Name: _____

Photoelectric Effect

Questions

Date:

Time:

Total marks available:

Total marks achieved: _____

Questions

Q1.

The wave and particle models of light have both contributed to our understanding of light.

Which row of the table correctly matches properties of light to the model that best explains them?

	Wave model	Particle model
☒ A	photoelectric effect	refraction
☒ B	diffraction	atomic line spectra
☒ C	atomic line spectra	photoelectric effect
☒ D	refraction	diffraction

(Total for question = 1 mark)

Q2.

An electron gun uses a potential difference V to accelerate electrons of mass m and charge e from rest to a speed v.
The potential difference V can be expressed as

☒ **A** $\frac{mv^2}{2e}$

☒ **B** $\frac{2ev^2}{m}$

☒ **C** $\sqrt{\frac{2ev}{m}}$

☒ **D** $\sqrt{\frac{mv}{2e}}$

(Total for question = 1 mark)

Q3.

When electromagnetic radiation is incident on a metal plate, electrons may be emitted.

(a) State what is meant by threshold frequency.

(1)

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(b) Calculate the threshold frequency for a metal with a work function of 2.28 eV.

(3)

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Threshold frequency = ...

(Total for question = 4 marks)

Q4.

A coulombmeter is used to measure charge.

In a laboratory demonstration of the photoelectric effect, a sheet of zinc was placed on top of a coulombmeter and the zinc was given a negative charge.

* The following observations were made:

- under normal lighting conditions the charge remained constant
- when the zinc was illuminated with ultraviolet light, the magnitude of the charge on the zinc decreased as time passed
- when a larger sheet of zinc was used the charge on the zinc decreased more rapidly.

In each case the initial charge on the zinc was the same.

Explain these observations.

(6)

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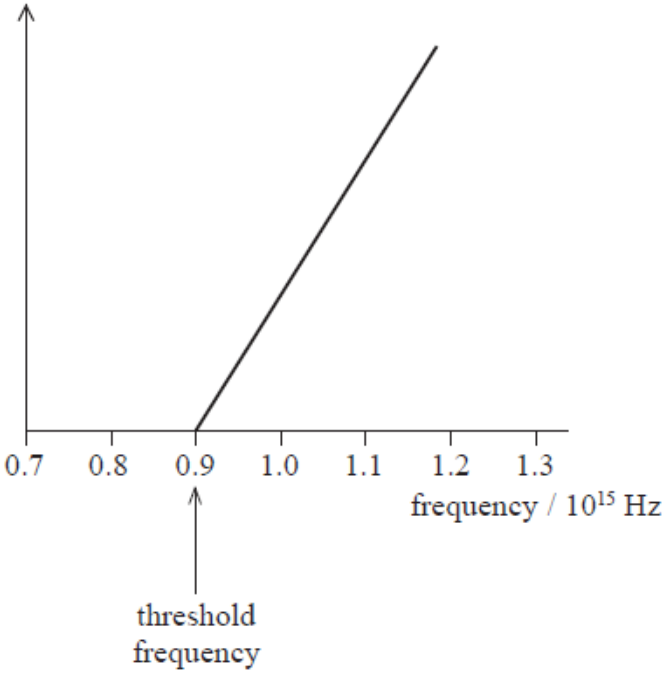
(Total for question = 6 marks)

Q5.

The graph shows the results for an experiment to demonstrate the photoelectric effect by illuminating a clean metal sheet with light of increasing frequency.



(a) State a quantity, and its unit, which could have been plotted on the Y-axis to produce this graph.

(2)

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(b) The threshold frequency is shown on the graph.

Explain why there is a threshold frequency.

(4)

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(Total for question = 6 marks)

Q6.

* The behaviour of electromagnetic radiation can be described in terms of a photon model or a wave model.

In the photoelectric effect, electromagnetic radiation is incident on a metal plate and under certain conditions electrons are emitted.

It is observed that, for a given metal,

- no electrons are emitted if the frequency of the incident radiation is below a certain threshold frequency.
- electrons are emitted instantaneously if the frequency of the incident radiation is above a certain threshold frequency.
- the kinetic energy of the emitted electrons depends only on the frequency of the incident radiation.

Discuss how the photon model of electromagnetic radiation can explain these observations and why the wave model of electromagnetic radiation cannot.

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(Total for question = 6 marks)

Q7.

In the late 1880s it was discovered that a negatively-charged zinc plate loses its charge when exposed to ultraviolet radiation.

Explain why this happens, but only with ultraviolet radiation and not white light. You are expected to complete a calculation to support your answer.

work function of zinc = 6.9×10^{-19} J

(6)

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(Total for question = 6 marks)

Q8.

In 2010, Andre Geim and Konstantin Novoselov were awarded the Nobel Prize in Physics for producing, identifying and studying graphene.

Graphene is a form of carbon which exists only as a single atomic layer of graphite. It has a breaking stress of 130 GPa compared to 0.5 GPa for steel. Some scientists claim that graphene is the strongest material ever measured.

(a) Explain why graphene, despite its greater strength, is unlikely to replace steel in many applications.

(2)

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(b) Graphite used in pencils consists of many layers of carbon. It can be assumed that a pencil deposits approximately 100 layers of carbon atoms when drawn across a piece of paper.

A student carried out an experiment to determine the resistivity of the graphite in a pencil.

A line of length 0.200m and width 0.50mm was drawn on a piece of paper. An ohmmeter was then used to measure the resistance of the graphite line.

Calculate the resistivity of graphite.

resistance = $1.029 \times 10^{6}\ \Omega$
diameter of carbon atom = 1.4×10^{-10} m

(4)

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Resistivity of graphite = ...

(c) Photocells traditionally use silicon to generate electricity using visible light. Research demonstrates that unlike silicon, graphene is able to respond at all wavelengths and releases multiple electrons as it absorbs one photon.

Deduce why it would be an advantage to use graphene in photocells to generate electricity.

(3)

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(Total for question = 9 marks)

Q9. When the photoelectric effect was first observed in the nineteenth century, scientists could not explain it using the wave theory of light.

In 1905 Albert Einstein published a paper, for which he won a Nobel Prize, explaining the photoelectric effect by using a photon model of light, rather than a wave model.

(a) Explain what is meant by a photon.

(2)

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*(b) Explain why the following observations may be understood by using a photon model of light, rather than a wave model.

- Light above a certain frequency causes the emission of electrons from the surface of a metal. This emission occurs instantaneously.
- Light below a certain frequency will not result in the emission of electrons however long it illuminates the surface.

(5)

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(c) Zinc has a work function of 4.3 eV.

(i) Calculate the threshold frequency for zinc.

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Threshold frequency = ...

(ii) State the part of the electromagnetic spectrum to which radiation of this frequency belongs.

(1)

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(Total for Question = 11 marks)

Q10.

Read the following extract and then answer the questions that follow.

Powdery dust, the by-product of fearsome meteor storms that pounded the Moon, coats much of the lunar surface. A build-up of this dust could damage sensitive machinery.

Scientists theorise that lunar dust must be electrostatically charged by ultraviolet solar radiation from the Sun. When ultraviolet radiation hits the Moon's "day side", the half that faces the Sun, it knocks electrons out of atoms in the lunar soil.

(a) Describe the particle model of ultraviolet radiation that explains how it can "knock electrons out of atoms".

(3)

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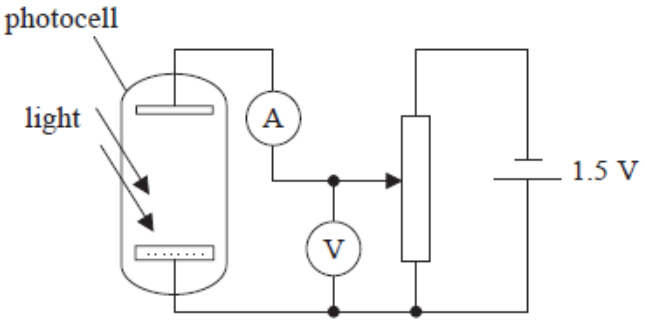
(b) A teacher uses the arrangement below to demonstrate that electrons can be knocked out of a metal surface in a photocell by visible light.

The arrangement can also be used to measure the maximum kinetic energy of these electrons.



(i) Explain how the potential divider circuit can produce a range of values from 0 to 1.5 V on the voltmeter.

(3)

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(ii) The potential difference on the voltmeter is increased until the ammeter reading is zero.

The voltmeter reads 0.6 V at this instant.

State the maximum kinetic energy of the electrons in eV.

(1)

Maximum kinetic energy = ... eV

(c) Discuss whether the photocell arrangement in part (b) gives a valid demonstration of how dust particles become charged on the Moon.

(4)

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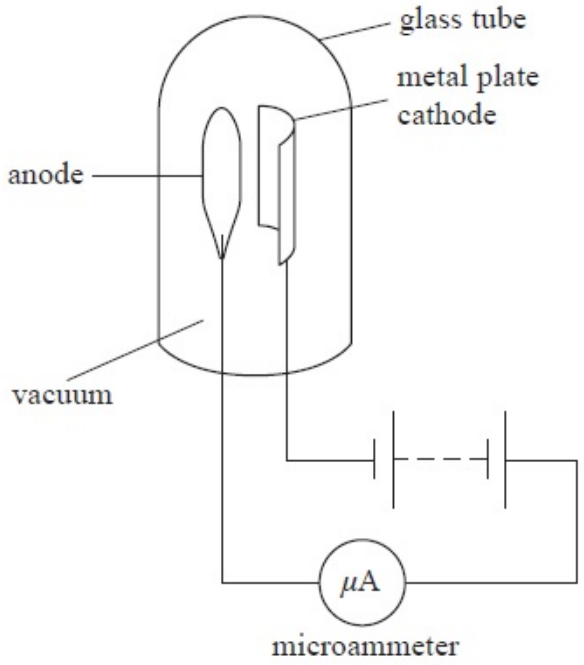
(Total for question = 11 marks)

Q11. Phototubes are devices which make use of the photoelectric effect to detect light above a specific frequency.



(a) Explain why

- no current flows when the phototube is in darkness
- current flows in the circuit when the phototube is illuminated by light above a specific frequency.

(5)

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(b) Make an appropriate calculation to explain why caesium is used as the cathode for visible light but zinc is not.

work function of zinc = 3.63 eV

work function of caesium = 2.14 eV

(4)

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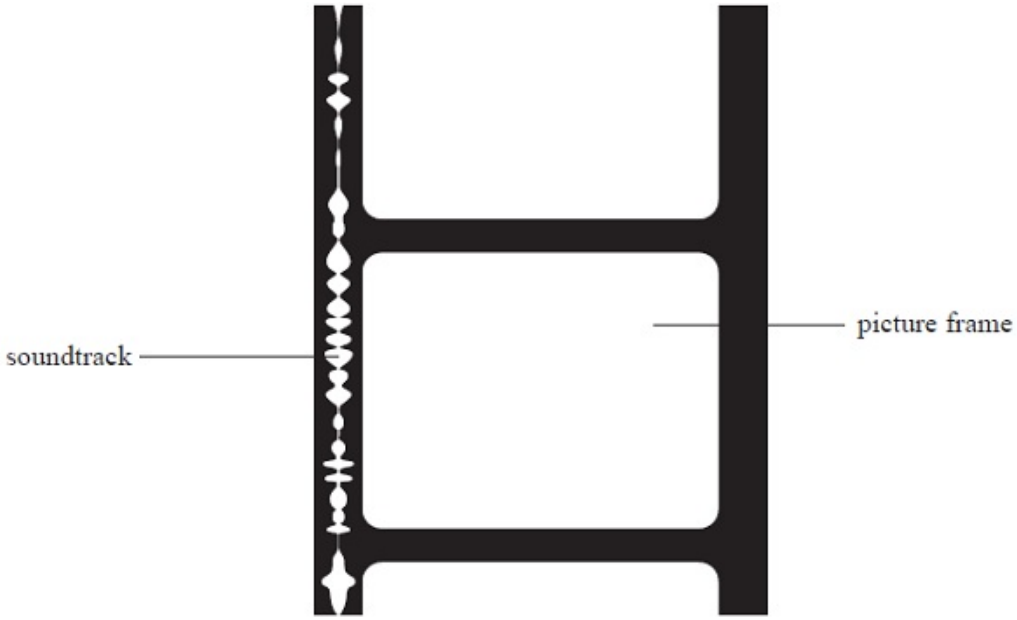
(c) Before digital technology was used, the films used at the cinema had an optical soundtrack next to the picture frames.



The film, including the soundtrack as shown, moves through a projector past a source of light. Light is detected by a phototube on the other side of the soundtrack. The changing current produced by the phototube circuit is converted to a sound signal with the same variation in amplitude and frequency as the original sound.

(i) State what is meant by amplitude.

(1)

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(ii) Explain how the changing pattern of the soundtrack produces a changing current in the

phototube circuit.

(3)

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(Total for Question = 13 marks)