

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 300V.

(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 $1 \times 10^7 \text{ m s}^{-1}$.

[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)

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

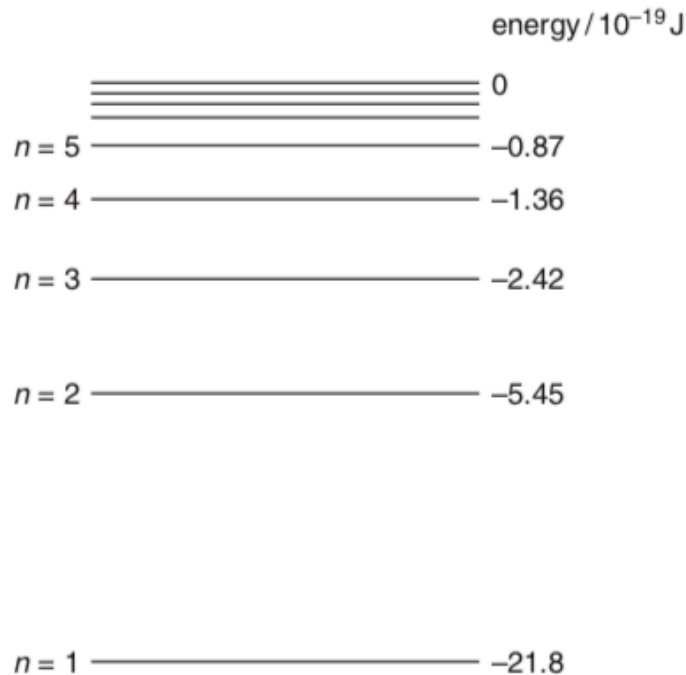


Fig. 8.1

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 490nm 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 490nm. [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 $19.38 \times 10^{-19} \text{ J}$ and to some of the hydrogen atoms.

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..... [3]

[Total: 8]

- (b) A photodiode is a circuit component which can be used to convert a light signal into an electrical one. Fig. 7.1 shows an enlarged cross-section through a photodiode to illustrate how it is constructed. Light incident on the thin transparent conducting surface layer of the diode passes through it to be absorbed in the insulating layer. The energy of each photon is sufficient to release one electron in the insulating layer. The potential difference V applied across the insulating layer causes these electrons to move to one of the conducting layers.

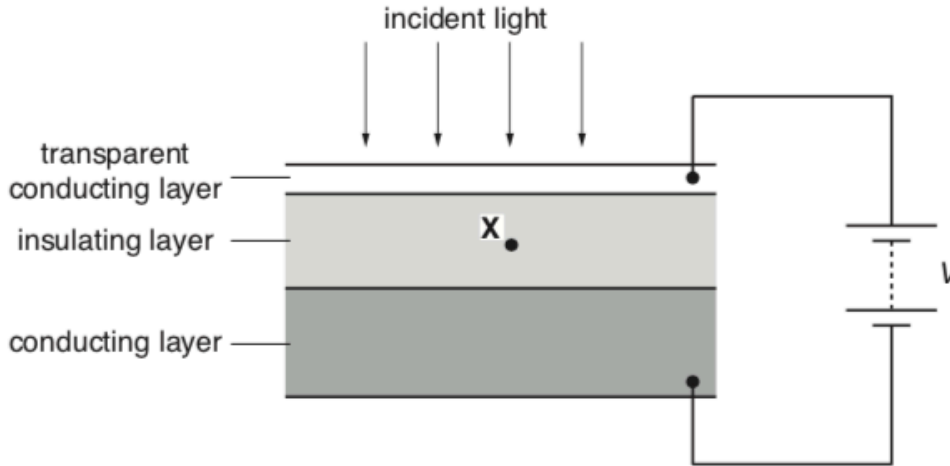


Fig. 7.1

- (i) Draw an arrow on Fig. 7.1 to show the direction of motion of an electron released at point **X** in the centre of the insulating layer. [1]
- (ii) The red light from the laser in (a) is incident on the photodiode. Experiments show that only 20% of the red light photons release electrons in the insulating layer and hence in the circuit of Fig. 7.1. Calculate the current through the photodiode.

current = A [3]

- (iii) Suggest one reason why the efficiency of the photodiode is less than 100%.

.....
 [1]

[Total: 14]

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 6.0×10^6 ms⁻¹.

[3]

- (c) The electrons in (b) are accelerated to a speed of $6.0 \times 10^6 \text{ ms}^{-1}$ using an electron gun shown diagrammatically in Fig. 8.1.

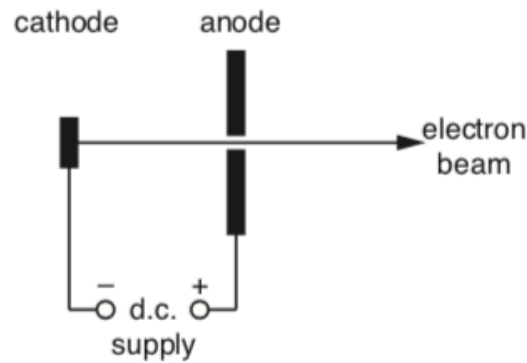


Fig. 8.1

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

$V = \dots\dots\dots V$ [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)

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

energy = J [3]

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.

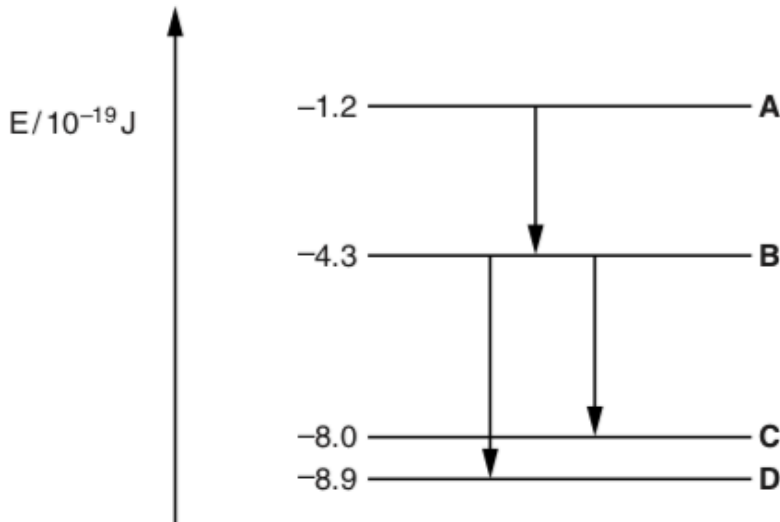


Fig. 6.2

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

6)

This question is about an experiment to measure the Planck constant h using light-emitting diodes (LEDs).

- (a) Each LED used in the experiment emits monochromatic light. The wavelength λ of the emitted photons is determined during the manufacturing process.

When the p.d. across the LED reaches a specific minimum value V_{\min} the LED suddenly switches on emitting photons of light of wavelength λ . V_{\min} and λ are related by the equation $eV_{\min} = hc/\lambda$.

Explain the meaning of this equation in words.

.....

.....

..... [2]

- (b) Describe the experiment that uses the circuit of Fig. 7.1 to generate the data shown in the table. The wavelength value for each LED is provided by the manufacturer.

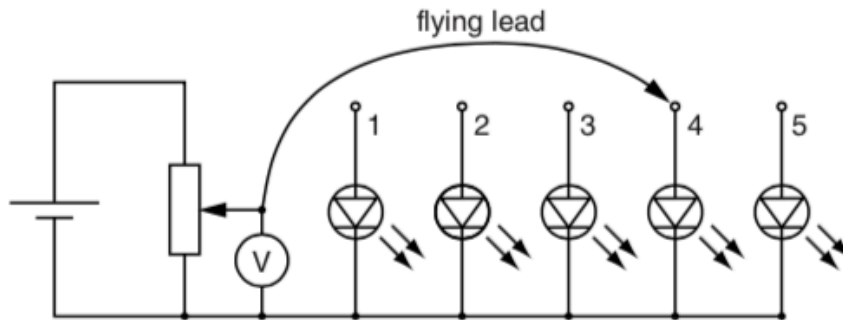


Fig. 7.1

LED	λ / nm	$1/\lambda / 10^6 \text{ m}^{-1}$	average V_{\min} / V
1 red	627	1.59	1.98
2 yellow	590	1.69	2.10
3 green	546	1.83	2.27
4 blue	468		2.66
5 violet	411		3.02

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.....

.....

..... [3]

- (c) (i) Complete the table and use the data to complete the graph of Fig. 7.2. Three of the points have been plotted for you.

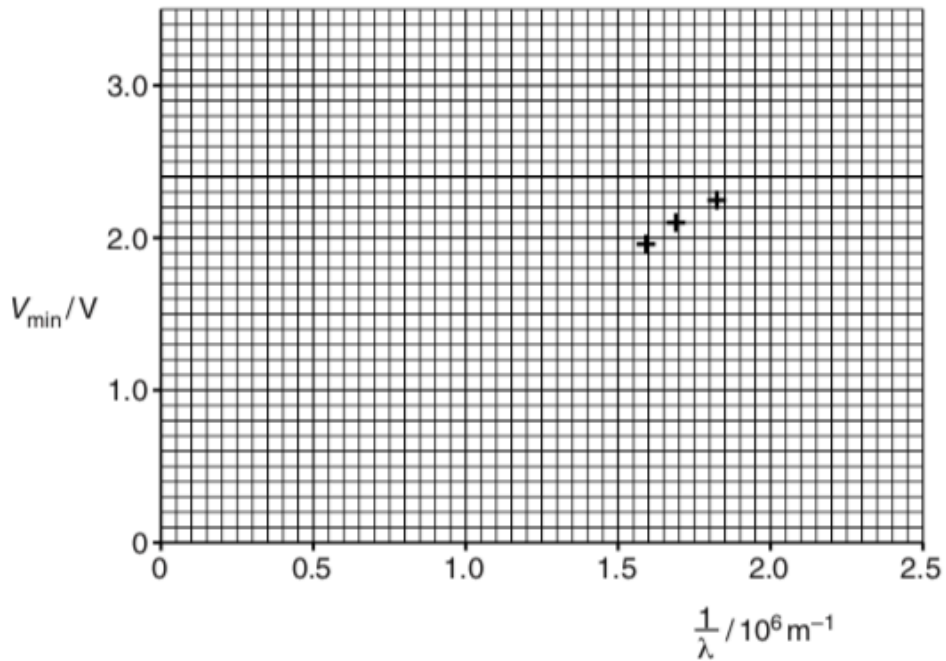


Fig. 7.2

Draw the line of best fit. Show that the gradient is about $1.2 \times 10^{-6} \text{ V m}$. Show your working clearly.

gradient = V m [4]

- (ii) Use the equation given in (a) to show that the gradient of the line in Fig. 7.2 is equal to hc/e .

[2]

- (iii) Calculate a value for the Planck constant using your value in (i) for the gradient of the graph. Show your working.

$h = \dots\dots\dots \text{ Js}$ [2]

[Total: 13]

7)

(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.

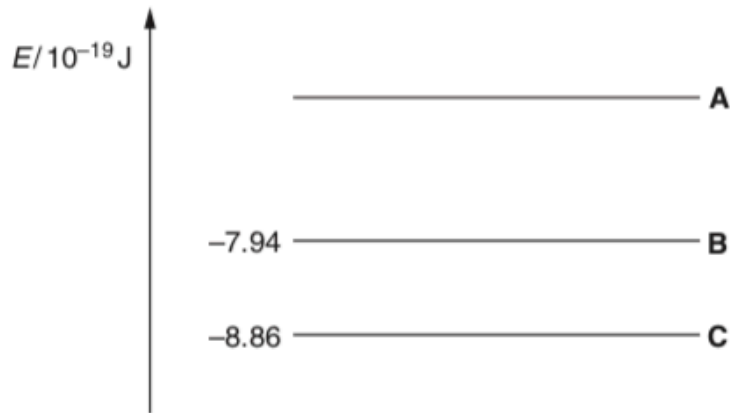


Fig. 7.1

- (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**.

$$E = \dots\dots\dots \text{ J [2]}$$

- (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 $3.3 \times 10^{-6} \text{ m}$.

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

$$\text{angle} = \dots\dots\dots^\circ \text{ [3]}$$

[Total: 15]

8)

This question is about electrons and photons.

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

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

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

(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.

.....
.....
..... [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.

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

[Total: 19]

- (b) Fig. 4.2 shows the positions of the five strongest lines in the emission spectrum of mercury when light from a mercury lamp is passed through a diffraction grating. The lines are labelled **A** to **E** and their wavelengths are shown on the diagram in nanometres.

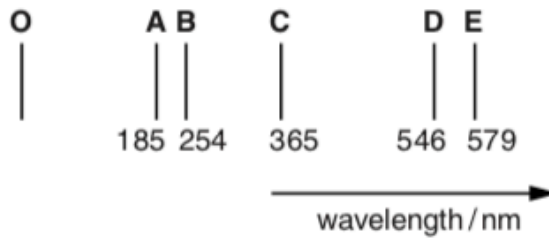


Fig. 4.2

- (i) Fig. 4.3 shows the angular position of line **E** in the first order spectrum and the bright central beam **O** caused by the incident beam of mercury light passing through the grating.

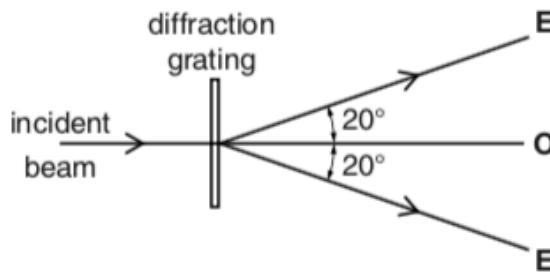


Fig. 4.3

- 1 On Fig. 4.3 add and label the approximate angular position of spectral line **C** in the first order spectrum. [1]
- 2 Use data from Figs 4.2 and 4.3 to calculate the line separation d for the grating.

$d = \dots\dots\dots$ m [3]

- (ii) State which **one** of the wavelengths, **A** to **E**, in Fig. 4.2 has the lowest photon energy.
 [1]

- (iii) State which of the wavelengths, **A** to **E**, in Fig. 4.2 are in the visible region of the spectrum.
 [1]

- (iv) Fig. 4.4 is an energy level diagram showing the electron transition for mercury atoms which results in one of the wavelengths **A** to **E** in Fig. 4.2.

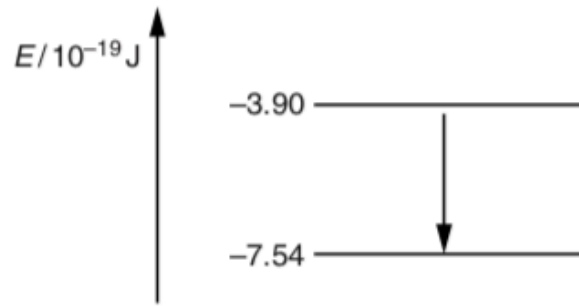


Fig. 4.4

Determine by calculation which one of the wavelengths corresponds to this transition.

wavelength = [3]

- (v) State **one** similarity and **one** difference between a line emission spectrum and a line absorption spectrum for mercury.

similarity

.....

difference

..... [2]

- (vi) Light from a mercury lamp is incident on a calcium surface. The work function of calcium is $4.7 \times 10^{-19} \text{ J}$. Show that a photon of wavelength 254 nm, spectral line **B** in Fig. 4.2, can cause the emission of an electron with maximum kinetic energy $3.1 \times 10^{-19} \text{ J}$.

[3]

11)

(a) (i) The de Broglie equation is often written in the form

$$\lambda = \frac{h}{mv}$$

Explain the meaning of each symbol used in the equation.

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.....
..... [3]

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

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

(iii) The electrons in a typical electron microscope are accelerated through a potential difference of $5.0 \times 10^4 \text{V}$.

1 Show that the final speed of an accelerated electron is about $1.3 \times 10^8 \text{ms}^{-1}$.

Ignore any relativistic effects.

[3]

