Question 1

(*c*) **Define the unit of charge, the coulomb. State Coulomb's law.**

1 C = charge that passes when 1 A flows for 1 s 6

correct statement of Coulomb's law 3

Calculate the force of repulsion between two small spheres when they are held 8 cm apart in a vacuum. Each sphere has a positive charge of +3 μC.

$F = \frac{q_1 q_2}{4\pi \varepsilon_0 d^2}$ 3

correct substitution 3

$F = 12.64$ N *(–1 for omission of or incorrect units)* 3

Copy the diagram above and show on it the electric field generated by the charges. Mark on your diagram a place where the electric field strength is zero.

correct curved deviation of the field lines on interaction 3

correct direction of field 3

(neutral/null) point marked halfway between charges 4

Question 2

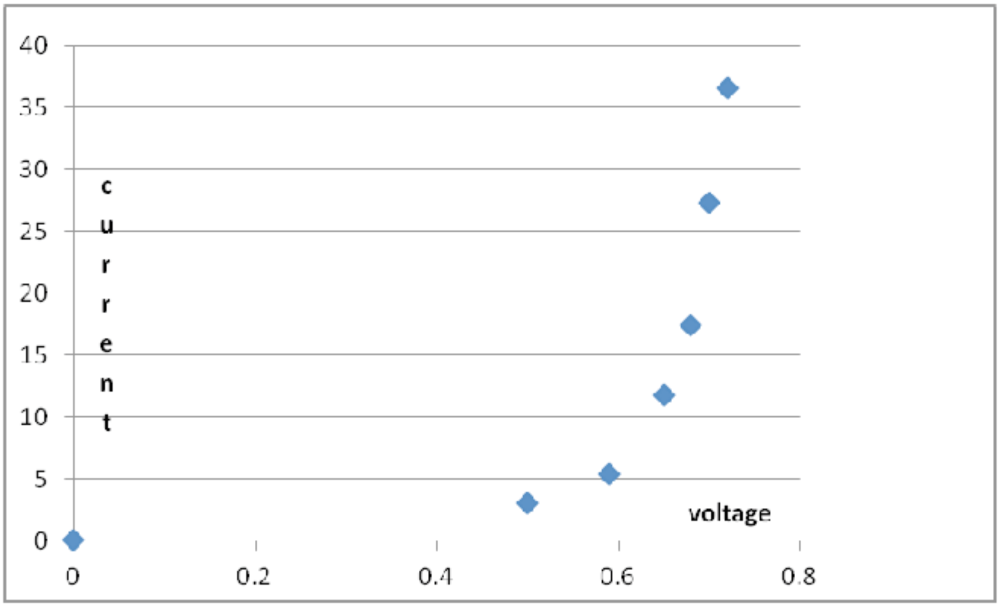
Draw a circuit diagram used by the student.

apparatus: p.s.u., ammeter, voltmeter, diode	**(−1 per missing item)**	3
correct arrangement		3
diode in forward bias (state/imply)		3

How did the student vary and measure the potential difference?

vary using rheostat /variable resistor / dial on (variable) p.s.u.		3
measure p.d. from voltmeter (across diode – stated or implied)		3

Using the data, draw a graph to show how the current varies with the potential difference for the semiconductor diode.



label axes correctly		3
plot points	**(−1 per each incorrect point)**	2×3
good distribution	**(−1 if not drawn from the origin)**	3

Does the resistance of the diode remain constant during the investigation? Justify your answer.

no / 'resistance not constant'		3
I not proportional to V or equivalent, e.g. 'graph is not a straight line through origin'.	**(−1 if 'through origin' omitted)**	3

The student continued the experiment with the connections to the semiconductor diode reversed.
What adjustments should be made to the circuit to obtain valid readings?

microammeter used (instead of ammeter/milliammeter) // voltmeter placed across diode and microammeter, etc.

any *two* 4 + 3

Question 3

(*c*) List the factors that affect the heat produced in a current-carrying conductor.

resistance, current (squared), time, (any valid answer) 3+2+2

An electric cable consists of a single strand of insulated copper wire. The wire is of uniform cross-sectional area and is designed to carry a current of 20 A. To preserve the insulation, the maximum rate at which heat may be produced in the wire is 2.7 W per metre length.

Calculate: (i) the maximum resistance per metre of the wire 3

$$P = RI^2$$

$$2.7 = R(20)^2 \quad 3$$

$$R = 6.75\times10^{-3}\,\Omega \quad 3$$

(–1 for omission of or incorrect unit)

(ii) the minimum diameter of the wire.

3

$$\rho = \frac{RA}{l}$$

3

$$r^2 = \frac{\rho l}{\pi R}$$

3

$$r^2 = \frac{(1.7\times10^{-8})(1)}{\pi(6.75\times10^{-3})} \quad // \; 8.017\times10^{-7}$$

3

$$r = 9.0\times10^{-4}\,\text{m} \;\; / \;\; 0.9\,\text{mm} \;\; / \;\; \text{diameter} = 1.8\,\text{mm}$$

(–1 if value for diameter not given in final answer; –1 for omission of or incorrect unit)

Question 4

(*d*)

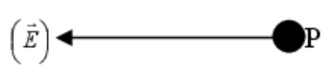
Define electric field strength and give its unit of measurement.

force // $E = F/q$ 3

per unit charge // correct notation 3

$N\,C^{-1}$ / $V\,m^{-1}$ 3

Copy the diagram into your answerbook and show on it the direction of the electric field at point P. 9



3

Calculate the electric field strength at P.

$$E = \frac{q}{4\pi\varepsilon d^2} \;\; / \;\; F = \frac{q_1 q_2}{4\pi\varepsilon d^2} \quad 3$$

$$\text{total field at P: } E_{total} = \frac{1}{4\pi\varepsilon}\left[\frac{q_1}{d_1^2} + \frac{q_2}{d_2^2}\right] \quad 3$$

$$E_{total} = \frac{1}{4\pi\varepsilon}\left[\frac{2\times10^{-6}}{(0.1)^2} + \frac{5\times10^{-6}}{(0.15)^2}\right] \quad 3$$

$$E_{total} = 3.77\times10^{6}\ \text{NC}^{-1}\ (\text{direction indicated}) \quad 3$$

(–1 for omission of or incorrect units) 15

Under what circumstances will point discharge occur?

large electric field strength / potential at a point / high charge density at a point 4

4

Question 5

(*g*) What are the charge carriers when an electric current
(i) passes through a semiconductor; (ii) passes through an electrolyte?

(i) electrons and (positive) holes 4
(ii) ions 3

Question 6

(*h*) **State the principle on which the definition of the ampere is based.**
force between (two) conductors // current-carrying conductor experiences a force 4
carrying current // in a magnetic field 3
[correct formula … 7 marks]

Question 7

Question 8

Define electric field strength and give its unit of measurement.

force // $(E=)F/q$ 3

per unit charge // correct notation 3

N C^{-1} or V m^{-1} 3

Describe how an electric field pattern may be demonstrated in the laboratory.

apparatus oil, metal plates, container, semolina, H.T. **(-1 for each omission)** 3

arrangement correct arrangement 3

procedure switch on power (state or imply) 3

observation semolina particles line up (to show field pattern) 3

The dome of a Van de Graff generator is charged. The dome has a diameter of 30 cm and its charge is 4 C. A 5 μC point charge is placed 7 cm from the surface of the dome.

Calculate:

(i) the electric field strength at a point 7 cm from the dome

(For +1 C at point P):

formula: $(E=)F=\dfrac{q_1q_2}{4\pi\varepsilon d^2}$ 3

substitution: $(E=)F=\dfrac{(1)(4)}{4\pi(8.9\times10^{-12})(0.22)^2}$ **(-1 if 0.07 used instead of 0.22 m)** 3

answer: $E = 7.39 \times 10^{11}$ N C^{-1} **(-1 for omission of or incorrect units)** 3

[Candidates may work with E or F initially but must conclude with answer showing E … otherwise -1]

(ii) the electrostatic force exerted on the 5 μC point charge.

formula: $F = E\ q$ 3

answer: $F = (7.39 \times 10^{11})(5 \times 10^{-6})$ or $F = 3.69 \times 10^{6}$ N **(-1 for omission of or incorrect units)** 3

All the charge resides on the surface of a Van de Graff generator's dome. Explain why.

like charges repel 3

charges are a maximum distance apart (on <u>outside</u>/<u>surface</u> of dome) 3

Describe an experiment to demonstrate that total charge resides on the outside of a conductor.

apparatus: metal can, gold leaf electroscope, proof plane **(-1 for each omission)** 3

procedure: charge metal can and use proof plane to test inside and outside 3

observation: leaves on g.l.e. deflect for outside sample only 3

conclusion: charge resides on outside only 3

(experiment could also be performed using a butterfly net)

Give an application of this effect.

electrostatic shielding / co-axial cable / TV (signal) cable
/ to protect persons or equipment, enclose them in hollow conductors
/Faraday cages (there is no electric field inside a closed conductor), etc.

any relevant application 2

(permittivity of free space = 8.9×10^{-12} F m^{-1})

Question 8

(f) **An RCD is rated 30 mA. Explain the significance of this current. (7)**

RCD <u>trips</u> /<u>switches off</u> / <u>breaks circuit</u> (at 30 mA or greater) 7

Question 9

(g) **Why is Coulomb's law an example of the inverse square law? (7)**

F α	// force inversely proportional to	4
$1/d^2$	// distance squared	3

[Formula or expression …. 3 marks. Specific example, e.g. $d \times 2 \rightarrow F/4$ … 7 marks]

Question 10

Question 9

What is an electric current? Define the ampere, the SI unit of current. (12)

flow of <u>charge</u> / <u>electrons (and + holes)</u> 3

two (infinitely) long parallel wires (of negligible cross-sectional area) 3
1 m apart in vacuum 3
experience a force of 2×10^{-7} N per metre (length) 3

Describe an experiment to demonstrate the principle on which the definition of the ampere is based. (15)

power supply , <u>(two) aluminium(foil) strip(s)</u>/ <u>conducting strip(s)</u> 3
correct arrangement (maybe shown in diagram) 3
(indicate means of keeping) strips parallel 3
switch on current 3
strips <u>move</u> / <u>repel</u> 3

Sketch a graph to show the relationship between current and time for
(i) alternating current;
(ii) direct current. (9)

(i) axes labelled (I and t) 3
sinusoidal curve (at least one full wave) 3
[-1 if + and – current not shown]
(ii) (axes labelled if not already done in a.c. graph showing) correct curve 3

The peak voltage of the mains electricity is 325 V. Calculate the rms voltage of the mains? (6)

$V_{max} = \sqrt{2}\ V_{rms}$ 3
$V_{rms} = 325/\sqrt{2}$ / 229.81 / 230 V **(unit not required)** 3

What is the resistance of the filament of a light bulb, rated 40 W, when it is connected to the mains? (9)
$P = V^2 / R$ 3
$40 = (229.81)^2 / R$ 3
$R = 1320(.32)\ \Omega$ [$R = 1322(.5)\ \Omega$ if $V_{rms} = 230$ V used in calculation] 3
(-1 for omission of or incorrect unit)

Explain why the resistance of the bulb is different when it is not connected to the mains. (5)

cold <u>filament</u> /<u>coil</u>	// hot <u>filament</u> /<u>coil</u>	3
has lower resistance	// has higher resistance	2

'*resistance of coil depends on temperature* '
/ *different coil temperatures result in different resistance (values)*
/ *heating changes resistance of coil* (3)

Question 11

Read the following passage and answer the accompanying questions.

The growth of rock music in the 1960s was accompanied by a switch from acoustic guitars to electric guitars. The operation of each of these guitars is radically different.
The frequency of oscillation of the strings in both guitars can be adjusted by changing their tension. In the acoustic guitar the sound depends on the resonance produced in the hollow body of the instrument by the vibrations of the string. The electric guitar is a solid instrument and resonance does not occur.
Small bar magnets are placed under the steel strings of an electric guitar, as shown. Each magnet is placed inside a coil and it magnetises the steel guitar string immediately above it. When the string vibrates the magnetic flux cutting the coil changes, an emf is induced causing a varying current to flow in the coil. The signal is amplified and sent to a set of speakers.
Jimi Hendrix refined the electric guitar as an electronic instrument. He showed that further control over the music could be achieved by having coils of different turns.

(Adapted from Europhysics News (2001) Vol. 32 No. 4)

(a) **How does resonance occur in an acoustic guitar?** (7)
energy is transferred from strings to hollow body / sound box /air within 4
both vibrate at the same frequency 3

(b) **What is the relationship between frequency and tension for a stretched string?** (7)
frequency proportional to / $f \;\alpha$ 4

square root of tension / $\sqrt{T}$ 3

(c) **A stretched string of length 80 cm has a fundamental frequency of vibration of 400 Hz. What is the speed of the sound wave in the stretched string?** (7)
$v = f\lambda$ 4
$v = 400(1.6)$ / 640 m s^{-1} **(-1 for omission of or incorrect units)** 3

(d) **Why must the strings in the electric guitar be made of steel?** (7)
any reference to *magnetism* 7

(e) **Define magnetic flux.** (7)
$(\Phi =)\ BA$ 4
give notation 3

(f) **Why does the current produced in a coil of the electric guitar vary?** (7)
(induced) emf / flux varies (due to amplitude of vibrating string) 7

(g) **What is the effect on the sound produced when the number of turns in a coil is increased?** (7)
louder sound / greater (sound) intensity) / greater amplitude 7

(h) **A coil has 5000 turns. What is the emf induced in the coil when the magnetic flux cutting the coil changes by 8×10^{-4} Wb in 0.1 s?** (7)

$E = (-)N\Delta\phi / \Delta t$ **(-1 if N omitted)** 4

$E = 5000(8 \times 10^{-4} / 0.1)$ / 40 V 3
(-1 for omission of or incorrect units)

Question 12

Question 10

Define electric field strength. (6)

$E = F/Q$ // force per 3

notation // unit charge 3

State Coulomb's law of force between electric charges. (6)

force proportional to product of charges // $F = Q_1Q_2/4\pi\varepsilon r^2$ // $F \propto Q_1Q_2/r^2$ 3

inversely proportional to square of distance // notation // notation 3

Why is Coulomb's law an example of an inverse square law? (6)

(because) F is proportional to $1/d^2$ / as distance is doubled force decreases by a factor of 4 6

Give two differences between the gravitational force and the electrostatic force between two electrons. (6)

gravitational force is much smaller (than the electrostatic force) 3

gravitational force is attractive, electrostatic force is repulsive 3

Describe an experiment to show an electric field pattern. (12)

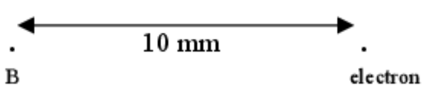
high voltage /H.T / E.H.T. and two metal plates /electrodes 3

semolina and oil in container 3

connect a (high) voltage to the plates (in container) 3

semolina lines up in the field 3

Calculate the electric field strength at the point B, which is 10 mm from an electron. (9)



E or $F = Q/4\pi\varepsilon d^2$ 3

$= (1.6 \times 10^{-19})/4\pi(8.9 \times 10^{-12})(0.01)^2$ 3

$E = 1.4 \times 10^{-5}$ N C^{-1} 3

(-1 for omission of or incorrect unit)

What is the direction of the electric field strength at B? (3)

<u>towards the electron</u> / <u>to the right</u> 3

A charge of 5 μC is placed at B. Calculate the electrostatic force exerted on this charge. (8)

(permittivity of free space = 8.9×10^{-12} F m^{-1}; charge on the electron = 1.6×10^{-19} C)

$F = Eq$ or $F = (1.4 \times 10^{-5})(5 \times 10^{-6})$ 3

$= 7.2 \times 10^{-11}$ N {accept range: $(7.1 \sim 7.2)10^{-11}$ N} (-1 for omission of or incorrect unit) 3

towards the electron 2

Question 13

(g) **A pear-shaped conductor is placed on an insulated stand is shown. Copy the diagram and show how the charge is distributed over the conductor when it is positively charged. (7)**

concentration of charge at pointed end 4

charge indicated throughout the conductor 3

Question 14

(*a*) **State Coulomb's law.**

force proportional to product of charges // $F \,\alpha\, \frac{q_1 q_2}{d^2}$ / $F = k\frac{q_1 q_2}{d^2}$ / $F = \frac{q_1 q_2}{4\pi\varepsilon d^2}$ 3

(force) inversely proportional to square of distance // correct notation 3

Two identical spherical conductors on insulated stands are placed a certain distance apart. One conductor is given a charge *Q* while the other conductor is given a charge 3*Q* and they experience a force of repulsion *F*. The two conductors are then touched off each other and returned to their original positions. What is the new force, in terms of *F*, between the spherical conductors?

$F = \frac{Q(3Q)}{4\pi\varepsilon d^2}$ / $\frac{(3Q^2)}{4\pi\varepsilon d^2}$ // $F \,\alpha\, (Q)(3Q)$ 6

$F' = \frac{2Q(2Q)}{4\pi\varepsilon d^2}$ / $\frac{4Q^2}{4\pi\varepsilon d^2}$ // $F' \,\alpha\, (2Q)(2Q)$ 6

$F' = \frac{4}{4\pi\varepsilon d^2}\left(\frac{4\pi\varepsilon d^2 F}{3}\right)$ // $\frac{F'}{F} = \frac{4Q^2}{3Q^2}$ 3

$F' = \frac{4}{3}F$ // $F' = \frac{4}{3}F$ 3

(*b*) **Draw a labelled diagram of an electroscope.**

(metal) cap, labelled leaves, chassis/frame **(–1 if no label)** 3

Why should the frame of an electroscope be earthed?

p.d. between leaves and <u>chassis</u>/<u>frame</u> (determines degree of deflection of leaves) / for safety 3
(reference to 'zero volt' … 3 marks)

Describe how to charge an electroscope by induction.

hold (say) + charged rod near cap of (uncharged) GLE 3

earth cap (touch with finger) 3

remove finger and then remove + rod 3

(*c*) **How does a full-body metal-foil suit protect an operator when working on high voltage power lines?**

(suit) blocks out external electrical fields / no field lines inside (hollow conductor) 5

Describe an experiment to investigate the principle by which the operator is protected.

apparatus 3

procedure 3

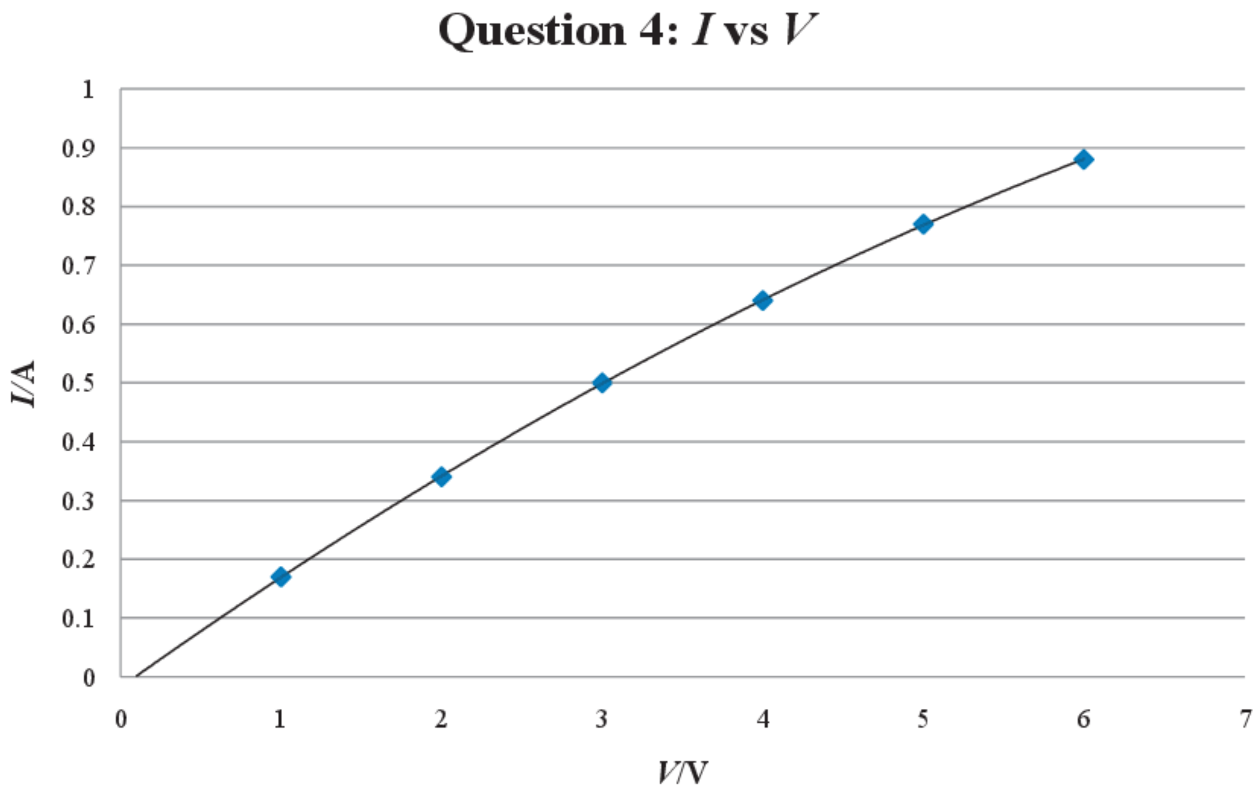
observation 3

conclusion 3

Question 15

residual current device; miniature circuit breaker **(6 × 1 + 1)**

Question 16



4. **A student was asked to investigate the variation of current with potential difference for a thin metallic conductor. The student set up a circuit using appropriate equipment. The student recorded the values of the current *I* passing through the conductor for the corresponding values of potential difference *V*. The recorded data are shown in the table.**

V/V	1.0	2.0	3.0	4.0	5.0	6.0
I/A	0.17	0.34	0.50	0.64	0.77	0.88

Draw and label the circuit diagram used by the student.

apparatus: p.s.u. / battery, ammeter, voltmeter 3
ammeter in series with conductor 3
voltmeter in parallel with conductor 3
(–1 if no label)

Name the device in the circuit that is used to vary the potential difference across the conductor.

variable p.s.u. / variable resistor (rheostat) / potential divider 6

Explain how the student used this device to vary the potential difference.

e.g. rotated the dial / moved sliding contact 3

Use the data in the table to draw a graph on graph paper to show the variation of current with potential difference.

label axes correctly 3
plot six points correctly *(–1 for each incorrectly plotted point)* 3
good distribution (for curved or linear graph) 3
(–1 for inappropriate scale)

Use your graph to find the value of the resistance of the conductor when the current is 0.7 A.

$V \approx 4.5$ V (when $I = 0.7$ A on graph) // slope method 3
$R \approx 6.4\ \Omega$ // answer compatible with graph drawn 3
(–1 for omission of or incorrect units)

Explain the shape of your graph.

resistance (of conductor) increases
with increasing temperature *(stated or implied)* 4 + 3
(for appropriate reference to Ohm's law and to resistance, 4 + 3 marks)

Question 17

8. ***(a)*** **The diagram shows a circuit used in a charger for a mobile phone.**

Name the parts labelled F, G and H.

transformer / iron core (F) 3

diode (G) 3

capacitor (H) 3

Describe the function of G in this circuit.

rectifier / converts a.c. to d.c. 6

Sketch graphs to show how voltage varies with time for

(i) the input voltage

(ii) the output voltage, V_{XY}.

axes correctly labelled on at least one graph 3

correct shape of input voltage (sine wave) 3

correct shape of output voltage 6

(–1 if no indication of smoothing effect of capacitor)

The photograph shows the device H used in the circuit. Use the data printed on the device to calculate the maximum energy that it can store.

$E = ½CV^2$ 3

$E = ½ \times (2200 \times 10^{-6}) \times (16)^2$ 3

$E = 0.2816$ J *(–1 for omission of or incorrect units)* 3

(b) **Electricity generating companies transmit electricity over large distances at high voltage. Explain why high voltage is used.**

(for a given power transmission) high voltage uses low current 3

minimising power (heat) loss 3

A 3 km length of aluminium wire is used to carry a current of 250 A. The wire has a circular cross-section of diameter 18 mm.

(i) Calculate the resistance of the aluminium wire.

$R = \frac{\rho l}{A}$ 3

$A = \pi r^2$ 3

$R = 0.33\ \Omega$ *(–1 for omission of or incorrect units)* 3

(ii) Calculate how much electrical energy is converted to heat energy in the wire in ten minutes.

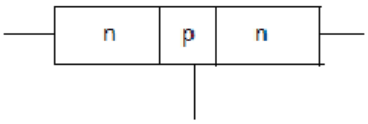
$E = I^2Rt$ 3

$E = (250)^2 \times 0.33 \times 600 = 1.238 \times 10^7$ J 2

(resistivity of aluminium = $2.8 \times 10^{-8}\ \Omega$ m)

Question 18

(b) **Draw a labelled diagram to show the basic structure of a bipolar transistor.**



labelled diagram showing npn (or pnp) layers — 3

pin connections to each layer — 3

Indicate the difference in the composition of the parts of the transistor that you have drawn.

<u>middle layer:</u> base is thin and lightly doped / +holes are majority carriers — 6

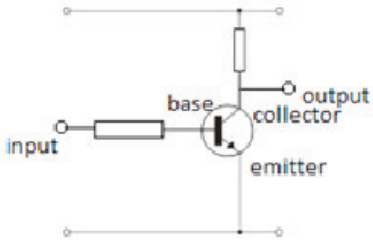
<u>outer layers</u>: <u>emitter and collector</u> are thicker / e^- are majority carriers — 6

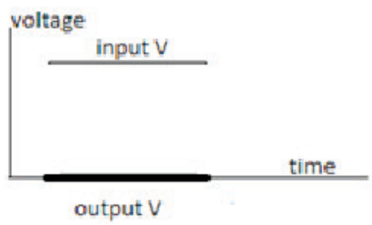
(i) **Complete the circuit diagram for the voltage inverter. Label each part of the circuit. Indicate the terminals used for the input and output voltages.**

draw the base (protective) resistor — 3

label *e,b,c* — 3×3

show input and output voltages — 3





I/P	O/P
0	1
1	0

(ii) **Draw a sketch of an input *V* and its corresponding output *V*, using the same axes and scale.**

labelled axes — 3

V_{in} shown high and V_{out} indicated low (digital or analogue signal) — 3+3

(iii) **Draw the symbol of a NOT gate.**

correct symbol — 3

Draw the truth table for a NOT gate.

input correctly presented — 3

output correctly presented — 3

(iv) **Give another application of a transistor.**

any valid answer, e.g. switching, amplification, etc. — 5

Question 19

A hair dryer with a plastic casing uses a coiled wire as a heat source. When an electric current flows through the coiled wire, the air around it heats up and a motorised fan blows the hot air out.

What is an electric current?

a flow of charge / e^- 6

Heating is one effect of an electric current. Give two other effects of an electric current.

magnetic 3
chemical 3

12

The diagram shows a basic electrical circuit for a hair dryer.

(i) Describe what happens:

(*a*) when switch A is closed and the rheostat is adjusted

fan operates and its speed (of rotation) changes 3

(*b*) when switch A and switch B are closed.

charge/current flows through coil // coil gets hot 3

fan blows hot air 3

9

(ii) The maximum power generated in the heating coil is 2 kW.

(*a*) What is the initial resistance of the coil?

(*b*) Calculate the current that flows through the coil when the dryer is turned on.

$P = IV$ 3

$I\left(=\frac{P}{V}\right)=\frac{2000}{230}$ / 8.7 A **(–1 for omission of or incorrect units)** 3

$V = RI$ / $R = \frac{230}{8.696}$ / = 26.4 Ω **(–1 for omission of or incorrect units)** 3

9

(iii) A length of nichrome wire of diameter 0.17 mm is used for the coil.

Calculate the length of the coil of wire.

$A = \pi r^2$ 3

$A = (3.14)(0.085\times10^{-3})^2$ 3

$A = 2.27\times10^{-8}\ (\mathrm{m}^2)$ 3

$\rho = \frac{RA}{l}$ 3

$l = \frac{(26.4)(2.27\times10^{-8})}{1.1\times10^{-6}}$ 3

$l = 0.5448$ m / 54.5 cm **(–1 for omission of or incorrect units)** 3

18

(iv) Explain why the current through the coil would decrease if the fan developed a fault and stopped working.

coil gets hot 4
its R increases 4
(any correct statement explaining why R_{cct} or R_{coil} has increased…. 2 × 4)

8

Question 20

(*b*)

Distinguish between intrinsic conduction and extrinsic conduction in a semiconductor.

intrinsic conduction:

pure semiconductor/pure silicon — 3

equal number of electrons and (positive) holes — 3

extrinsic conduction:

doped/impure semiconductor // reference to majority/minority charge carriers — 3

9

The circuit shows four light-emitting diodes connected to a resistor *R* and a 6 V a.c. supply of frequency 1 Hz.

(i) What is observed when the circuit is operating?

during one second/cycle — 3

D_1 and D_4 flash (together during one half cycle) — 3

followed by D_2 and D_3 (flashing) — 3

(two leds flash at any one instant ... 6 marks: leds flash on and off ... 3 marks)

Explain what is observed by referring to the circuit.

when D_1 and D_4 are forward biased (and so they will conduct) — 3

D_2 and D_3 are reverse biased — 3

(two of the leds are only forward biased every half cycle/second ... 6 marks)

What is observed when the frequency of the a.c. supply is increased to 50 Hz?

(flash so fast that) leds (appear to) light continuously — 3

18

(ii) Give two functions of the resistor R?

protects leds (from over-load) / limits the current — 3

(acts as a) load (resistor) — 3

How was the output voltage displayed?

cathode ray oscilloscope / c.r.o. / computer (monitor) / datalogger — 6

Draw graphs to show the differences between the input voltage and the output voltage.

(in phase) a.c input — 6

full wave rectified output (in phase) — 6

24

(iii) It is noticed that the output voltage is lower than the input voltage. Explain why.

voltage drop across a led ($\approx$1.6 V) / '(some) voltage lost across leds'
/ some reference to 'energy conversion' — 5

5

Question 21

(h) Explain why high voltages are used in the transmission of electrical energy. (7)

high voltages ➔ smaller currents (required for equivalent power transmission) — 4

less power / heat / energy losses — 3

Question 22

(g) When will an RCD (residual current device) disconnect a circuit?

(when magnitude of the) current flowing in differs // leakage of current 4

from that flowing out // to earth (ground) 3

Question 23

(g) A positively charged rod is brought near to a neutral, conducting sphere that is on top of an insulating stand, as shown in the diagram. How would a student charge the sphere negatively by induction?

earth the sphere *(stated or implied)* 4

remove earth (connection) and then remove rod 3

Question 24

Explain the underlined terms.

capacitance is the ratio of charge (on a capacitor) // C = Q/V (3)

to the potential difference (across it) // correct notation (3)

an electric field is a region (of space) (3)

where electrostatic forces are experienced / forces experienced by charged particles (3)

Describe an experiment to demonstrate an electric field pattern.

high voltage (3)

connected to two plates (3)

in oil and semolina (3)

semolina forms electric field pattern (3)

Two parallel metal plates are placed a distance *d* apart in air. The plates form a parallel plate capacitor with a capacitance of 12 μF. A 6 V battery is connected across the plates.

Calculate (*i*) the charge on each plate and (*ii*) the energy stored in the capacitor.

(i) C = Q/V (3)

Q = 72 μC *(–1 for omission of or incorrect units)* **(3)**

(ii) E = ½CV^2 (3)

E = 216 μJ *(–1 for omission of or incorrect units)* **(3)**

While the battery is connected the distance *d* is increased by a factor of three. Calculate the new capacitance.

(iii) 4 (μF) (4)

A capacitor and a battery are both sources of electrical energy. State two differences between a capacitor and a battery.

capacitor discharges faster than a battery / capacitor stores (electrostatic) potential energy while a battery stores chemical energy / battery gives a constant current / battery stores more energy *(any two)* **(4 + 2)**

Touchscreens also contain two polarising filters. What is meant by polarisation of light?

vibration (of a wave) (3)

is in one plane (3)

Give one application of capacitors, other than in touchscreens.

e.g. flash of a camera / tuning circuits / defibrillator (4)

Question 25

A student investigated the variation of the current I through an electrolyte as the potential difference V across the electrolyte was changed. The electrolyte used was a solution of copper sulfate. The electrodes used were made of copper.

The student recorded the following data:

V / V	0	1	2	3	4	5	6
I / mA	0	30	64	93	122	160	195

Draw a suitable circuit diagram for this investigation and label the components.

arrangement: power supply unit, label ammeter, label voltmeter, electrolyte, electrodes 3 × 3

(–3 marks per missing component)

How was the potential difference changed during the investigation?

adjusting (dial/selector on) variable p.s.u. // adjusting rheostat 3

Draw a suitable graph to show the relationship between the current and the potential difference in this investigation.

label axes correctly on graph paper 3

plot six points correctly **(–1 per each incorrect point; –1 mark if inappropriate scale)** 3

straight line 3

good distribution 3

Use your graph to calculate the resistance of the electrolyte.

method for slope 3

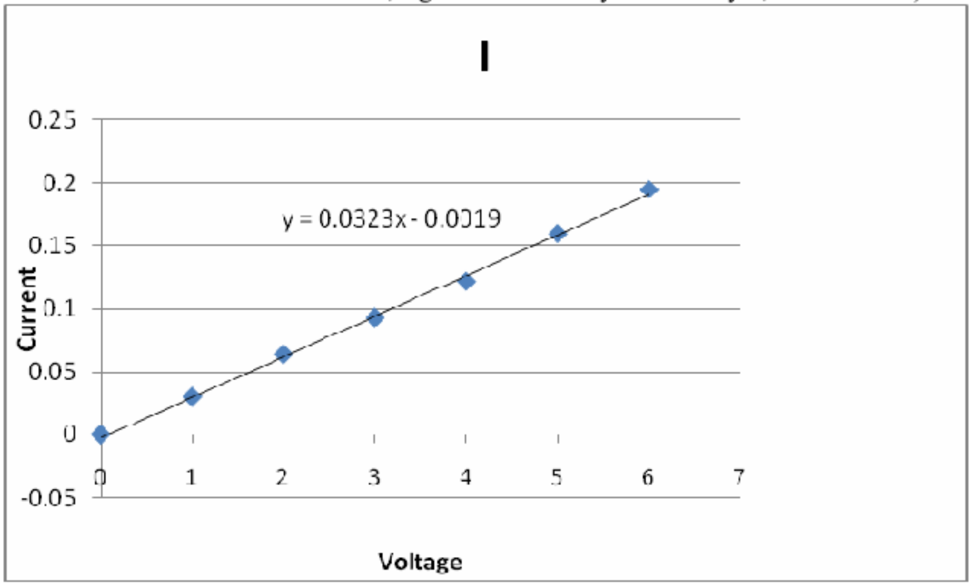
$R =$ 1/0.0323 / 30.96 / ≈ 31 Ω **(–1 for omission of or incorrect unit)** 3

What was observed at the electrodes as current flowed through the electrolyte?

cathode got heavier /coated with fresh copper 5

anode got lighter 5

(Any valid observation re anode and cathode, e.g. colour intensity of electrolyte, etc. … 5 + 5)



Question 26

Question 9

Define (i) potential difference, (ii) capacitance.

(i) work per	// equation (e.g. $V = \frac{W}{q}$)	3
unit charge	// correct notation	3
(ii) charge per	// equation (e.g. $C = \frac{q}{V}$)	3
unit volt	// correct notation	3
		12

Describe an experiment to demonstrate that a capacitor stores energy.

apparatus: capacitor, p.s.u., (bulb)	3
charge capacitor (C) // connect capacitor across p.s.u.	3
discharge C (through bulb)	4
(bulb) flashes/lights	4
	14

The ability of a capacitor to store energy is the basis of a defibrillator. During a heart attack the chambers of the heart fail to pump blood because their muscle fibres contract and relax randomly. To save the victim, the heart muscle must be shocked to re-establish its normal rhythm. A defibrillator is used to shock the heart muscle.

A 64 μF capacitor in a defibrillator is charged to a potential difference of 2500 V. The capacitor is discharged through electrodes attached to the chest of a heart attack victim.

Calculate

(i) the charge stored on each plate of the capacitor;

$q = CV$ / $q = (64 \times 10^{-6})(2500)$ 3

$q = 0.16$ C 3

(–1 for omission of or incorrect unit)

(ii) the energy stored in the capacitor;

$E = \frac{1}{2}CV^2$ 3

correct substitution // $E = \frac{1}{2}(64 \times 10^{-6})(2500)^2$ 3

$E = 200$ J **(–1 for omission of or incorrect unit)** 3

(iii) the average current that flows through the victim when the capacitor discharges in a time of 10 ms;

$I = \frac{q}{t}$ 3

correct substitution 3

$I = 16$ A **(–1 for omission of or incorrect unit)** 3

(iv) the average power generated as the capacitor discharges.

$(P =) \frac{W}{t}$ / $\frac{E}{t}$ / $\frac{200}{10 \times 10^{-3}}$ 3

$P = 20000$ W **(–1 for omission of or incorrect unit)** 3

30

Question 27

(*d*) Define capacitance.

(ratio of)charge // $C = \frac{Q}{V}$ 3

<u>to</u>/<u>over</u> potential / per unit voltage // correct notation 3

(–1 per incorrect/omitted item)

Describe how an electroscope can be charged by induction.

charged object adjacent to electroscope 4

earth electroscope (briefly) 3

remove charged object 3

(award full credit for a correct sequence of diagrams: award a maximum of 4 marks if 'conduction' is used)

How would you demonstrate that the capacitance of a parallel plate capacitor depends on the distance between its plates?

arrangement: connect digital multimeter with capacitance setting (state/imply) to plates 3

method: switch on meter (state/imply) 3

(slowly)separate plates 3

observation: capacitance (reading) is lowered 3

<u>Alternative method:</u>

arrangement: connect electroscope correctly to parallel plate capacitor (3)

method: (earth one plate and) place a charge on the other (using a h.t. power supply) (3)

(slowly) separate plates (3)

observation: leaves diverge indicating (voltage increasing) capacitance is lowered (3)

Question 28

(*f*) **Calculate the energy stored in a 5 µF capacitor when a potential difference of 20 V is applied to it.**

$E = \frac{1}{2}CV^2$ 4

$E = ½ (5 \times 10^{-6})(20)^2$ or 1.0×10^{-3} J or 1.0 mJ 3

Question 29

(b) **List the factors that affect the capacitance of a parallel plate capacitor. (6)**

(common) area (of plates),
distance (apart),
permittivity (of dielectric) / dielectric / medium (between plates) 3 x 2

The plates of an air filled parallel plate capacitor have a common area of 40 cm^2 and are 1 cm apart. The capacitor is connected to a 12 V d.c. supply.
Calculate

(i) the capacitance of the capacitor;
(ii) the magnitude of the charge on each plate. (15)

$$C = \frac{\varepsilon A}{d}$$ 3

$C = [(8.85 \times 10^{-12})(40 \times 10^{-4})] / (0.01)$ …. **(-1 for each incorrect substitution)** 3

$C = 3.5(4) \times 10^{-12}$ F 3

(-1 for omission of or incorrect units)

$Q = CV$ 3

$Q = (3.54 \times 10^{-12})(12)$ / $4.2(5) \times 10^{-11}$ C 3

(-1 for omission of or incorrect units)

What is the net charge on the capacitor? Give a use for a capacitor. (7)

(net charge) = 0 4

blocks d.c. /smoothing /tuning circuits / timing circuits / flash guns (for cameras) 3
(any valid answer)

(permittivity of free space = 8.85×10^{-12} F m^{-1})

Question 30

(e) A capacitor of capacitance 100 μF is charged to a p.d. of 20 V. What is the energy stored in the capacitor? (7)

$E = ½CV^2$ / $E = ½(100 \times 10^{-6})(20)^2$ /

$E = ½(100)(20)^2$ 4

$E = 0.02$ J **(-1 for omission of or incorrect unit)** 3

Question 31

(f) **Define the volt.**

potential difference (between two points)
if 1 J (of work) is needed to move 1 C (from one point to the other) 4 + 3

Question 32

How would an observer know that a Wheatstone bridge is balanced?

zero reading on / no deflection of / no current flowing through **(2)**
galvanometer **(2)**

The Wheatstone bridge in the diagram is balanced.

What is the resistance of the unknown resistor?

$R_1 \div R_2 = R_3 \div R_4$ **(3)**
17.36 Ω *(–1 for omission of or incorrect units)* **(3)**

Write an expression for the resistance of a wire in terms of its resistivity, length and diameter.

$R = \rho l/A$ **(3)**
$R = 4\rho l/\pi d^2$ **(3)**

The radius of a wire is doubled. What is the effect of this on the resistance of the wire?

resistance decreases **(3)**
by a factor of 4 **(3)**

Question 33

(*d*) **What is meant by the term thermometric property?**

(physical) property that changes (measurably) 3
with temperature 3

This graph was obtained during an experiment where the resistance *R* of a thermistor was measured as its temperature *θ* was raised from 0 °C to 100 °C (as measured by a mercury-in-glass thermometer). The thermistor is used in a circuit to keep the water in a tank at a constant temperature. What is the temperature of the water when the resistance of the thermistor is 420 kΩ?

37 ± 1 °C 6

A thermocouple thermometer has emf values of 0 μV at 0 °C and 815 μV at 100 °C. When the thermocouple thermometer was placed in the tank of water, its emf was found to be 319 μV. What is the temperature of the water in the tank as measured by the thermocouple thermometer?

$\theta = \frac{100(E_\theta - E_0)}{E_{100} - E_0}$	(assuming linearity):	815 μV → 100 °C divisions	3
$\theta = \frac{100(319-0)}{815-0}$		1 μV → 0.1227 °C divisions	3
$\theta = 39.14$ (°C)		319 μV → 39.14 (°C)	3

Why do the thermistor and the thermocouple thermometer give different temperature readings for the water in the tank?

each of the devices has a different thermometric property
that changes differently with temperature 4 + 3

Question 34

In an experiment to investigate the variation of the resistance R of a thermistor with its temperature θ, a student measured its resistance at different temperatures.

The table shows the measurements recorded.

θ/°C	20	30	40	50	60	70	80
R/Ω	2000	1300	800	400	200	90	40

Draw a labelled diagram of the apparatus used.

thermistor /resistance in liquid 3
thermometer (in waterbath/oil) 3
thermistor connected to ***labelled*** ohmmeter/(digital) multimeter/DMM 3

9

How was the resistance measured?

Th3 connected to meter 3
ohmmeter indicated (state/imply) 3

6

Describe how the temperature was varied.

heat source/hotplate/bunsen burner 6

6

Using the recorded data, plot a graph to show the variation of the resistance of a thermistor with its temperature.

label axes correctly on graph paper 3
plot six points correctly **(–1 per each incorrect/omitted point)** 3
smooth curve 3
good distribution 3

Use your graph to estimate the average variation of resistance per Kelvin in the range 45°C – 55°C.

(±) 30 Ω ($^0C^{-1}$) or Ω (K^{-1}) [range: 28↔ 32] 3

(–1 for omission of or incorrect units)

15

In this investigation, why is the thermistor usually immersed in oil rather than in water?

oil is a better conductor of heat / water contains air / (impure) water conducts electricity /good thermal contact 4

4

Question 4

In an experiment to measure the resistivity of nichrome, the resistance, the diameter and appropriate length of a sample of nichrome wire were measured.

The following data were recorded:

resistance of wire	**= 7.9 Ω**
length of wire	**= 54.6 cm**
average diameter of wire	**= 0.31 mm**

Describe the procedure used in measuring the length of the sample of wire.

straighten/taut wire 3
measure (the distance) between the points for which the resistance was measured 3

6

Describe the steps involved in finding the average diameter of the wire.

(zero) micrometer / digital callipers **(–1 if *digital* not indicated)** 3
place wire between jaws (state/imply) 3
[tighten (jaws) and] take reading 3
repeat at different points on wire 3
get average diameter

15

Use the data to calculate the resistivity of nichrome.

Formula:	$\rho = \frac{R\pi d^2}{4l}$	2×3
Substitution:	$\rho = \frac{(7.9)(3.14)(0.31\times10^{-3})^2}{4(0.546)}$	2×3
Answer:	$\rho = 1.092\times10^{-6}\ \Omega\text{m}$	3

$A = \pi r^2$ 3
$A = 7.55 \times 10^{-8}$ 3
$\rho = \frac{RA}{l}$ 3
correct substitution 3
$\rho = 1.09(2) \times 10^{-6}\ \Omega$ m 3
(–1 for omission of or incorrect unit)

15

The experiment was repeated on a warmer day. What effect did this have on the measurements?

resistance increased / length increased (or wire expands) / diameter increased
(any *one*) 4

4

Question 36

Question 4

A student investigated the variation of the resistance R of a metallic conductor with its temperature θ.
The student recorded the following data.

θ/°C	20	30	40	50	60	70	80
R/Ω	4.6	4.9	5.1	5.4	5.6	5.9	6.1

Describe, with the aid of a labelled diagram, how the data was obtained.

metallic conductor in container of liquid 3

heat source indicated + thermometer 3

labelled ohmmeter connected to conductor 3

Draw a suitable graph to show the relationship between the resistance of the metal conductor and its temperature.

axes labelled correctly 3

plot points correctly **(–1 for each incorrect point)** 3

straight line 3

good distribution 3

Use your graph to

(i) **estimate the resistance of the metal conductor at a temperature of –20 °C;**

any reference to slope / equation $y = mx + c$ / y-intercept (value) 6

$R = 3.621$ / 3.6 (ohm) [range: $(3.6 \pm 0.1)\Omega$] 6

(for correct value from extrapolated graph, award full marks (6+6):

for estimate from table, award maximum of 6 marks)

(ii) **estimate the change in resistance for a temperature increase of 80 °C;**

for proper use of graph, (e.g. y-intercept value $\approx 4.12\ \Omega$)

$\Delta R = 1.979$ / 2 (ohm) [range: (2.0 ± 0.1)] 6

(estimate from table, maximum of 3 marks)

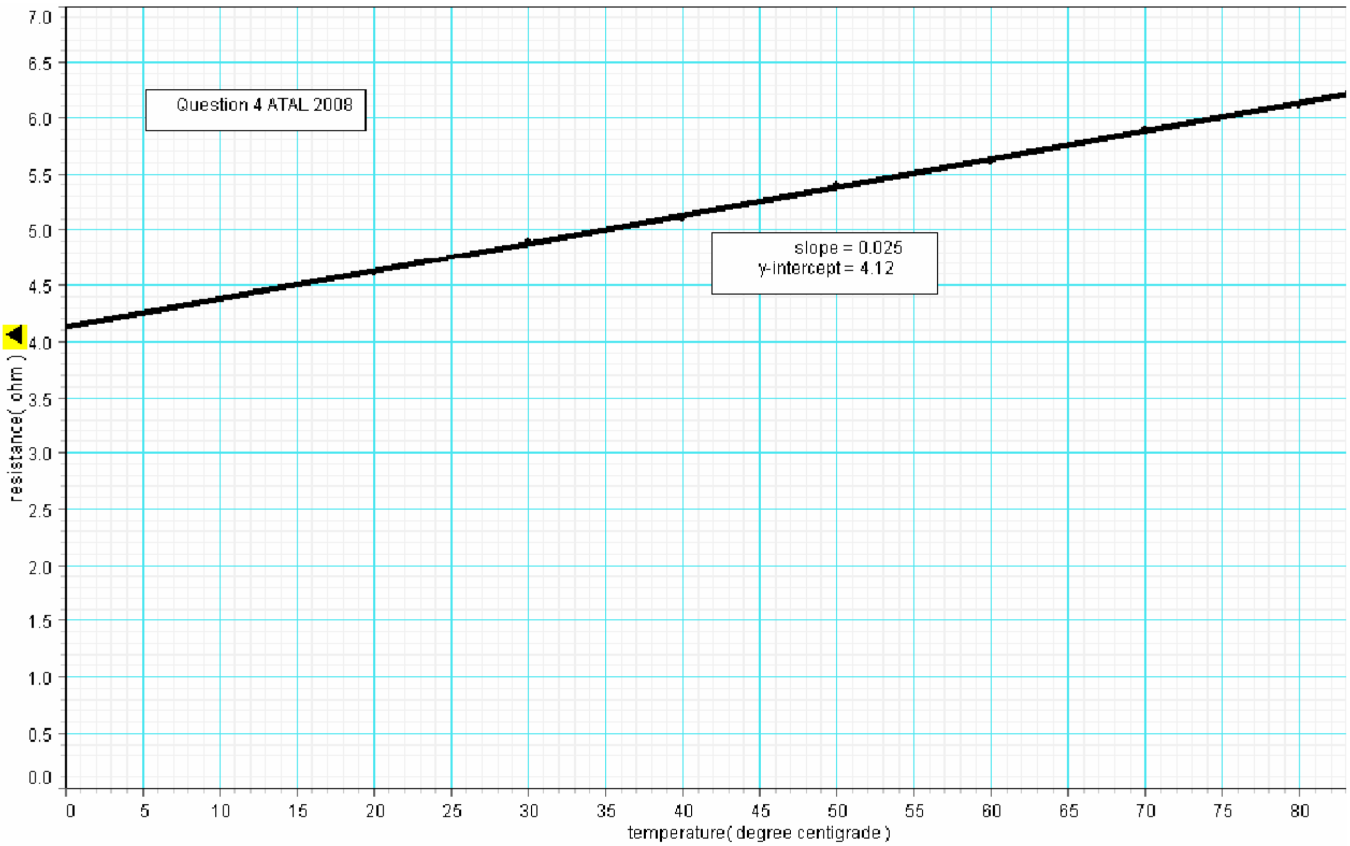
(iii) **explain why the relationship between the resistance of a metallic conductor and its temperature is linear.**

a (straight) line is obtained / any reference to $y = mx + c$ / any reference to microscopic model re molecular structure, etc. / e.g. 'linear over a narrow range of temperature' / e.g. 'linear at low temperatures' /any correct relevant answer 1

For '*non-linear*' statement:

(iii) explain why the relationship between the resistance of a metallic conductor and its temperature is not linear.

linear only for a narrow range of temperature / behaves as a superconductor at low T / R is non-linear at high T / plotted points form a curve / any correct relevant answer (1)



Question 4 ATAL 2008
slope = 0.025
y-intercept = 4.12
resistance(ohm)
temperature(degree centigrade)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Question 7.

Define resistivity and give its unit of measurement.

resistance of cube of material // $\rho = \frac{RA}{l}$ 3

of side 1 m // correct notation **(–1 for each one omitted)** 3

unit: ohm metre / Ω m 3

An electric toaster heats bread by convection and radiation. What is the difference between convection and radiation as a means of heat transfer?

convection requires a medium, radiation does not (or correct reference to vacuum) / movement of medium in convection, no movement of medium with radiation, etc. any correct comparison 4 + 4

A toaster has a power rating of 1050 W when it is connected to the mains supply. Its heating coil is made of nichrome and it has a resistance of 12 Ω. The coil is 40 m long and it has a circular cross-section of diameter 2.2 mm.

Calculate:
(i) the resistivity of nichrome;

$\rho = \frac{RA}{l}$ **(–1 if diameter used instead of radius)** 3

$= \frac{12 \times \pi \left(1.1 \times 10^{-3}\right)^2}{40}$ 3

$\rho = 1.1404 \times 10^{-6}$ / $1.14 \times 10^{-6}\ \Omega$ m 3
(–1 for omission of or incorrect units)

(ii) the heat generated by the toaster in 2 minutes if it has an efficiency of 96%.

heat generated = power × time	any relevant formula		3
$H = 1050 \times 120$ / 1.26×10^5	substitution	**(–1 if minutes used instead of seconds)**	3
96% ➔ 1.21×10^5 J	answer		3

(-1 for omission of or incorrect units)

The toaster has exposed metal parts. How is the risk of electrocution minimised?

(metal parts are) earthed / reference to RCD / reference to (double) insulation / etc. 9
(award 6 marks for any relevant safety feature)

When the toaster is on, the coil emits red light. Explain, in terms of movement of electrons, why light is emitted when a metal is heated.

electrons excited/gain energy 3
jump to higher energy state 3
return to lower state 3
emit energy / emr / i.r / light / photon 3
[(4 × 3) marks awarded for appropriate diagram]

Question 38

Question 9

Define (i) resistance

voltage // V / I or P / I^2 — 3

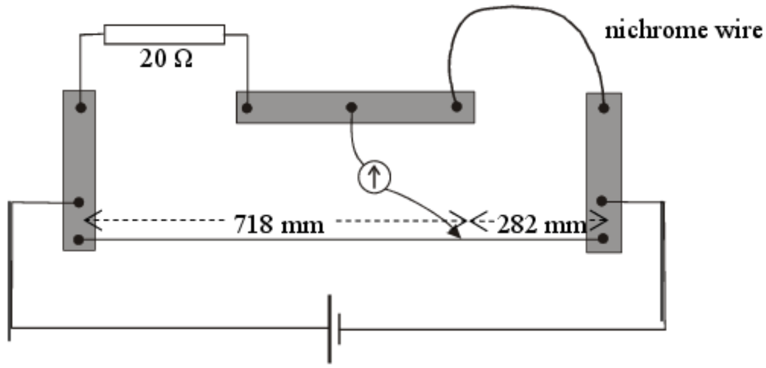
divided by current /per unit current // correct notation — 3

(ii) resistivity.

the resistance // RA/L — 3

of a cube of material of side 1 m // correct notation — 3

A metre bridge was used to measure the resistance of a sample of nichrome wire. The diagram indicates the readings taken when the metre bridge was balanced. The nichrome wire has a length of 220 mm and a radius of 0.11 mm.



Calculate:

(i) the resistance of the nichrome wire

$$\frac{R_1}{R_2} = \frac{L_1}{L_2}\left(= \frac{R_3}{R_4}\right)$$ 3

$$\frac{R}{20} = \frac{282}{718}$$ 3

$\Rightarrow R = 7.86\ \Omega$ **(-1 for omission of or incorrect units)** 3

(ii) the resistivity of nichrome.

$\rho = \frac{RA}{L}$ state or imply 3

$\rho = \frac{(7.855)(3.801 \times 10^{-8})}{0.220}$ **(-1 if incorrect *A*)** 3

$\Rightarrow \rho = 1.36 \times 10^{-6}\ \Omega\ \text{m}$ **(-1 for omission of or incorrect units)** 3

Sketch a graph to show the relationship between the temperature and the resistance of the nichrome wire as its temperature is increased.

axes labelled R and T (or θ) — 3

correct linear graph with intercept showing R greater than zero **(-1 if line passes through origin)** — 3

What happens to the resistance of the wire:

(i) as its temperature falls below 0°C?

R decreases — 3

(ii) as its length is increased?

R increases — 4

(iii) if its diameter is increased?

R decreases — 4

Name another device, apart from a metre bridge, that can be used to measure resistance.

ohmmeter / wheatstone bridge / /multimeter / DMM / ammeter + voltmeter — any one 6

Give one advantage and one disadvantage of using this device instead of a metre bridge.

	Advantage	Disadvantage
ohmmeter:	compact, portable, faster method, etc.	less accurate, fragile, difficult to <u>calibrate</u>/<u>check,</u>
wheatstone bridge:	compact, portable, more accurate etc.	'black box' difficult to comprehend, expensive,
ammeter +voltmeter:	easy to use, easy to understand, etc.	range selection difficult, fragile, less accurate

one advantage + one disadvantage of the chosen device — 2 + 1

Question 39

correct arrangement showing power supply, bulb, and means of varying voltage	2 x 3
(each item omitted or incorrectly located ... -3)	
ammeter in series with filament bulb	3
voltmeter in parallel with filament bulb	3

Describe how the student varied the potential difference. (4)

adjust rheostat / potentiometer / voltage on (variable) p.s.u. — 4

With reference to the graph,

(i) explain why the current is not proportional to the potential difference (3)

not a straight-line graph — 3

(ii) calculate the change in resistance of the filament bulb as the potential difference increases from 1 V to 5 V. (15)

At 1 V:	$R = V/I$	3
	$= 1/0.028$	3
	$= 35.7\ \Omega$	3
At 5 V:	$R = (5/0.091) = 54.9\ \Omega$	3

change in resistance $(= 54.9 - 35.7) = 19.2\ \Omega$ **(-1 for omission of or incorrect unit)** — 3

(Accept range: 17 ~ 20 Ω for change in resistance. **Zero for any attempt using 'slope of graph' method.)**

Give a reason why the resistance of the filament bulb changes. (6)

(as current increases) temperature of filament increases / filament gets hotter — 3

more difficult for electrons /charge to pass through (due to increased vibrations of metal atoms) / R (of filament) increases with temperature — 3

Question 40

Question 9

Define (i) potential difference. (6)

work done	// $V = W / Q$	3
moving unit charge between two points	// notation	3

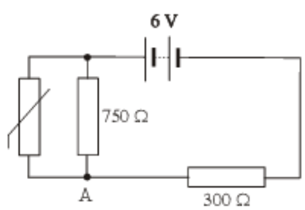
(ii) resistance. (6)

$R = V/I$	// voltage per	3
notation	// unit current	3

Two resistors, of resistance R_1 and R_2 respectively, are connected in parallel. Derive an expression for the effective resistance of the two resistors in terms of R_1 and R_2. (12)

$I_T = I_1 + I_2$	3
(apply Ohm's law) $V = IR$	3
$V/R_T = V/R_1 + V/R_2$	3
$1/R_T = 1/R_1 + 1/R_2$	3

In the circuit diagram, the resistance of the thermistor at room temperature is 500 Ω.
At room temperature, calculate:



(i) the total resistance of the circuit. (9)

$1/R_p = 1/500 + 1/750$	3
$R_p = 300\ \Omega$	3
$R_{cct} = 600\ \Omega$	3

(no penalty incurred here re units)

(ii) the current flowing through the 750 Ω resistor. (9)

$I_{cct} = \underline{(V / R)_{cct}}$ / $= \underline{6 \div 600}$ / $= \underline{0.01}$ A	3
(V_{branch} =) $V_{300} = \underline{(0.01)(300)}$ / $\underline{3\ V}$	3
I_{750} (= 3 ÷ 750) = $\underline{4 \times 10^{-3}\ A}$ / $\underline{4\ mA}$	3

(-1 for omission of or incorrect unit)

As the temperature of the room increases, explain why:

(iii) the resistance of the thermistor decreases (7)

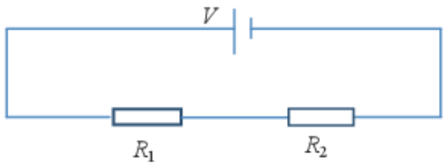
more energy added to the thermistor / temperature of Th3 increases	3
(more) electrons <u>produced</u> / <u>released</u>	2
(resistance is reduced because) more <u>electrons</u> /<u>charge carriers</u> are available for conduction	2

(iv) the potential at A increases. (7)

resistance of thermistor (and 750 Ω combination) decreases	3
potential difference across thermistor and 750 Ω combination decreases	2
potential at A increases	2

Question 41

(i) **Two resistors of resistance R_1 and R_2 are connected in series. Derive an expression for the effective resistance of the two resistors in terms of R_1 and R_2.**



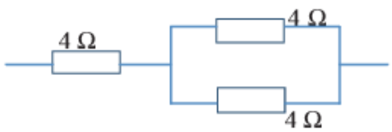
diagram/circuit 3

$V = V_1 + V_2$ 6

$IR_s = IR_1 + IR_2$ 3

$R_s = R_1 + R_2$ 3

(ii) **Two 4 Ω resistors are connected in parallel. Draw a circuit diagram to show how another 4 Ω resistor could be arranged with these two resistors to give an effective resistance of 6 Ω.**



draw parallel branch 3

arrangement for effective $R = 6\ \Omega$ 6

(iii) **A fuse is a resistor used as a safety device in a circuit. How does a fuse operate?**

fuse in live part of circuit 3

gets hot if current exceeds a certain (rated) value (state/imply) 3

melts/breaks 3

circuit is broken 2

A Wheatstone bridge circuit is used to measure the resistance of an unknown resistor R.
The bridge ABCD is balanced when X = 2.2 kΩ, Y = 1.0 kΩ and Z = 440 Ω.

(iv) **What test would you use to determine that the bridge is balanced?**

connect galvanometer (G) / millivoltmeter (mV) across points AC 3

no deflection in G (when balanced) 3

(v) **What is the resistance of the unknown resistor R?**

$\frac{R_1}{R_2} = \frac{R_3}{R_4}$ 3

$\frac{2200}{1000} = \frac{R}{440}$ / $R = 968\ \Omega$ 3

(vi) **When the unknown resistor R is covered by a piece of black paper, the bridge goes out of balance. What type of resistor is it?**

light dependent resistor / l.d.r. / photoresistor / CdS cell 3

Give a use for this type of resistor.

used in light meters / (to control) street lights / security alarms / (control) traffic lights / used in re-charging circuits, etc.

any *one* valid answer 3