1 **(a)** When a glowing gas discharge tube is viewed through a diffraction grating an emission line spectrum is observed.

(i) Explain what is meant by a *line spectrum*.

....

....

.... **[2]**

(ii) Describe how an absorption line spectrum differs from an emission line spectrum.

....

.... **[1]**

(b) A fluorescent tube used for commercial lighting contains excited mercury atoms. Two bright lines in the visible spectrum of mercury are at wavelengths 436 nm and 546 nm.

$1\,\text{nm} = 10^{-9}\,\text{m}$

Calculate

(i) the energy of a photon of violet light of wavelength 436 nm

energy = ... J **[3]**

(ii) the energy of a photon of green light of wavelength 546 nm.

energy = ... J **[1]**

(c) Electron transitions between the three levels **A**, **B** and **C** in the energy level diagram for a mercury atom (Fig. 7.1) produce photons at 436 nm and 546 nm. The energy *E* of an electron bound to an atom is negative. The ionisation level, not shown on the diagram, defines the zero of the vertical energy scale.

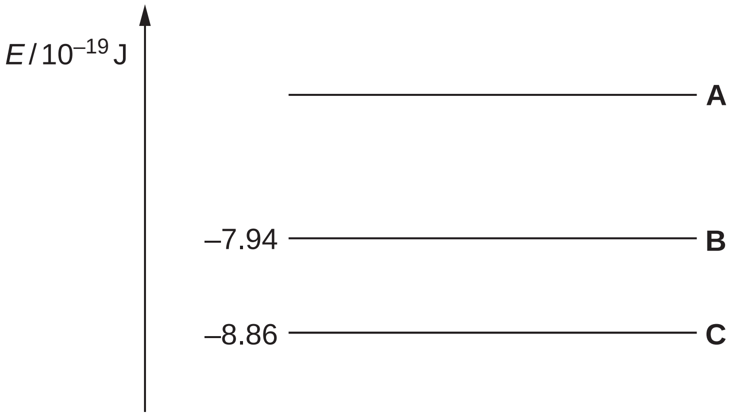

Fig. 7.1

(i) Draw two arrows on Fig. 7.1 to represent the transitions which give rise to these photons. Label each arrow with its emitted photon wavelength. **[3]**

(ii) Use your values for the energy of the photons from **(b)** to calculate the value of the energy level **A**.

E = ... J **[2]**

(d) The light from a distant fluorescent tube is viewed through a diffraction grating aligned so that the tube and the lines on the grating are parallel. The light from the tube is incident as a parallel beam at right angles to the diffraction grating.

The line separation on the grating is 3.3×10^{-6} m.

Calculate the angle to the straight through direction of the first order green (546 nm) image of the tube seen through the grating.

angle = ... ° **[3]**

[Total: 15]

2 This question is about the light from low energy compact fluorescent lamps which are replacing filament lamps in the home.

(a) The light from a compact fluorescent lamp is analysed by passing it through a diffraction grating. Fig. 6.1 shows the angular positions of the three major lines in the first order spectrum and the bright central beam.

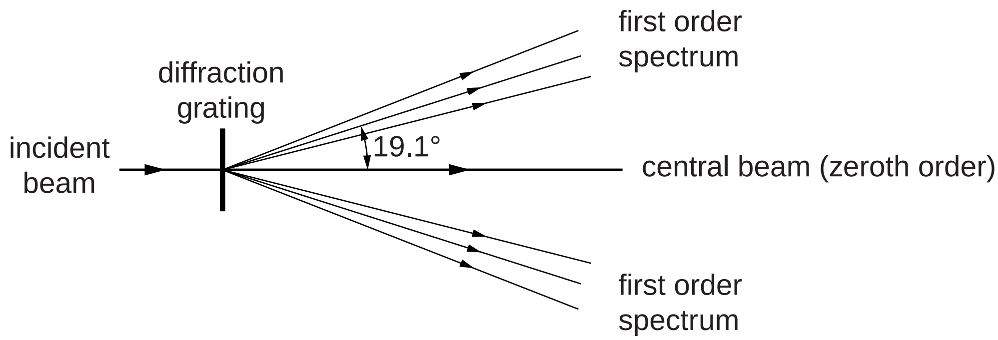

Fig. 6.1

(i) On Fig. 6.1 label one set of the lines in the first order spectrum **R**, **G** and **V** to indicate which is red, green and violet. **[1]**

(ii) Explain why the bright central beam appears white.

....

....

.... **[1]**

(iii) The line separation *d* on the grating is 1.67×10^{-6} m.

Calculate the wavelength λ of the light producing the first order line at an angle of 19.1° to the central bright beam.

λ = ... m **[3]**

(b) The wavelength of the violet light is 436 nm. Calculate the energy of a photon of this wavelength.

energy = ... J **[3]**

(c) The energy level diagram of Fig. 6.2 is for the atoms emitting light in the lamp. The three electron transitions between the four levels **A**, **B**, **C** and **D** shown produce the photons of red, green and violet light. The energy *E* of an electron bound to an atom is negative. The ionisation level, not shown on the diagram, defines the zero of the vertical energy scale.

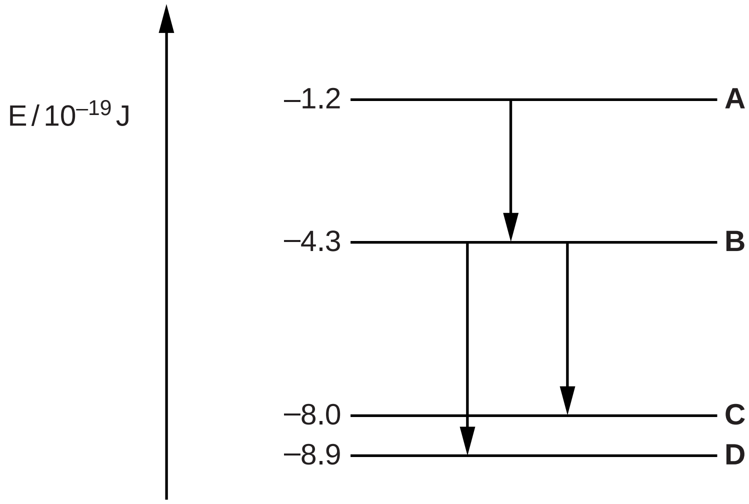

Fig. 6.2

Label the arrows on Fig. 6.2 **R**, **G** and **V** to indicate which results in the red, green and violet photons. **[2]**

[Total: 10]

3 **(a)** A 5.0 eV photon can cause the photoelectric effect from most metals.

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

....

.... **[1]**

(ii) State what is meant by an *electron volt* (eV).

....

.... **[1]**

(iii) Calculate the value of 5.0 eV in SI units.

value = ... unit .... **[1]**

(b) A photon of energy 8.0×10^{-19} J incident on a clean zinc surface can cause photoelectric emission. The maximum kinetic energy of an electron emitted from the surface is 1.1×10^{-19} J.

(i) **1** Define the term *work function* of a metal.

....

.... **[1]**

2 Calculate the work function for zinc.

work function = ... unit .... **[1]**

(ii) **1** Show that the maximum speed v of an electron emitted from the surface is about $5 \times 10^{5}\,\mathrm{m\,s^{-1}}$.

[2]

2 Calculate the de Broglie wavelength of an electron emitted from the surface at the maximum speed.

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

(c) The spacing between atoms in a thin sheet of graphite is about 2.5×10^{-10} m.

(i) A beam of electrons in a vacuum can travel through a thin sheet of graphite placed perpendicular to the beam to produce a pattern of **rings** on a fluorescent screen beyond the graphite sheet. Explain why this pattern is produced.

....

....

....

....

....

....

.... **[3]**

(ii) Explain whether or not the electrons in **(b)(ii)** would be suitable for use in such an experiment.

....

....

.... **[1]**

[Total: 14]

4 This question is about the Young double slit experiment. See Fig. 7.1. The fringe pattern seen on the screen is shown to the right.

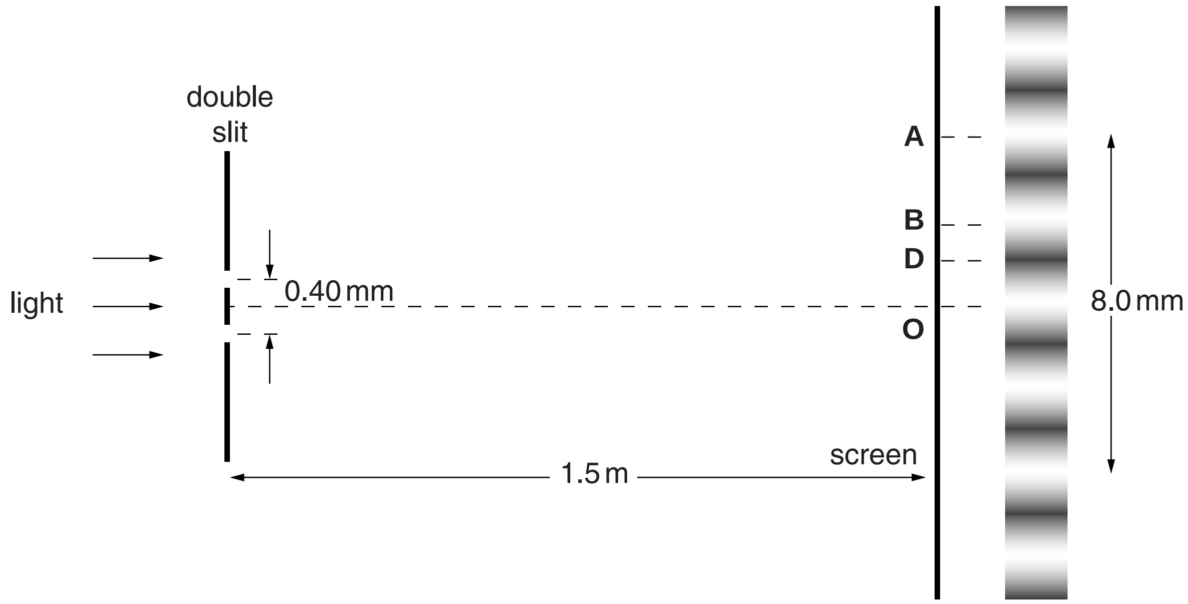

Fig. 7.1

Two parallel clear lines are scratched on a darkened glass slide 0.40 mm apart. When a beam of monochromatic visible light is shone through these slits, interference fringes are observed on a screen placed 1.5 m from the slide. The fringe at point **B** is bright and the fringe at point **D** is dark.

(a) Explain why this arrangement with two slits is used to produce visible fringes on the screen rather than two separate identical light sources.

....

....

.... **[2]**

(b) State the **phase difference** between the light waves from the two slits that meet on the screen in Fig. 7.1 at point

D ....

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

(c) (i) Use Fig. 7.1 to calculate the separation of adjacent bright fringes, the distance between **O** and **B**.

fringe separation = ... m **[1]**

(ii) Show that the wavelength λ of the monochromatic light is about 5×10^{-7} m.

[3]

(d) Calculate the **path difference**, in nanometres, between the light waves from the two slits that meet on the screen in Fig. 7.1 at point **A**.

path difference = ... nm **[2]**

(e) The energy level diagram of Fig. 7.2 is for the atoms emitting photons in the light source. Electron transitions between the three levels shown produce three photons of different wavelength. The energy E of an electron bound to an atom is negative.

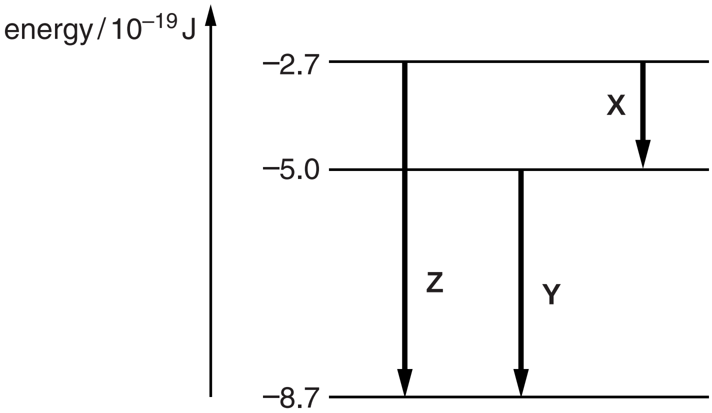

Fig. 7.2

(i) Use data from Fig. 7.2 to justify that the arrow labelled **Y** produces the photons of wavelength about 5×10^{-7} m used in the interference experiment.

[4]

(ii) Neither of the photons shown by the other transitions can be used for the experiment because they are not visible. State in which region of the electromagnetic spectrum each photon is produced, by the other transitions, **X** and **Z**.

X ....

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

[Total: 16]