1 **(a)** In atomic physics electron energies are often stated in *electronvolts* (eV)

Define the *electronvolt*. State its value in joule.

....

....

.... **[2]**

(b) An electron is accelerated from rest through a potential difference of 300 V.

(i) Calculate the final kinetic energy of the electron

1 in eV

kinetic energy = ... eV **[1]**

2 in J.

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

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

[2]

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

....

....

.... **[2]**

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

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

[Total: 10]

2 The tungsten filament of a 12V 24W lamp glows white hot emitting photons across a continuous spectrum of energies. The intensity variation with wavelength of the electromagnetic radiation from the filament is shown in Fig. 7.1.

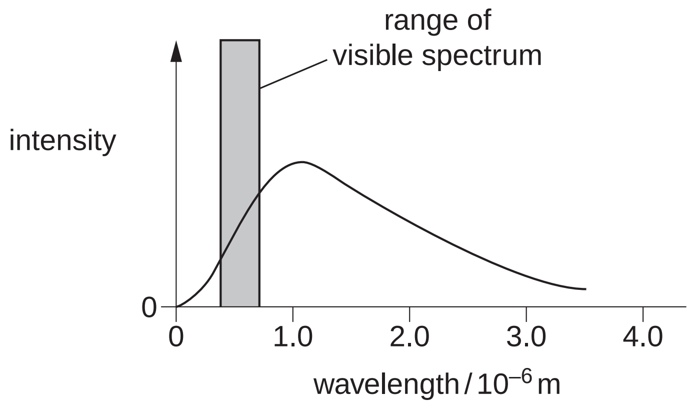

Fig. 7.1

(a) Explain what is meant by

(i) a *photon*

....

.... **[1]**

(ii) a *continuous spectrum*.

....

.... **[1]**

(b) (i) Fig. 7.1 shows that only a small percentage of the energy radiated from the filament lamp is emitted in the visible region. The majority of the energy is emitted in other regions of the electromagnetic spectrum.

1 State the region of the spectrum in which most of the radiation from the lamp is emitted.

.... **[1]**

2 State a simple observation which is evidence for your answer to **1**.

....

.... **[1]**

(ii) The 12 V filament lamp emits 24 W of power as electromagnetic waves. Only 5.0% of this power is converted into photons of visible light of average energy 4.0×10^{-19} J.

Estimate the number of these visible photons emitted from the filament per second.

number = ... s^{-1} **[3]**

(c) The light from the filament is viewed through a diffraction grating, having 300 lines per millimetre. The continuous first order spectrum appears between angles θ of 7° and 12° to the direction of the incident light. See Fig. 7.2.

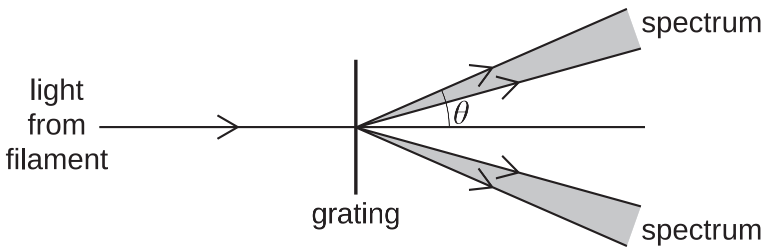

Fig. 7.2

(i) State the colour of the light that is seen at the angle of

7° ....

12° .... **[2]**

(ii) Calculate the angle at which green light of wavelength 5.4×10^{-7} m is observed in this first order spectrum.

angle = ... ° **[3]**

[Total: 12]

3 Fig. 8.1 shows some energy levels of the hydrogen atom. The diagram is not to scale.

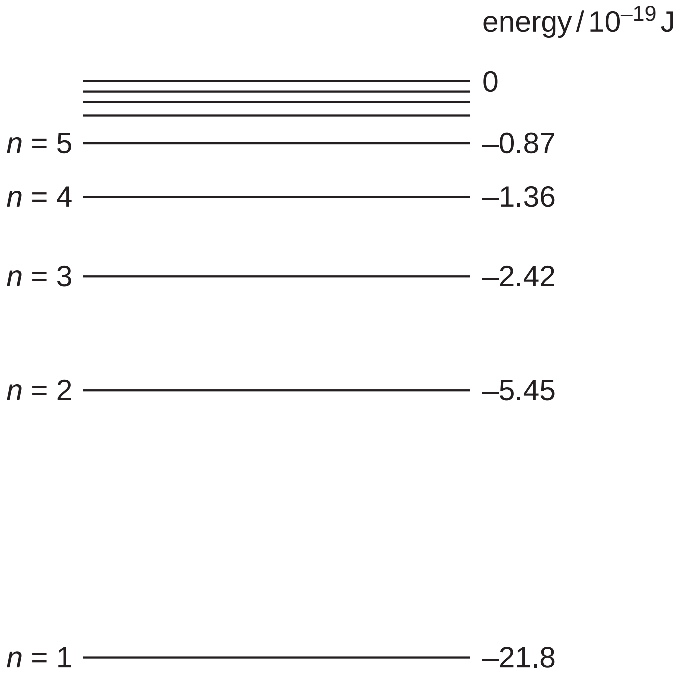

Fig. 8.1

The energy level corresponding to the lowest energy (ground) state of the atom is $n = 1$.

The hydrogen atom is ionised when it absorbs sufficient energy for the electron to escape from the proton; that is, for the energy labelled on Fig. 8.1 to become zero or positive.

(a) **(i)** Draw an arrowed line on Fig. 8.1 to indicate the process of ionisation of an atom initially in its ground state. **[1]**

(ii) Write down the value of the minimum energy required to ionise an atom in its ground state.

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

(b) **(i)** Show that the energy change between levels required for the emission of a photon of wavelength 490 nm is about 4×10^{-19} J.

[2]

(ii) Draw an arrowed line on Fig. 8.1 to indicate the transition which results in the emission of a photon of wavelength 490 nm. **[1]**

(c) In space, a beam of photons of different energies passes through a cloud of atomic hydrogen gas. Explain, with a reason, what is likely to happen to photons of energy 19.38×10^{-19} J and to some of the hydrogen atoms.

....

....

....

....

....

....

....

.... **[3]**

[Total: 8]

4 In 1927 it was shown by experiment that electrons can produce a diffraction pattern.

(a) **(i)** Explain the meaning of the term *diffraction*.

....

....

.... **[1]**

(ii) State the condition necessary for electrons to produce observable diffraction when passing through matter, e.g. a thin sheet of graphite in an evacuated chamber.

....

....

....

.... **[2]**

(b) Show that the speed of an electron with a de Broglie wavelength of 1.2×10^{-10} m is $6.0 \times 10^{6}\ \mathrm{m\,s^{-1}}$.

[3]

(c) The electrons in **(b)** are accelerated to a speed of 6.0×10^6 m s^{-1} using an electron gun shown diagrammatically in Fig. 8.1.

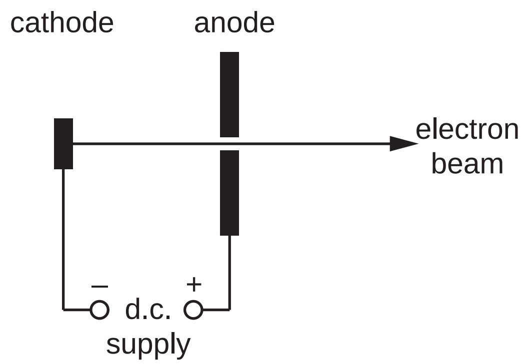

Fig. 8.1

(i) Calculate the potential difference V across the d.c. supply between the cathode and the anode.

V = ………………………………. V **[3]**

(ii) Suggest why, in an electron gun, the cathode is connected to the negative terminal of the supply rather than the positive terminal.

....

....

.... **[1]**

[Total: 10]

5 Lasers are often used to form precision-welded joints in titanium. To form one such joint it is first necessary to increase the temperature of the titanium to its melting point. Fig. 5.1 shows the joint and the volume of titanium to be heated.

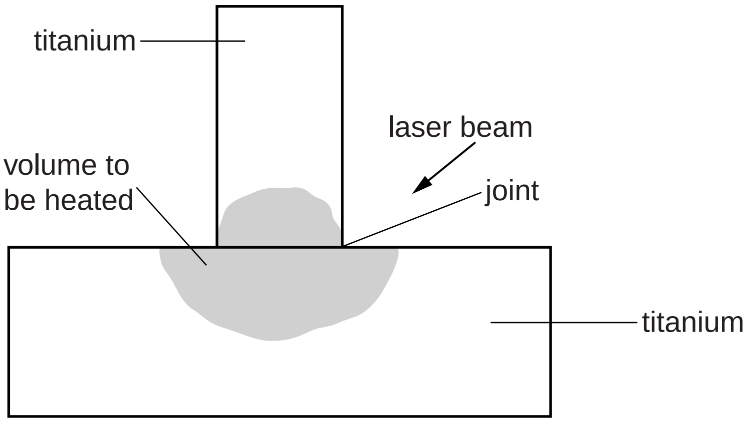

Fig. 5.1

The photon beam from the laser is focused onto the shaded volume of the joint and is converted into thermal energy in the titanium.

(a) The wavelength of the photons is 1.1×10^{-6} m.

Show that the energy of a photon in the beam is 1.8×10^{-19} J.

[1]

(b) Photons are emitted from the laser at a constant rate of $6.3 \times 10^{19}\,s^{-1}$.

Estimate the time taken to raise the temperature of the shaded volume of titanium shown in Fig. 5.1 to melting point. Use the data below for your calculations.

initial temperature = 20 °C
melting point of titanium = 1700 °C
density of titanium = $4.5 \times 10^3\,kg\,m^{-3}$
specific heat capacity of titanium = $520\,J\,kg^{-1}\,K^{-1}$
shaded volume of titanium being heated = $8.1 \times 10^{-12}\,m^3$.

time = ... s **[3]**

(c) In practice it takes a longer time to reach the melting point.
State and explain **two** factors that will increase the time taken.

....

....

....

.... **[2]**

(d) To complete the weld more photons must be focused onto the joint. During this final stage the temperature remains constant. Explain why this is to be expected.

....

....

.... **[1]**