1 Fig. 7.1 shows the three lowest energy levels of the hydrogen atom, labelled $n = 1, 2$ and 3.

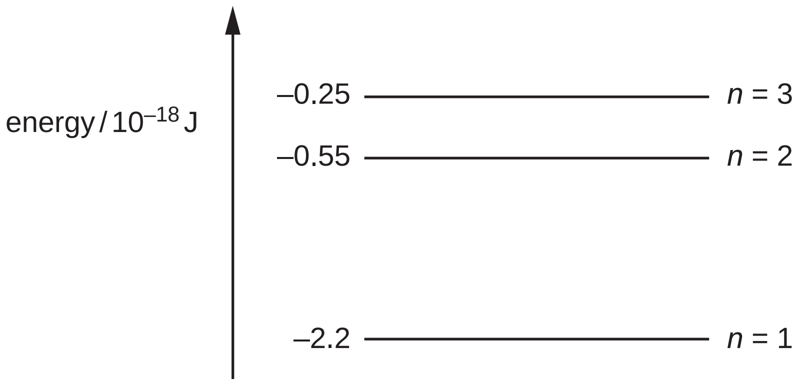

Fig. 7.1

(a) (i) Explain why electron transitions between the energy levels can produce three different wavelengths of radiation. You may draw lines on Fig. 7.1 to illustrate your explanation.

....

....

....

....

....

....

.... **[3]**

(ii) The strong red line in the hydrogen spectrum has a wavelength of 6.56×10^{-7} m.

1 Calculate the energy of the photon at this wavelength.

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

2 Use Fig. 7.1 to identify the electron transition responsible for the spectral line of this wavelength.

....

.... **[1]**

(b) A parallel beam of light from a hydrogen lamp is incident on a diffraction grating. The first order red spectral line at 6.56×10^{-7} m is seen at an angle of 11.4° as shown in Fig. 7.2.

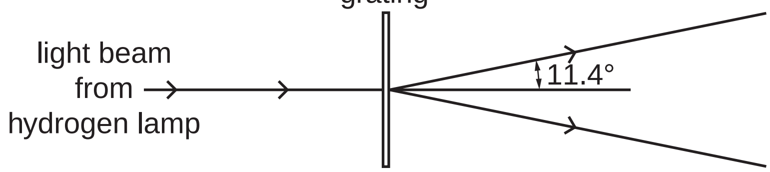

Fig. 7.2

(i) Calculate

1 the separation *d* of the lines on the grating

d = ... m **[3]**

2 the number of lines per millimetre on the grating.

number = ... lines mm^{-1} **[1]**

(ii) The hydrogen lamp also emits blue light at a wavelength of 4.86×10^{-7} m.

Draw rays on Fig. 7.2 to indicate roughly, that is without calculation, the direction of the **first** order blue spectral line as the rays leave the grating. **[1]**

[Total: 11]

2 A photoelectric cell is an electronic device that can detect photons.

(a) Fig. 4.1 shows a cross-section through a simple photocell.

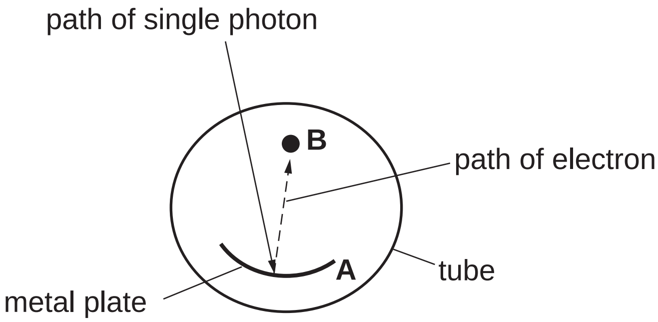

Fig. 4.1

A metal plate **A** is coated with potassium in an evacuated transparent tube. A photon entering the tube is absorbed by the plate, causing one electron to be released from the surface towards the collector rod **B**.

(i) State the name of this process.

.... **[1]**

(ii) Potassium has a work function of 3.5×10^{-19} J.

1 Define the term *work function*.

....

.... **[1]**

2 Calculate the threshold frequency of potassium.

threshold frequency = ... Hz **[2]**

(iii) The photon incident on plate **A** has a wavelength of 4.2×10^{-7} m. Show that its energy is about 5×10^{-19} J.

[2]

(iv) Calculate the maximum kinetic energy of the electron emitted from the potassium surface of plate **A**.

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

(b) An electron is released with zero speed from plate **A**. It is accelerated from plate **A** through a potential difference of 12V to the metal rod **B** in Fig. 4.1.

(i) **1** State the increase in kinetic energy of the electron in electronvolts (eV).

increase in k.e. = ... eV **[1]**

2 Show that this increase is about 2×10^{-18} J.

[1]

(ii) Calculate the speed of the electron as it hits rod **B**.

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

(c) The photocell is connected to a 12V d.c. supply through a very sensitive ammeter. Light of wavelength 4.2×10^{-7} m shines on plate **A**. The plate absorbs 1.2×10^{-6} J of light energy every second. One per cent of the absorbed photons cause electrons to be emitted from the plate. Estimate the current in the circuit.

current = ... A **[3]**

[Total: 16]

3 **(a)** A parallel beam of red light of wavelength 6.3×10^{-7} m from a laser is incident normally on a diffraction grating as shown in Fig. 6.1.

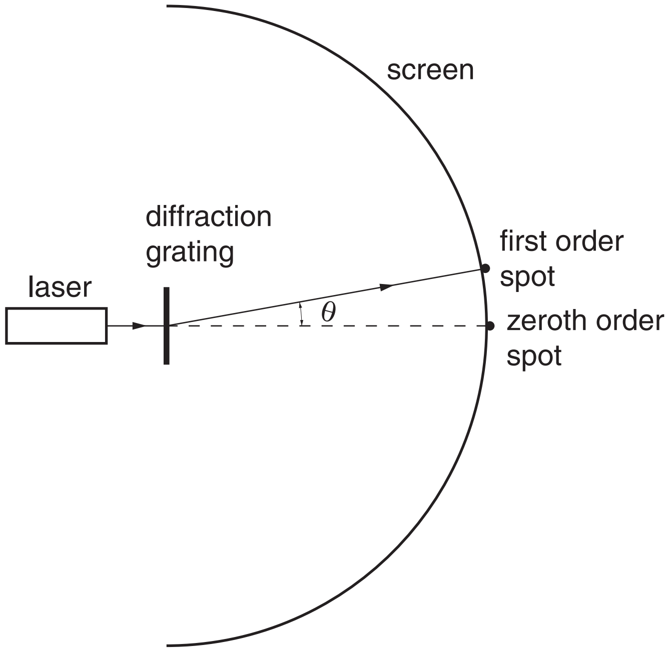

Fig. 6.1

Bright red spots are observed on the curved screen placed beyond the grating.

(i) The diffraction grating has 300 lines per millimetre. Show that the separation d between adjacent lines of the grating is 3.3×10^{-6} m.

[1]

(ii) Calculate the angle θ at which the first order red spot is seen. This is the first spot away from the straight through position.

θ = ... degrees **[3]**

(iii) The screen curves around the full 180° in front of the grating. Explain why there are eleven bright red spots on the screen.

....

....

....

....

.... **[3]**

(b) Calculate

(i) the energy of each photon of light emitted by the laser at a wavelength of 6.3×10^{-7} m

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

(ii) the number of photons emitted each second to produce a power of 0.50 mW.

number = ... **[2]**

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

....

....

....

....

.... **[3]**

(ii) Calculate

1 the speed v of electrons with a de Broglie wavelength of 5.0×10^{-11} m

v = ... $m\,s^{-1}$ **[2]**

2 the potential difference V required to accelerate the electrons to this speed.

V = ... V **[3]**

[Total: 19]