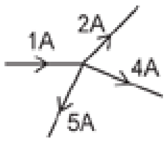
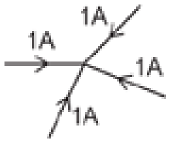
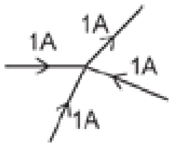
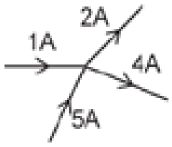
1. The diagrams show the currents entering and leaving a junction in an electric circuit.

Which diagram could be correct?

A 

B 

C 

D 

Your answer ☐ **[1]**

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

A amp
B coulomb
C ohm
D volt

Your answer ☐ **[1]**

3. A copper wire **P** has electrical resistance *R* and number density of charge carriers *n*.

A copper wire **Q** has:

- area of cross section equal to **P**
- twice the length of **P**.

Which row gives the correct values of resistance and number density of charge carriers for **Q**?

	Resistance of Q	Number density of charge carriers in Q
A	$\frac{R}{2}$	n
B	$\frac{R}{2}$	$2n$
C	$2R$	n
D	$2R$	$2n$

Your answer ☐ **[1]**

4. This question is about lightning.

Fork lightning is an electrical discharge that occurs between the bottom of the cloud and the surface of the Earth.

A cloud has a charge of 155 C and is at a height of 2.0 km.

The surface of the Earth has an electrical potential V of 0 V.

i. Assume the cloud acts as a **point** charge.

Calculate the magnitude of the electrical potential V between the cloud and the surface of the Earth.

V = ... V **[2]**

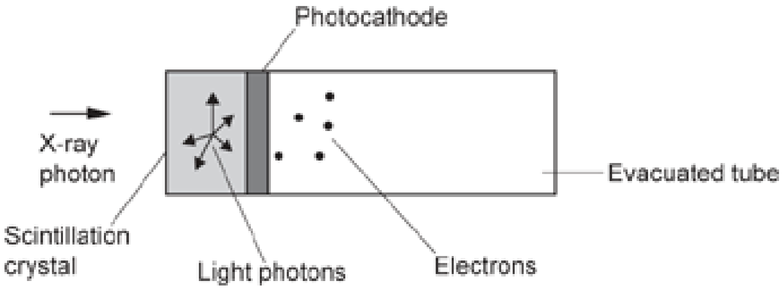
ii. A fork lightning strike has a duration of 25 ms. The cloud discharges at a constant rate. The cloud is uncharged after the strike.

Calculate the number of electrons reaching the ground in 1.0 ms.

number of electrons in 1.0 ms = ... **[3]**

5(a). The diagram shows part of an X-ray telescope which uses a crystal scintillation device to detect low energy X-rays from the stars.

X-rays hit the crystal and cause it to emit visible light photons. These travel to the photocathode in an evacuated tube. The photocathode uses the light photons to produce electrons.



Each X-ray photon detected by the telescope has an energy of 32 keV.

The light photons have a wavelength of 510 nm.

The efficiency of the crystal is 15%.

Show that each X-ray photon produces about 2000 light photons.

[3]

(b). The photocathode has a work function of 2.3 eV.

i. Explain what is meant by the *work function*.

____ **[1]**

ii. Calculate the maximum kinetic energy of the electrons leaving the photocathode.

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

iii. 12 X-ray photons are detected every minute.

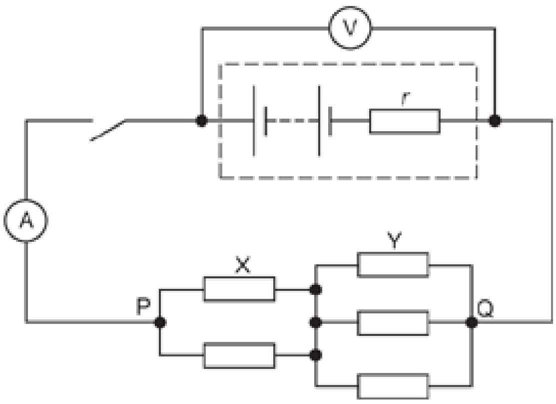
Use your answer to **(a)** to calculate the current *I* leaving the photocathode. Assume that all the photons of light produce photoelectrons.

I = ... A **[2]**

iv. State one other assumption you have made to enable you to calculate the current *I* in **(b)(iii)**.

[1]

6(a). A battery of electromotive force (e.m.f.) *ε* and internal resistance *r* is connected to five identical wire wound resistors in a circuit.



Each resistor between points P and Q has a resistance of 300Ω. Two of the resistors are labelled X and Y as shown.

The table shows the ammeter and voltmeter readings when the switch is open and when the switch is closed.

Switch position	Ammeter reading	Voltmeter reading
open	0.0 mA	4.57 V
closed	18.0 mA	4.50 V

i. Suggest why a student deduces that the e.m.f. *ε* of the battery has the value of 4.57 V.

[1]

ii. Show that the resistance *r* is approximately 3.9 Ω.

[1]

iii. Show that the total resistance of the resistors between P and Q is 250 Ω.

[1]

(b). The switch is closed for 300 s.

Calculate:

i. the energy *E* dissipated in *r*.

E = ... J **[1]**

ii. the number of electrons *N* passing through *r*.

N = ... **[2]**

iii. the ratio

$$\frac{\text{mean drift speed of electrons in resistor X}}{\text{mean drift speed of electrons in resistor Y}}$$

ratio = ... **[2]**

(c). Resistor Y is removed from the circuit.

The switch is closed.

Complete the sentences to state the change, if any, in the meter readings.

Choose from **increases, decreases,** or **stays the same**.

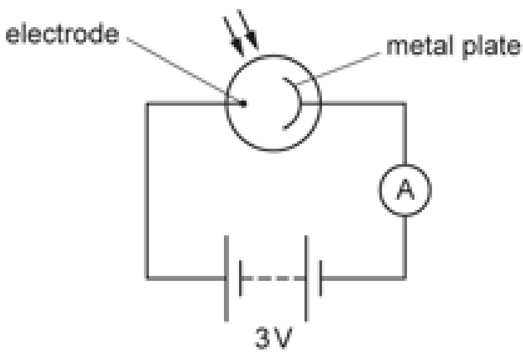
i. The ammeter reading

____ **[1]**

ii. The voltmeter reading

____ **[1]**

7. 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.

i. The reading on the ammeter is proportional to the intensity of the radiation. Use your knowledge of the photoelectric effect to explain why.

[3]

ii. When the light meter is irradiated with monochromatic radiation of frequency 8.2×10^{15} Hz, the number of electrons emitted every second is 3.1×10^{18} s^{-1}.

The surface area of the metal plate normal to the incident radiation is 4.9×10^{-3} m^2.

Determine the intensity of the radiation.

intensity = ...W m^{-2} **[4]**

8. An uncharged oil drop gains a charge of $+4.0 \times 10^{-18}$ C.

What is the change in the number of electrons on the oil drop?

A Gained 25 electrons
B Gained 64 electrons
C Lost 25 electrons
D Lost 64 electrons

Your answer ☐ **[1]**

9. Two copper wires, **X** and **Y**, are connected in series to a source of e.m.f.

The length of **X** is equal to the length of **Y**.
The cross-sectional area of **X** is greater than the cross-sectional area of **Y**.

Which **two** quantities are equal in value for both **X** and **Y**?

A charge carrier density, current
B charge carrier density, electron drift velocity
C current, resistance
D electron drift velocity, resistance

Your answer [ ] **[1]**

10. A student experiments with microwaves emitted from a transmitter. The frequency *f* of the microwaves from the transmitter can be adjusted.

The microwaves are produced by an alternating current in the transmitter.

In one experiment, *f* is 11 GHz. In a wire in the transmitter, the magnitude of the **maximum** alternating current is 20 mA. The wire has cross-sectional area 1.4×10^{-8} m^2 and is made of a metal with free electron number density 8.0×10^{28} m^{-3}.

i. Show that the maximum drift velocity of each free electron in the wire is about 0.1 mms^{-1}.

[3]

ii. The student models the average motion of the free electrons in the wire as simple harmonic motion.

Use your answer to **(i)** to calculate the amplitude *A* of this motion.

A = ... m **[3]**

iii. Without further calculation, explain how the maximum acceleration of a free electron varies as the frequency *f* is adjusted, provided that the maximum alternating current remains constant.

[2]

11.

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

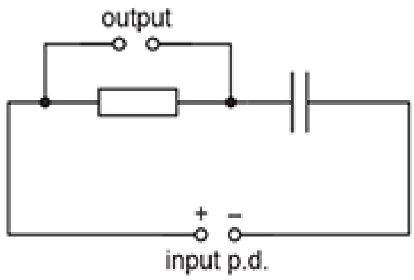


Fig. 6.1

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

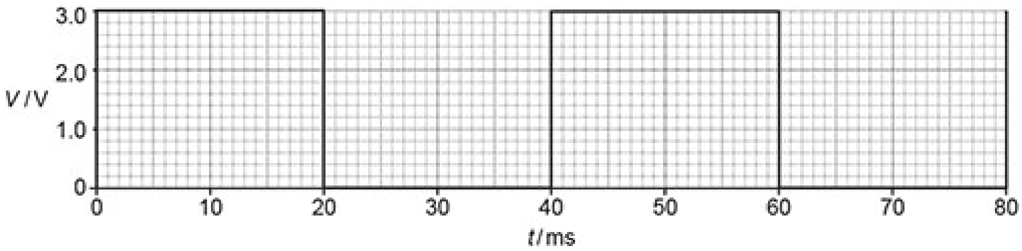


Fig. 6.2

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*.

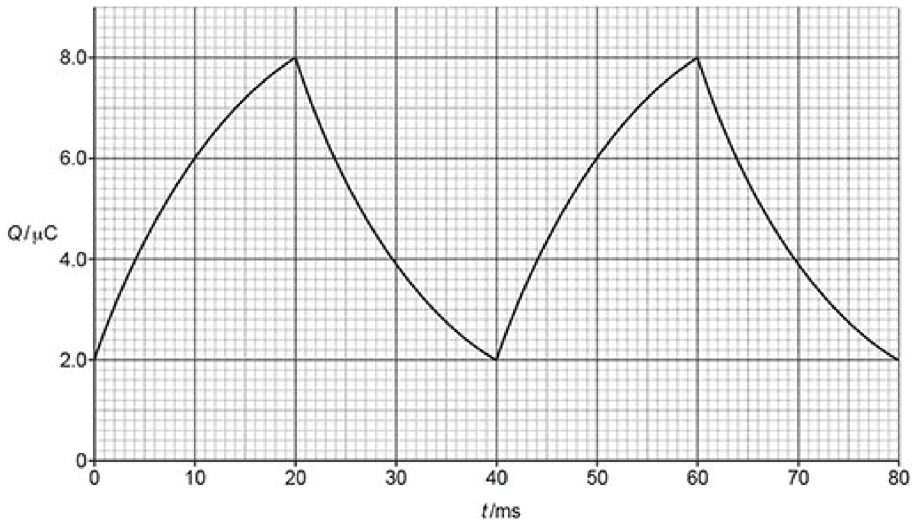


Fig. 6.3

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.

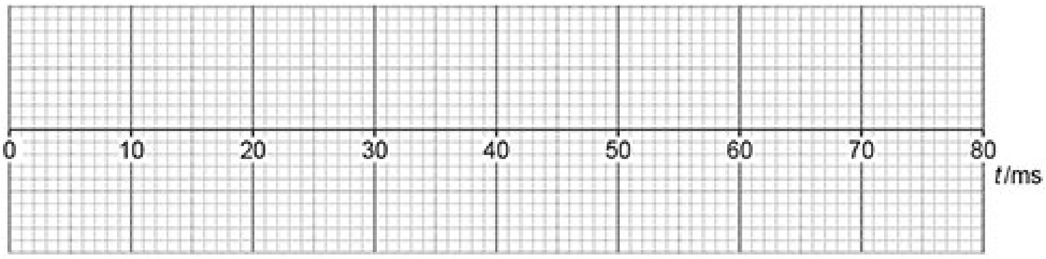


Fig. 6.4

[3]

12(a). A gamma camera has several important components including a collimator, scintillator and photomultiplier tubes.

Suggest why the collimator needs to be long and narrow.

[1]

(b). State the function of the scintillator.

[1]

(c). In a single photomultiplier tube, a photon of light produces a 0.32 μA pulse of current for a duration of 1.2 ns.

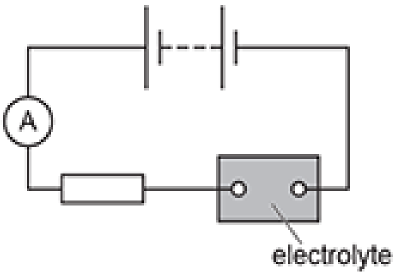
Calculate the number of electrons responsible for this pulse of current.

number of electrons = ... **[2]**

(d). State one diagnostic application of a gamma camera.

[1]

13. A current is present in the circuit below.



The resistor is made from a length of wire.

Which row gives the correct charge carriers in the resistor and in the electrolyte?

	Charge carriers in the resistor	**Charge carriers in the electrolyte**
A	Electrons	Electrons
B	Electrons	Ions
C	Electrons and protons	Ions and electrons
D	Electrons and ions	Ions and protons

Your answer ☐ **[1]**

14.

A power supply of electromotive force (e.m.f.) 14.4 V and negligible internal resistance is connected by two identical metal wires to two filament lamps, as shown in **Fig. 25.3**.

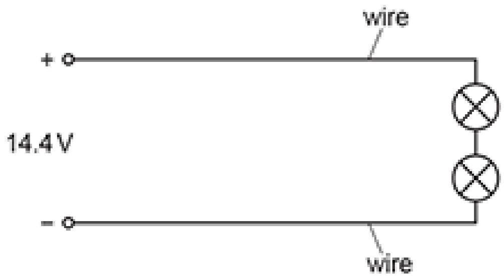


Fig. 25.3

The current in the circuit is 3.0 A.
The potential difference across **each** lamp is 6.0 V.
The **total** length of the metal wire is 25.0 m. The cross-sectional area of the wire is 0.54 mm^2.

i. Calculate the resistivity ρ of the metal from which the wire is made.

ρ = ... Ω m **[4]**

ii. The number of electrons per unit volume n in the metal wire is 8.5×10^{28} m^{-3}.

Calculate the mean drift velocity v of the electrons in the metal.

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

15. 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]**

16. A total of 3.8×10^{7} electrons flow through a wire in a time of 1.2 μs.
What is the current in the wire?

A 6.1×10^{-12} A
B 7.3×10^{-12} A
C 5.1×10^{-6} A
D 3.2×10^{13} A

Your answer ☐ **[1]**

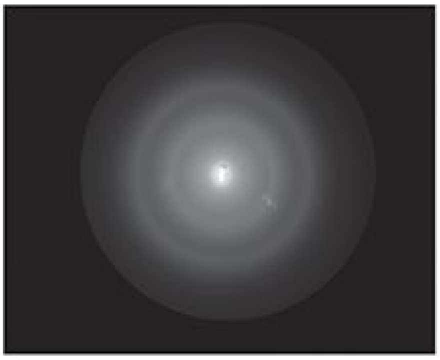
17. Which term is **not** used in either of Kirchhoff's two laws?

A charge
B current
C electromotive force
D potential difference

Your answer [ ] **[1]**

18. A student is investigating electron diffraction. A beam of electrons is directed towards a thin slice of graphite in an evacuated tube.

The electrons are accelerated by a potential difference of 1800 V. The diagram below shows the pattern formed on the fluorescent screen of the evacuated tube.



The relationship between the de Broglie wavelength λ and the accelerating potential difference V is $\lambda = \frac{h}{\sqrt{2meV}}$

where m is the mass of the electron and e is the elementary charge.

Calculate the momentum p of an electron.

p = ... kg m s^{-1} **[2]**

END OF QUESTION PAPER