

9 (a) For a particular metal surface, it is observed that there is a minimum frequency of light below which photoelectric emission does not occur. This observation provides evidence for a particulate nature of electromagnetic radiation.

(i) State two further observations from photoelectric emission that provide evidence for a particulate nature of electromagnetic radiation.

1. ....

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2. ....

..... [2]

(ii) When electromagnetic radiation of wavelength  $\lambda$  is incident on a metal surface, electrons of maximum kinetic energy  $E_{\text{MAX}}$  are emitted.

1. On Fig. 9.1, sketch the variation with  $1/\lambda$  of  $E_{\text{MAX}}$ .

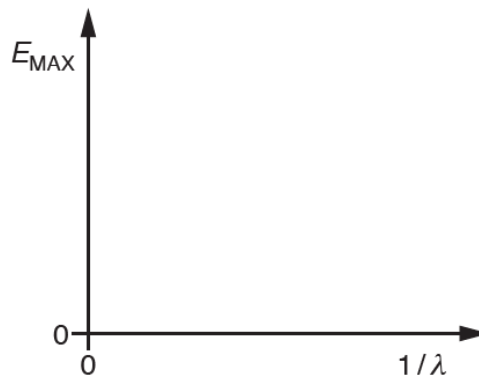


Fig. 9.1

[2]

2. State an equation relating the gradient of the graph drawn on Fig. 9.1 to the Planck constant  $h$ .  
Explain any symbols you use.

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..... [1]

3. Light of a particular wavelength is incident on a metal surface and gives rise to a photoelectric current.

The wavelength is reduced. The intensity of the light is kept constant.

State and explain the effect, if any, on the photoelectric current.

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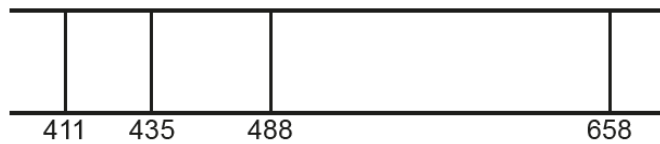
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..... [3]

- (b) Fig. 9.2 shows the visible part of the emission spectrum from hydrogen gas in a laboratory on the Earth. The numbers indicate the wavelength, in nm, represented by each line.



**Fig. 9.2**

- (i) Explain how the emission spectrum provides evidence for the existence of discrete energy levels for the electron in a hydrogen atom.

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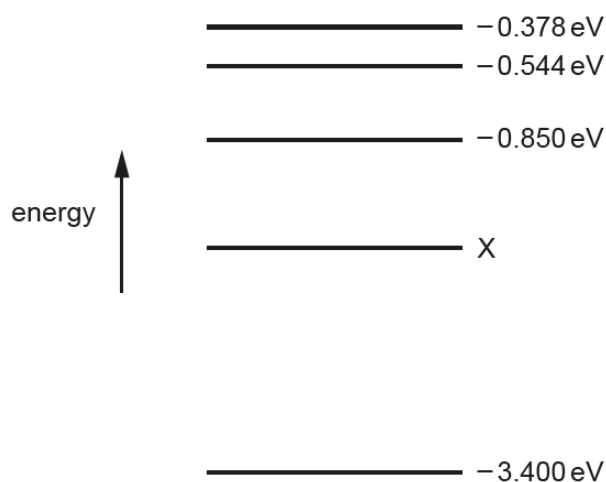
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- (ii) Fig. 9.3 shows five of the energy levels in the hydrogen atom. The wavelengths of radiation shown in Fig. 9.2 relate to transitions to the  $-3.400\text{ eV}$  level in Fig. 9.3.



**Fig. 9.3** (not to scale)

Show that the energy level X is  $-1.51\text{ eV}$ .

[3]

- (c) Electrons are accelerated through a potential difference of  $15\text{ kV}$ . The electrons collide with a metal target and a spectrum of X-rays is produced.

- (i) Calculate the wavelength of the highest energy X-ray photon produced.

wavelength = .....m [2]

- (ii) Describe and explain the changes, if any, in the x-ray spectrum if the accelerating potential is increased.

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..... [4]