1. Which of the following is a correct statement about the e.m.f. of a cell?

A It is equal to the energy transferred from chemical energy per volt.
B It is equal to the energy transferred to thermal energy in the load resistance.
C It is equal to the p.d. measured across the internal resistance of the cell.
D It is equal to the p.d. measured across the terminals of the cell when there is no current.

Your answer ☐ **[1]**

2. Which is an S.I. base unit?

A amp
B coulomb
C ohm
D volt

Your answer ☐ **[1]**

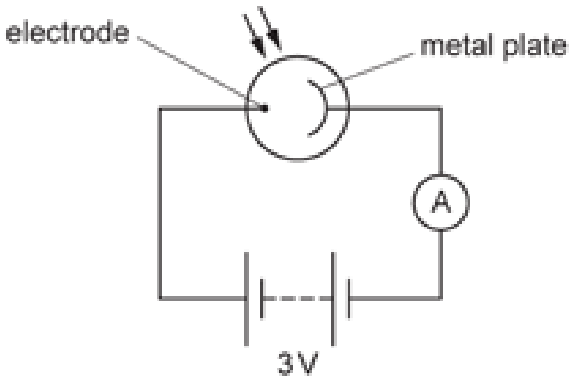
3. Which sequence shows the energies below in **increasing** order of magnitude?

1 The change in kinetic energy of an electron accelerated through a potential difference of 1 V.
2 The kinetic energy of a proton with a velocity of 1000 ms^{-1}.
3 The energy of an X-ray photon with a frequency of 3×10^{17} Hz.

A 1 2 3
B 3 1 2
C 2 1 3
D 1 3 2

Your answer ☐ **[1]**

4. A light meter is used to measure the intensity of electromagnetic radiation. The meter consists of a metal plate and an electrode within an evacuated glass tube. It is connected to a circuit with an ammeter, a battery of e.m.f. 3.0 V and negligible internal resistance.

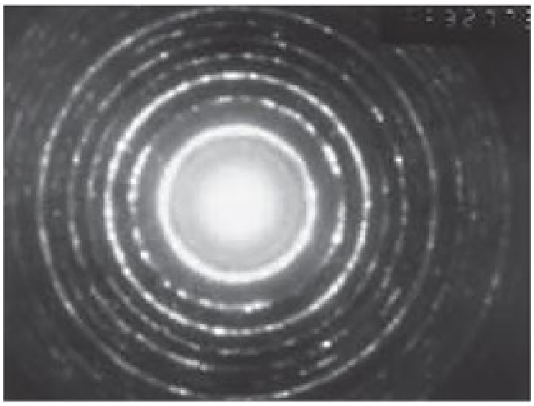


Electromagnetic radiation is incident on the metal plate. Electrons are released due to the photoelectric effect and are attracted to the electrode.

Calculate the work done on an electron as it moves from the metal plate to the electrode.

work done = ...J **[2]**

5. The picture shows an electron diffraction pattern produced by graphite in a cathode-ray tube.



A potential difference (p.d.) 5 kV is used to accelerate the electrons.

i. Calculate the work done *W* on the electrons.

W = ...J **[1]**

ii. Calculate the de Broglie wavelength λ of the accelerated electrons.

λ = ... m **[2]**

iii. Suggest a value for the spacing between the graphite atoms.
Justify your answer.

---

[1]

6.

The capacitor circuit shown in **Fig. 6.1** can be used to smooth oscillating electrical signals.

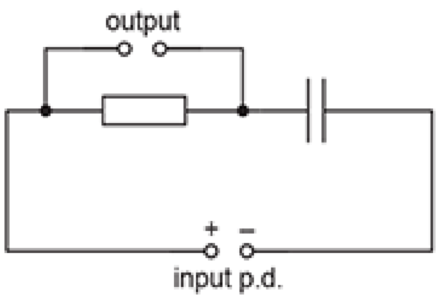


Fig. 6.1

i. **Fig. 6.2** shows the input signal of potential difference (p.d.) *V* against time *t*.

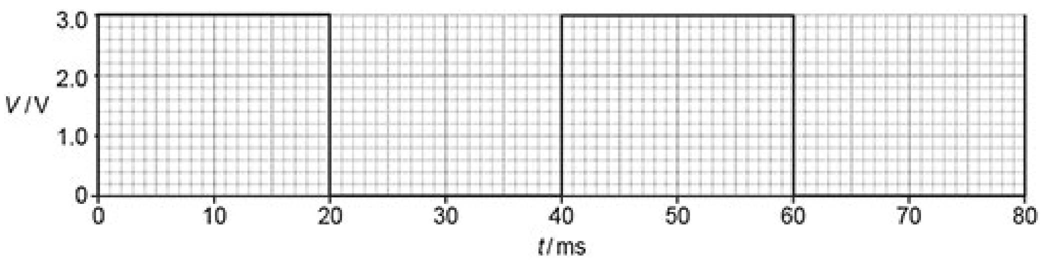


Fig. 6.2

Calculate the frequency *f* of this input signal.

f = ... Hz **[2]**

ii. **Fig. 6.3** shows the variation of the charge Q on the positive plate of the capacitor with time t.

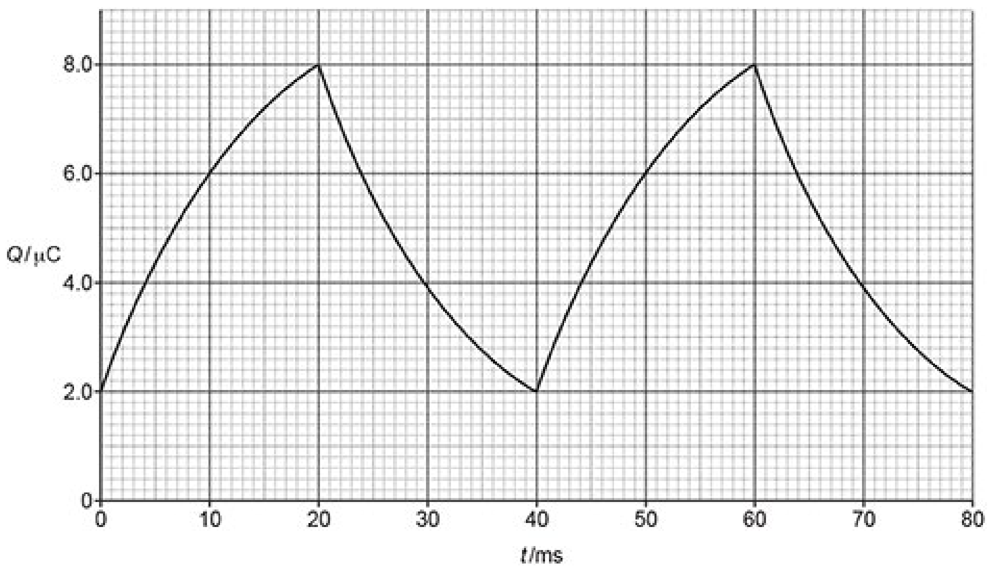


Fig. 6.3

Use a discharging section of the graph in **Fig. 6.3** to determine the time constant of the circuit. Give your answer in ms.

time constant = ... ms **[2]**

iii. By drawing a suitable tangent to the graph in **Fig. 6.3**, calculate the maximum current in the resistor.

maximum current = ...A **[2]**

iv. On **Fig. 6.4** below, sketch the variation of the current I in the resistor with time t. Include an appropriate label and scale on the vertical axis.

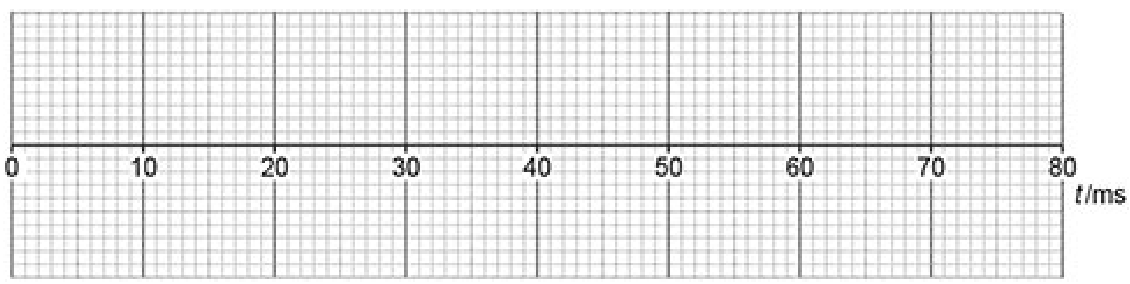


Fig. 6.4

[3]

7(a). The diagram below shows two parallel plates, **E** and **C**, in an evacuated glass tube.

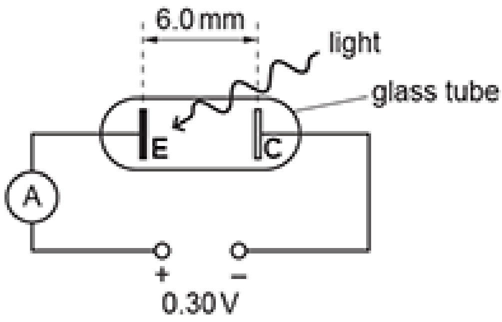


Plate **E** is made from potassium, which is sensitive to light. Plate **C** is not sensitive to light.

The separation between the plates is 6.0 mm and the potential difference between the plates is 0.30 V.

Light of frequency 6.3×10^{14} Hz is incident on plate **E**. The photoelectrons emitted from this plate have **maximum** kinetic energy 0.30 eV (4.8×10^{-20} J). The photoelectrons are repelled by the negative plate **C**. The ammeter reading is zero because these photoelectrons reach plate **C** with zero kinetic energy.

This question is about a photoelectron emitted perpendicular to plate **E** and with an initial kinetic energy of 4.8×10^{-20} J.

i. Show that the magnitude of deceleration of this photoelectron is 8.8×10^{12} ms^{-2}.

[3]

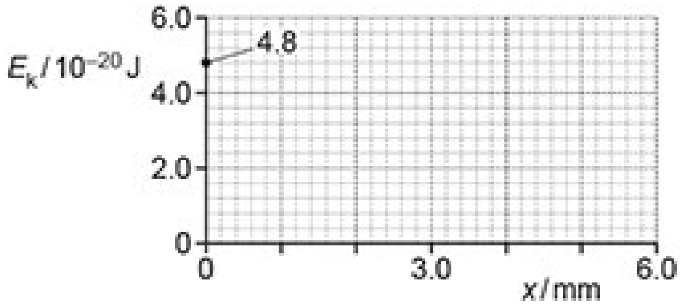
ii. Show that the initial speed of the photoelectron is about 3×10^{5} ms^{-1}.

[2]

iii. Calculate the time *t* taken by the photoelectron to travel from plate **E** to plate **C**.

t = ... s **[2]**

iv. Using the axes shown below, sketch a graph of kinetic energy E_k against distance x from plate **E**.

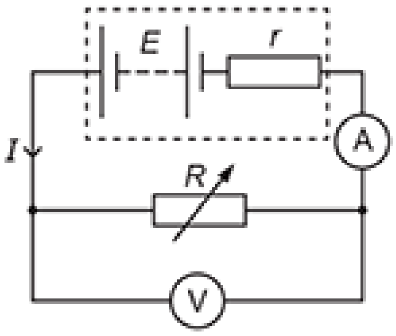


[2]

(b). Explain, in terms of photons, what happens to the ammeter reading when light of frequency greater than 6.3 × 10^{14} Hz is now incident on plate **E**.

[2]

8(a). A battery is connected to a variable resistor.



The variable resistor is made from a length of wire. The resistance of the variable resistor is *R*.
The battery has electromotive force (e.m.f.) *E* and internal resistance *r*. The current in the circuit is *I*.

Compare the e.m.f. of the battery and the potential difference (p.d.) across the variable resistor in terms of energy transfers or changes.

[1]

(b). State which physical quantity of the variable resistor is changed to alter its resistance.

[1]

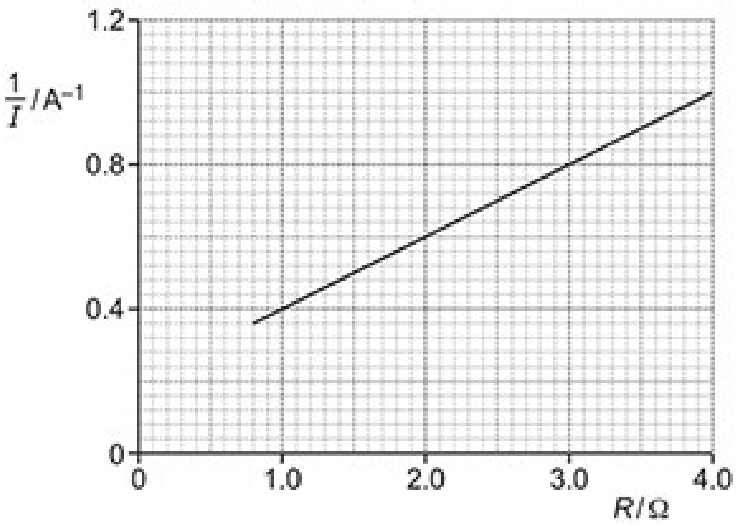
(c). A student connects up the circuit above to determine *r*.

i. Show that $\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$

[2]

ii. The student varies *R* and measures the current *I*.

The student plots a graph of $\frac{1}{I}$ against *R*.



1 Use the graph to determine the power dissipated in the variable resistor when *R* = 3.0 Ω.

power = ... W **[2]**

2 The e.m.f. *E* of the battery is 5.0 V.

Determine *r* from the intercept of the line with the vertical axis.

r = ... Ω **[2]**

9. What is the total energy E gained by N electrons travelling through a potential difference V?

A $E = N \times V$
B $E = V \times 10^{-19}$
C $E = V \times 1.60 \times 10^{-19}$
D $E = N \times V \times 1.60 \times 10^{-19}$

Your answer ☐ **[1]**

10.

Potential difference (p.d.) and electromotive force (e.m.f.) can both be defined in terms of transfer of energy per unit charge.
State one other **similarity** between p.d. and e.m.f.

-- **[1]**

END OF QUESTION PAPER