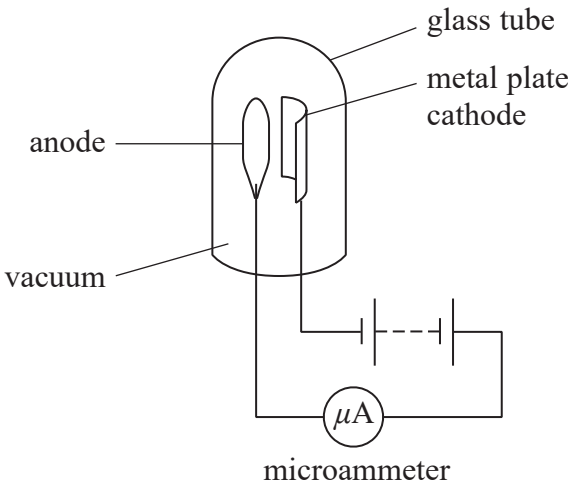
2 The diagram shows a phototube. One use of phototubes is in light meters to measure the intensity of light.



When light is incident on the cathode, the microammeter shows a current.

The following observations are made when varying the frequency and intensity of light incident on the phototube.

- There is only a current if the frequency of the incident light is greater than a certain value.
- The size of the current increases as the intensity of the incident light increases.

*(a) Explain these observations.

(5)

(b) For a particular phototube the minimum frequency required for a current to be produced is 6.34×10^{14} Hz. The phototube is illuminated with light of frequency 7.52×10^{14} Hz.

Calculate the maximum kinetic energy of the released electrons in eV.

(3)

Maximum kinetic energy = eV

(Total for Question = 8 marks)

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

(a) State what is meant by threshold frequency.

(1)

.....

.....

(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)

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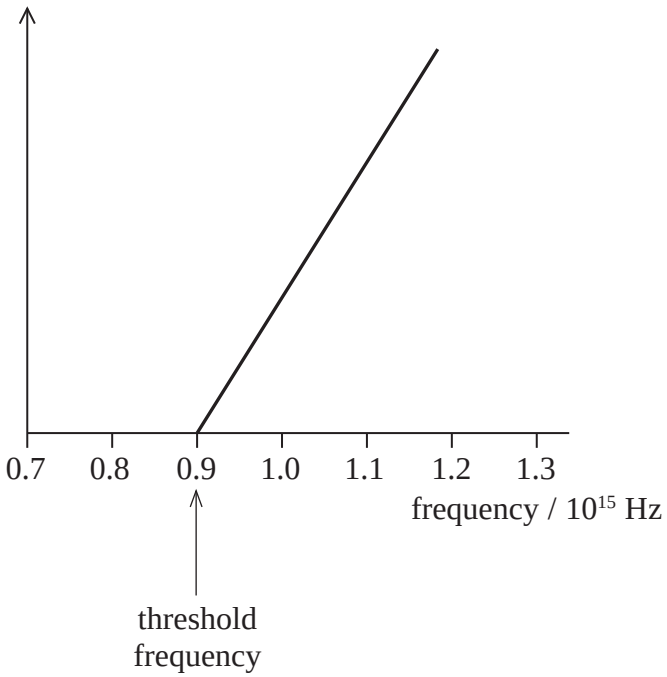
4 The graph shows the results for an experiment to demonstrate the photoelectric effect by illuminating a clean metal sheet with light of increasing frequency.



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

(2)

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

Explain why there is a threshold frequency.

(4)

(Total for Question = 6 marks)

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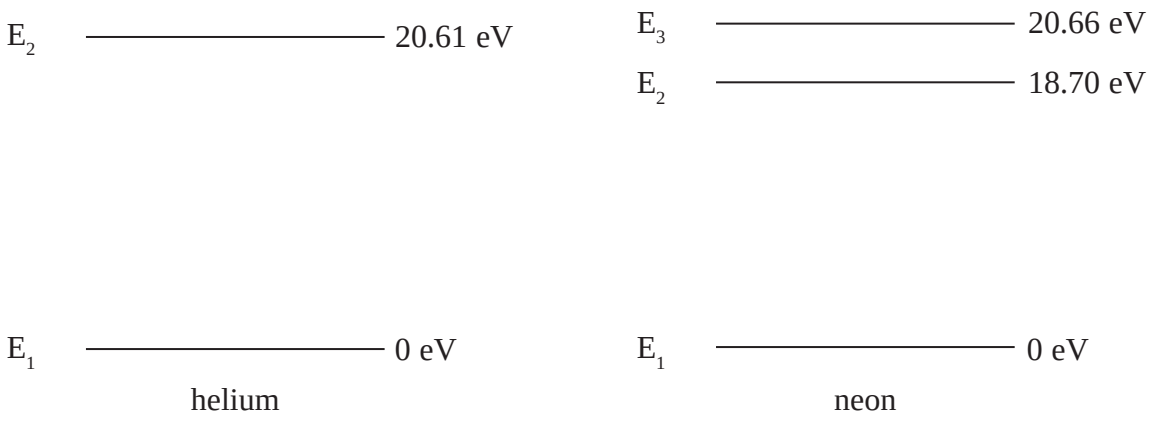
5 A helium-neon gas laser is often used in the laboratory as a source of high intensity, coherent, monochromatic light.

The diagram shows some of the energy levels above the ground level E_3 for helium atoms and for neon atoms. The highest shown levels for helium atoms and neon atoms are almost identical.



Helium atoms in the gas are excited to level E_2 by the current passing through the laser. They collide at high speed with neon atoms. Because the energies are so similar, the energy is transferred from the helium atoms to the neon atoms. The neon atoms become excited in turn to level E_3. As the neon atoms subsequently drop to level E_2 they emit photons.

(a) Explain what is meant by a photon.

(2)

(b) Calculate the frequency of the photons produced as the neon atoms drop from level E_3 to level E_2.

(3)

Frequency =

(c) An electron in level E_3 of neon has 0.05 eV more energy than an electron in level E_2 of helium.

Suggest the source of the energy to make up this difference.

(1)

(d) The photograph shows a device for making a vertical slit with variable width.

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When the slit is fully open a laser beam is shone through it and a single point of light is seen on a screen.

As the slit is reduced in width the point of light becomes a horizontal line that gets longer as the slit gets narrower.

Explain this observation.

(3)

(Total for Question = 9 marks)

6 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)

*(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)

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

(i) Calculate the threshold frequency for zinc.

(3)

Threshold frequency =

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

(1)

(Total for Question = 11 marks)

7 Monochromatic light is shone onto the surface of a clean metal plate. The photoelectric effect results in electrons being emitted from the surface.

(a) State and explain the effect on the emitted electrons if

(i) the frequency of the light is increased

(2)

(ii) the intensity of the light is increased.

(2)

*(b) Explain how the photoelectric effect supports the particle model of light and not the wave model of light.

(4)

(Total for Question 8 marks)

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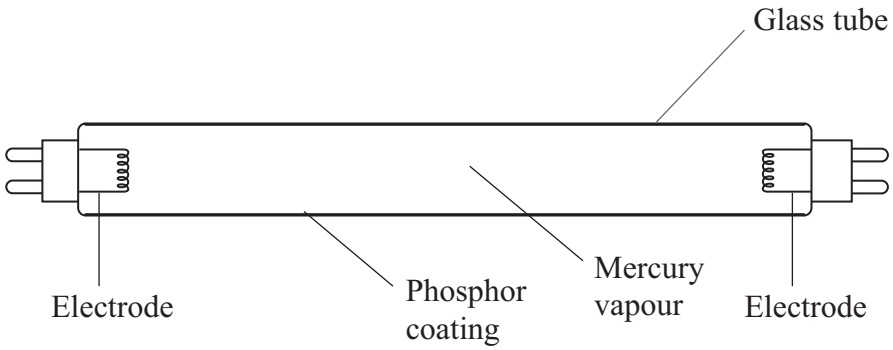
8 The diagram shows the main components of a fluorescent light tube.



When the light is switched on, charge flows between the electrodes and the mercury atoms become excited. The mercury atoms then emit electromagnetic radiation.

(a) What is meant by *the mercury atoms become excited*?

(2)

.....

.....

.....

.....

(b) (i) Explain how the excited atoms emit radiation.

(2)

(ii) Explain why only certain frequencies of radiation are emitted.

(3)

(iii) Some of the radiation is ultraviolet radiation which the human eye cannot detect. The phosphor coating absorbs the ultraviolet radiation and emits visible light.

Suggest why the phosphor coating emits different wavelengths from the mercury.

(1)

(Total for Question 8 marks)

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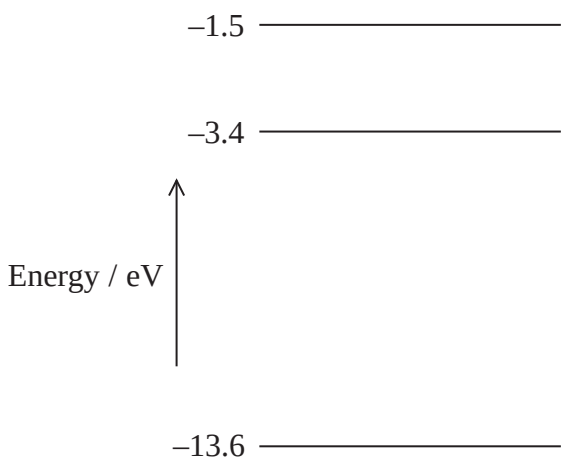
9 The diagram shows the lowest three energy levels of a hydrogen atom.



(a) Excited hydrogen atoms can emit light of wavelength 6.56×10^{-7} m.

(i) Calcula the frequency of this light.

(2)

Frequency =

(ii) The energy of a photon of this frequency is 3.03×10^{-19} J.
By means of a calculation determine which electron transition emits this photon.

(2)

from to

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(b) The spectrum of light from the Sun has a dark line at a wavelength of 656 nm. In the spectrum of light received from a distant galaxy, the corresponding line appears at a wavelength of 690 nm.

Explain what the observation tells us about this galaxy. Do not include calculations in your answer.

(2)

(Total for Question = 6 marks)