1 In an experiment it is observed that when blue light is shone on a clean metal surface electrons are emitted, but with red light there is no electron emission.

(a) State the name of the effect observed in this experiment.

..... **[1]**

(b) Describe Einstein's theory to explain these observations.

In your answer you should include technical terms to explain how the physics of quantum behaviour is used to explain the observations.

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..... **[4]**

(c) The longest wavelength of light incident on the metal surface which causes electrons to be emitted is 480 nm.

(i) Show that the work function of the metal is about 4×10^{-19} J.

[3]

(ii) Calculate the maximum speed of an emitted electron when a photon of energy 5.2×10^{-19} J is incident on the metal surface.

speed = ... $m\,s^{-1}$ **[3]**

(d) (i) Describe briefly one piece of evidence for believing that electrons sometimes behave like waves.

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..... **[2]**

(ii) Calculate the de Broglie wavelength of an electron moving at 500 $km\,s^{-1}$.

wavelength = ... m **[3]**

2 In a demonstration experiment of the photoelectric effect, light of wavelength 440 nm incident on a clean metal surface causes electrons to be emitted. No electrons are emitted from the surface when the wavelength of the incident light is greater than 550 nm.

(a) (i) Define the term *work function*.

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..... **[2]**

(ii) Explain how the work function is related to the threshold frequency.

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..... **[2]**

(iii) Calculate the value of the work function for this metal.

work function = ... J **[2]**

(b) (i) Show that the maximum speed of the emitted electrons in the experiment is about $4.5 \times 10^5\,\text{m}\,\text{s}^{-1}$.

[3]

(ii) Calculate the minimum de Broglie wavelength of an emitted electron.

wavelength = ... m **[2]**

(c) The light source for this experiment is a discharge lamp containing excited atoms which emit light at several wavelengths. Fig. 8.1 shows the three lowest energy levels of one of these atoms, labelled n = 1, 2 and 3.

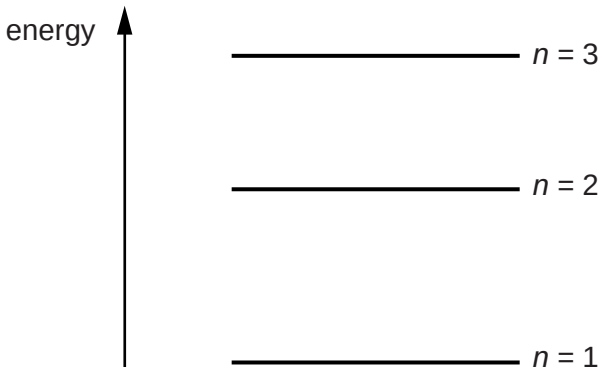

Fig. 8.1

Electron transitions between these energy levels can produce three different wavelengths of radiation. The transition between n = 2 and n = 1 causes the 440 nm photons.

(i) Photons at 590 nm are also emitted. Which transition causes these photons?

..... **[1]**

(ii) Hence calculate the wavelength of the photons emitted by the third transition.

wavelength = ... m **[3]**

[Total: 15]

3 This question is about electrons and photons.

(a) Both electrons and photons can be considered as particles. State **two** differences between their properties.

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..... **[2]**

(b) An electron is accelerated from rest through a p.d. of 5000 V.

(i) Show that the energy gained by the electron is 8.0×10^{-16} J.

[2]

(ii) Show that the speed of the electron is about 4×10^{7} m s^{-1}.

[3]

(c) **(i)** Explain what is meant by the de Broglie wavelength of an electron.

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..... **[1]**

(ii) Calculate the de Broglie wavelength of the electron in **(b)**.

wavelength = ... m **[3]**

(d) Calculate the wavelength of a photon of energy 8.0×10^{-16} J.

wavelength = ... m **[3]**

(e) Photons of energy 9.0×10^{-19} J are incident on a clean tungsten surface causing electrons to be emitted.

(i) State the name of this process.

..... **[1]**

(ii) Calculate the maximum kinetic energy of the emitted electrons. Tungsten has a work function of 7.2×10^{-19} J.

maximum kinetic energy = ... J **[2]**

(iii) Explain why your answer to **(ii)** is a maximum value.

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..... **[2]**

[Total: 19]