intensity the resistance of the LDR is 50 kΩ. The resistance of  
R is 5.0 kΩ and the variable resistor is set to a value of 35 kΩ.

(i)      Calculate the current in the circuit.

current\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_A

**(2)**

(ii)     Calculate the reading on the voltmeter.

voltmeter reading \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_V

**(2)**

(b)     State and explain what happens to the reading on the voltmeter if the intensity of the light incident on the LDR increases.

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

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**(2)**

(c)     For a certain application at a particular light intensity the pd across R needs to be 0.75 V. The resistance of the LDR at this intensity is 5.0 kΩ.

Calculate the required resistance of the variable resistor in this situation.

resistance \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ω

**(3)**

**(Total 9 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 does a traditional light microscope work?
* What roles do electron microscopes play in biological sciences?
* What did Binnig and Rohrer with the Nobel Prize for in 1986?

**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* |
| 2.6 | Electron Microscopes | 3.12.2.6 Electron microscopes | ***Textbook page(s): 34-36***  Review:   * YouTube: [The Principle of the Electron Microscope](https://www.youtube.com/watch?v=H4tPyaQq0wg&t=135s) * YouTube: [Electron Microscopes](https://www.youtube.com/watch?v=ImzPskS2w5k) (AQA Specific) * YouTube: [Wave-Particle Duality](https://www.youtube.com/watch?v=H4tPyaQq0wg&t=135s) (whole topic overview)   Practice:   * Attempt Questions 19 and 20 on page 35 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Attempt Question 21 on page 36 of the [Turning Points Textbook.](https://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Turning%20points%20in%20physics.pdf) * Seneca Learning Section(s): 12.2.5   Extend:   * Video: [The World’s Smallest Movie](https://www.youtube.com/watch?v=ImzPskS2w5k) * Impressed by the above? See how it was made [here](https://www.youtube.com/watch?v=kFX8m_h3TOA). * Podcast: [Quantum Tunnelling](http://titaniumphysicists.brachiolopemedia.com/2012/10/01/episode-23-quantum-tunneling-with-justin-pierce/) |

**Assignment 1: Looking at the ‘Speed of Light’ Timeline**

**Aim:** To understand the observations that led to the estimation of the Speed of Light and how these evolved over time.

**Context:**Whether the speed of light was finite or infinite was probably a topic of discussion as early as 500 BC. The Greek philosopher and poet, Empedocles (495–430 BC), is quoted as having argued that the light from the Sun must take time to reach the Earth. However, Aristotle (385–322 BC) is known to have expressed the view that the speed of light was infinite, and such was his influence

that few scientists and philosophers expressed the alternative view for the next two millennia. In 1638, Galileo suggested an experiment to try to measure the speed of light. He and his assistant stood a mile apart each with a lantern that had a shutter. Galileo opened the shutter on his lantern and as soon as his assistant saw the light, he would then open the shutter on his lantern. Having practised sufficiently so as to factor in their reaction times, Galileo had hoped to be able to measure the time of travel of the light and therefore calculate the speed of light. However, he was unable to establish that the light took any time at all to travel between him and his assistant and concluded that, if not instantaneous, light certainly travelled very fast.

The first successful attempt to measure the speed of light was made by the Danish astronomer Olaus Roemer in 1676. Roemer had been observing Io, one of Jupiter’s moons. He had noticed that the time interval between successive eclipses of the moon by the planet was about 7 minutes shorter when the Earth, in its orbit, was at its closest to  
  
Jupiter than when it was at its furthest from Jupiter, about 6 months later. Roemer concluded that the time difference was as a result of the light having to traveldifferent distances. He calculated the speed of the light to be 214 000 000 ms-1.

**Activities:**

1. Most early scientists believed that light travelled either extremely quickly or infinitely fast. Suggest an everyday observation that indicates that light travels at considerable speed.
2. Suggest two practical difficulties that prevented Galileo from measuring the time for light to travel between him and his assistant.
3. Why was it likely that the first successful attempt to measure the speed of light involved making astronomical observations?
4. Table A1 includes a few of the many scientists who successfully measured the speed of light, each value being closer to the current accepted value (c = 299 792 458 ms-1) than the previous one, as technological developments led to more accurate measurements. Select one of the scientists listed, do some research and briefly outline the technique they used for measuring c.   
     
   Table

   Description automatically generated

**Assignment 2: Using Electron Diffraction to Determine Crystal Lattice Spacing**

**Aim:** To use your understanding of electron diffraction and geometry to determine the space of atoms inside a crystal.

**Context:**The electron diffraction tube consists of an electron gun generating electrons by thermionic emission and accelerated by an anode voltage towards a grid on to which a thin film of graphite has been deposited (Figure A1). As the electrons pass through the graphite, they are diffracted to form a pattern consisting of a series of circular rings corresponding to the arrangement of the carbon atoms in the polycrystalline graphite specimen. The inside surface at the end of the tube is coated with a fluorescent material to enable the electron diffraction pattern to be observed.

Diagram, schematic

Description automatically generated

The type of diffraction occurring can be represented by the equation λ ≈ dsinθ, where l is the de Broglie wavelength of the electrons, d is the spacing between the carbon atoms and q is the diffraction angle for the first ring illustrated in Figure A2.

A picture containing text, sky

Description automatically generated

From Figure A2 it can be seen that, for the first ring of the diffraction pattern, , where D s the diameter of the first ring, L is the distance from the carbon target to the screen and it is assumed that L >> D, so that the small-angle approximation applies.

Also applying the small-angle approximation to the diffraction equation λ ≈ d sin θ produces λ = dθ, which can be equated to , where V is the anode voltage. Hence

Since , we can write

Squaring both sides and rearranging gives:

Table

Description automatically generatedThis means a graph of against D2 will have a gradient equal to from which the carbon atom spacing (d) can be determined.

In such an experiment, measurements of the first ring diameter for various values of anode voltage were obtained, as shown in Table A1.

**Activity:**

Use the data from Table A1 to plot a suitable graph, and from the gradient of the graph determine the carbon atom spacing in the graphite specimen used, given that the distance from the carbon target to the screen, L, is 0.18m.   
  
[Take h = 6.63×10−34 Js; e = 1.6 ×10−19 C; m = 9.11×10−31 kg]