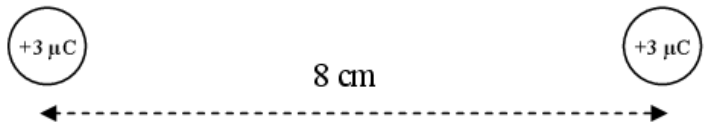
Question 1

(*c*) Define the unit of charge, the coulomb. State Coulomb's law. (9)

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. (9)



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. (10)

Question 2

4. The following is part of a student's report on an experiment to investigate the variation of the current I with potential difference V for a semiconductor diode.

"I set up the apparatus as shown in the circuit diagram. I measured the current flowing through the diode for different values of the potential difference. I recorded the following data."

V/V	0	0.50	0.59	0.65	0.68	0.70	0.72
I/mA	0	3.0	5.4	11.7	17.4	27.3	36.5

Draw a circuit diagram used by the student.

How did the student vary and measure the potential difference? (15)

Using the data, draw a graph to show how the current varies with the potential difference for the semiconductor diode.
Does the resistance of the diode remain constant during the investigation? Justify your answer. (18)

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? (7)

Question 3

(*c*) List the factors that affect the heat produced in a current-carrying conductor. (7)

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
(ii) the minimum diameter of the wire. (21)

(resistivity of copper = 1.7×10^{-8} Ω m)

Question 4

(*d*) Define electric field strength and give its unit of measurement. (9)

The diagram shows a negative charge of 2 μC, positioned 25 cm away from a positive charge of 5 μC.

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

Calculate the electric field strength at P. (15)

Under what circumstances will point discharge occur? (4)

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

Question 5

(*g*) What are the charge carriers when an electric current
(i) passes through a semiconductor; (ii) passes through an electrolyte? (7)

Question 6

(*h*) State the principle on which the definition of the ampere is based. (7)

Question 7

8. Define electric field strength and give its unit of measurement. (9)

Describe how an electric field pattern may be demonstrated in the laboratory. (12)

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

(ii) the electrostatic force exerted on the 5 μC point charge. (15)

All the charge resides on the surface of a Van de Graff generator's dome. Explain why. Describe an experiment to demonstrate that total charge resides on the outside of a conductor. Give an application of this effect. (20)

(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)

Question 9

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

Question 10

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

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

Sketch a graph to show the relationship between current and time for

(i) alternating current;

(ii) direct current. (9)

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

What is the resistance of the filament of a light bulb, rated 40 W, when it is connected to the mains? (9)

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

Question 11

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

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

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

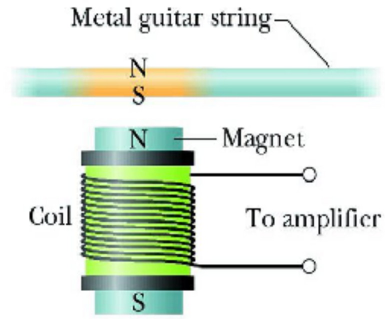
The peak voltage of the mains electricity is 325 V. Calculate the rms voltage of the mains? (6)

What is the resistance of the filament of a light bulb, rated 40 W, when it is connected to the mains? (9)

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

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)

(b) What is the relationship between frequency and tension for a stretched string? (7)

(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)

(d) Why must the strings in the electric guitar be made of steel? (7)

(e) Define magnetic flux. (7)

(f) Why does the current produced in a coil of the electric guitar vary? (7)

(g) What is the effect on the sound produced when the number of turns in a coil is increased? (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)

Question 12

10. Define electric field strength.

State Coulomb's law of force between electric charges. (12)

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

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

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

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

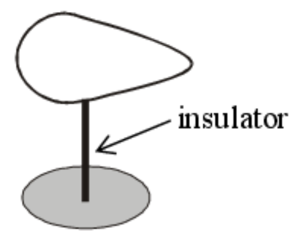
What is the direction of the electric field strength at B?

A charge of 5 μC is placed at B. Calculate the electrostatic force exerted on this charge. (20)

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

Question 13

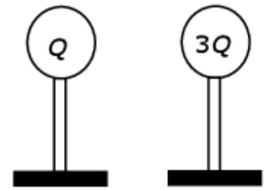
(g) A pear-shaped conductor is placed on an insulated stand is shown. Copy the diagram and show how the charge is distributed over the conductor when it is positively charged. (7)



Question 14

9. (*a*) State Coulomb's law. (6)

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 $3Q$ 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? (18)



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

Why should the frame of an electroscope be earthed?

Describe how to charge an electroscope by induction. (15)

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

Describe an experiment to investigate the principle by which the operator is protected. (17)

Question 15

(*g*) With reference to domestic electric circuits, what do the letters in the acronyms (*i*) RCD and (*ii*) MCB stand for?

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.

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

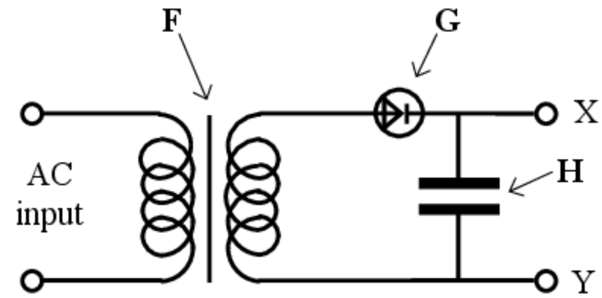
Explain how the student used this device to vary the potential difference. (18)

Use the data in the table to draw a graph on graph paper to show the variation of current with potential difference. Use your graph to find the value of the resistance of the conductor when the current is 0.7 A. (15)

Explain the shape of your graph. (7)

Question 17

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



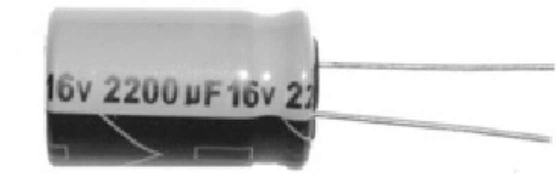
Name the parts labelled **F**, **G** and **H**. (9)

Describe the function of **G** in this circuit. (6)

Sketch graphs to show how voltage varies with time for

(i) the input voltage

(ii) the output voltage, V_{XY}. (12)



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. (9)

(*b*) Electricity generating companies transmit electricity over large distances at high voltage. Explain why high voltage is used. (6)

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.

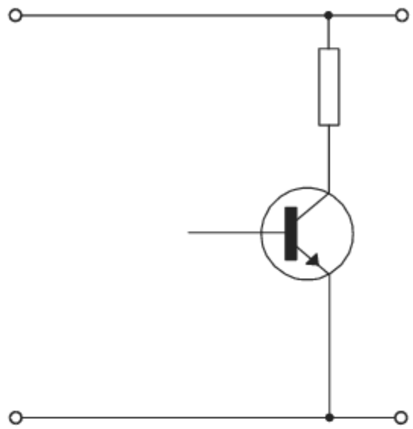
(ii) Calculate how much electrical energy is converted to heat energy in the wire in ten minutes. (14)

(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. Indicate the difference in the composition of the parts of the transistor that you have drawn. (18)

The diagram shows part of a circuit in which a transistor is to be used as a voltage inverter.



(i) Copy the diagram into your answerbook and complete the circuit diagram.
Label each part of the circuit.
Indicate on your diagram the terminals used for the input and output voltages. (15)

(ii) Draw a sketch of an input voltage and its corresponding output voltage, using the same axes and scale. (9)

(iii) A voltage inverter can be used as a NOT gate.
Draw the symbol of a NOT gate.
Draw the truth table for a NOT gate. (9)

(iv) Give another application of a transistor. (5)

Question 19

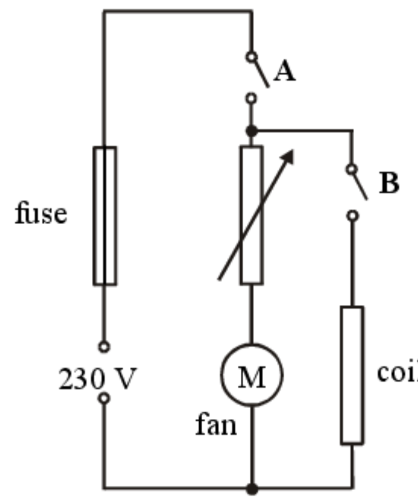
8. A hair dryer with a plastic casing uses a coiled wire as a heat source. When an electric current flows through the coiled wire, the air around it heats up and a motorised fan blows the hot air out.

What is an electric current?

Heating is one effect of an electric current.

Give two other effects of an electric current. (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

(*b*) when switch **A** and switch **B** are closed. (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. (9)

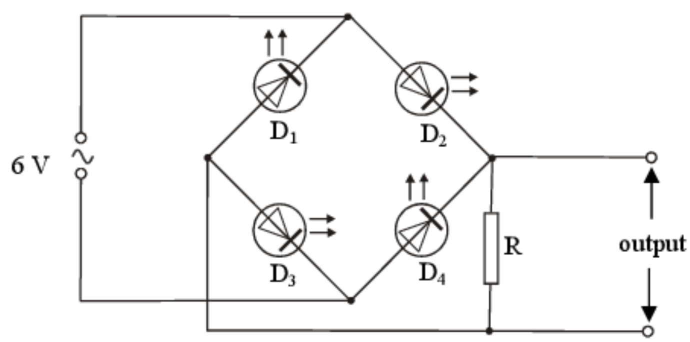
(iii) A length of nichrome wire of diameter 0.17 mm is used for the coil. Calculate the length of the coil of wire. (18)

(iv) Explain why the current through the coil would decrease if the fan developed a fault and stopped working. (8)

(resistivity of nichrome = 1.1×10^{-6} Ω m)

Question 20

(*b*) Distinguish between intrinsic conduction and extrinsic conduction in a semiconductor. (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?

Explain what is observed by referring to the circuit.

What is observed when the frequency of the a.c. supply is increased to 50 Hz? (18)

(ii) Give two functions of the resistor R?

How was the output voltage displayed?

Draw graphs to show the differences between the input voltage and the output voltage. (24)

(iii) It is noticed that the output voltage is lower than the input voltage. Explain why. (5)

Question 21

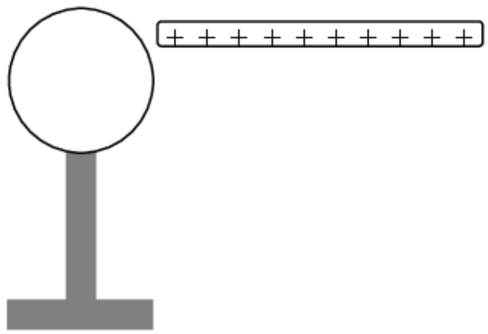
(*h*) Explain why high voltages are used in the transmission of electrical energy. (7)

Question 22

(*g*) When will an RCD (residual current device) disconnect a circuit? (7)

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?



Question 24

9. Most modern electronic devices contain a touchscreen. One type of touchscreen is a capacitive touchscreen, in which the user's finger acts as a plate of a capacitor. Placing your finger on the screen will alter the <u>capacitance</u> and the <u>electric field</u> at that point.

Explain the underlined terms. (12)

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

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. (12)

While the battery is connected the distance *d* is increased by a factor of three. Calculate the new capacitance. (4)

A capacitor and a battery are both sources of electrical energy. State two differences between a capacitor and a battery. (6)

Touchscreens also contain two polarising filters. What is meant by polarisation of light? (6)

Give one application of capacitors, other than in touchscreens. (4)

Question 25

4. 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.

How was the potential difference changed during the investigation? (12)

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

Use your graph to calculate the resistance of the electrolyte. (18)

What was observed at the electrodes as current flowed through the electrolyte? (10)

Question 26

9. Define (i) potential difference, (ii) capacitance. (12)

A capacitor stores energy.
Describe an experiment to demonstrate that a capacitor stores energy. (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;

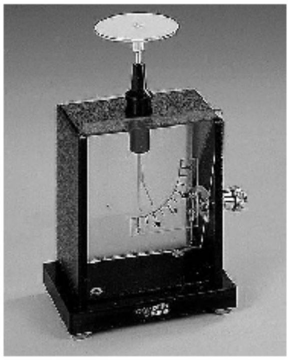
(ii) the energy stored in the capacitor;

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

(iv) the average power generated as the capacitor discharges. (30)

Question 27

(*d*) Define capacitance. (6)



Describe how an electroscope can be charged by induction. (10)

How would you demonstrate that the capacitance of a parallel plate capacitor depends on the distance between its plates? (12)

Question 28

(*f*) Calculate the energy stored in a 5 μF capacitor when a potential difference of 20 V is applied to it. (7)

Question 29

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

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)

What is the net charge on the capacitor?

Give a use for a capacitor. (7)

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

Question 30

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

Question 31

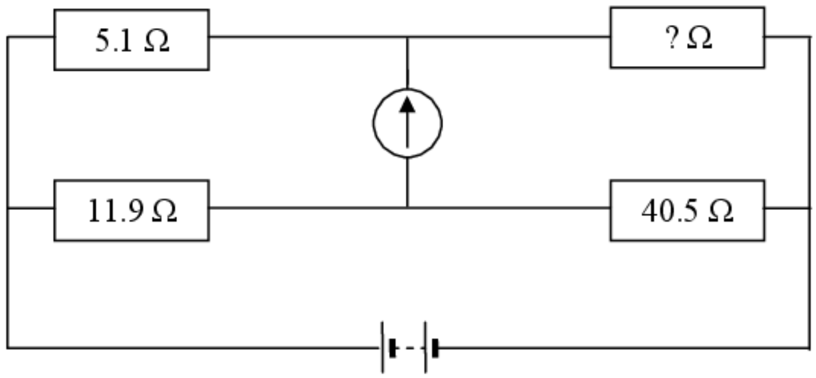
(*f*) Define the volt.

Question 32

The resistance of the conductor in a strain gauge increases when a force is applied to it. Strain gauges can act as the resistors in a Wheatstone bridge, and any change in their resistance can then be detected.

How would an observer know that a Wheatstone bridge is balanced? (4)

The Wheatstone bridge in the diagram is balanced.



What is the resistance of the unknown resistor? (6)

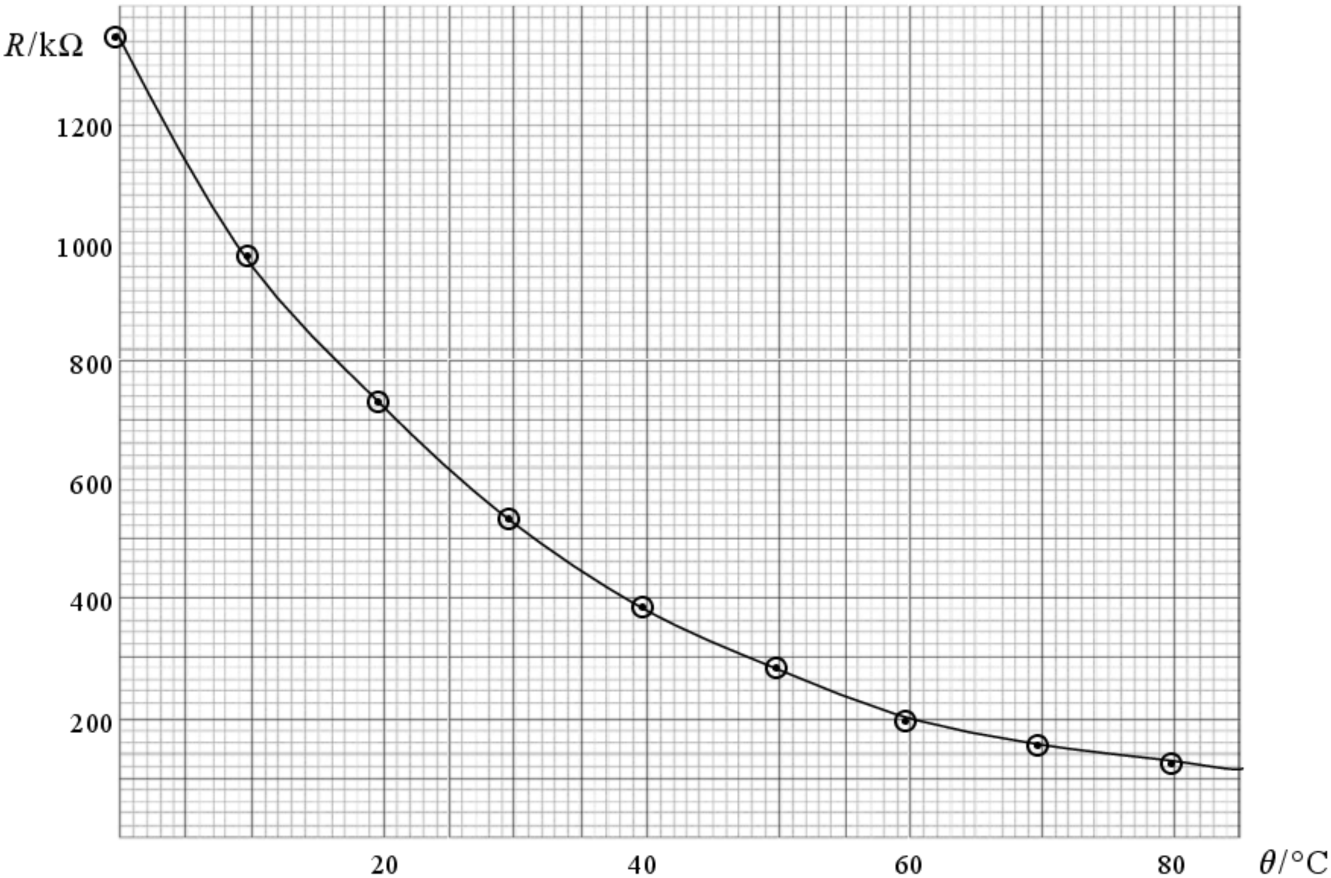
Write an expression for the resistance of a wire in terms of its resistivity, length and diameter.

The radius of a wire is doubled. What is the effect of this on the resistance of the wire? (12)

Question 33

(*d*) What is meant by the term thermometric property? (6)

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? (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? (9)

Why do the thermistor and the thermocouple thermometer give different temperature readings for the water in the tank? (7)

Question 34

4. 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. (9)

How was the resistance measured? (6)

Describe how the temperature was varied. (6)

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

Use your graph to estimate the average variation of resistance per kelvin in the range 45 °C – 55 °C. (15)

In this investigation, why is the thermistor usually immersed in oil rather than in water? (4)

Question 35

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. (6)

Describe the steps involved in finding the average diameter of the wire. (15)

Use the data to calculate the resistivity of nichrome. (15)

The experiment was repeated on a warmer day. What effect did this have on the measurements? (4)

Question 36

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. (9)

Draw a suitable graph to show the relationship between the resistance of the metal conductor and its temperature. (12)

Use your graph to:

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

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

(iii) explain why the relationship between the resistance of a metallic conductor and its temperature is **not** linear. (19)

Question 37

7. Define resistivity and give its unit of measurement. (9)

An electric toaster heats bread by convection and radiation.
What is the difference between convection and radiation as a means of heat transfer? (8)

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;

(ii) the heat generated by the toaster in 2 minutes if it has an efficiency of 96%. (18)

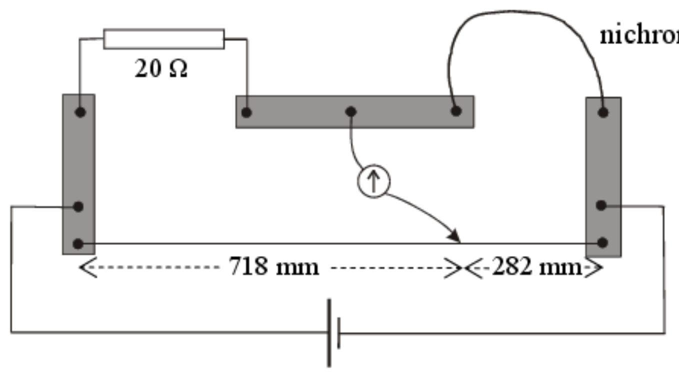
The toaster has exposed metal parts. How is the risk of electrocution minimised? (9)

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. (12)

Question 38

9. Define (i) resistance, (ii) resistivity. (12)

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
(ii) the resistivity of nichrome. (18)

Sketch a graph to show the relationship between the temperature and the resistance of the nichrome wire as its temperature is increased. (6)

What happens to the resistance of the wire:

(i) as its temperature falls below 0°C?
(ii) as its length is increased?
(iii) if its diameter is increased? (11)

Name another device, apart from a metre bridge, that can be used to measure resistance.
Give one advantage and one disadvantage of using this device instead of a metre bridge. (9)

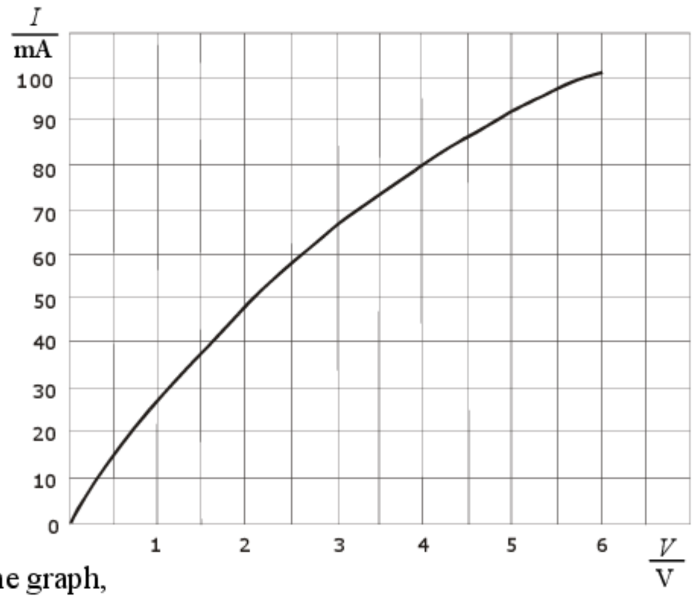
Question 39

4. A student investigated the variation of the current I flowing through a filament bulb for a range of different values of potential difference V.

Draw a suitable circuit diagram used by the student.

Describe how the student varied the potential difference. (16)

The student drew a graph, as shown, using data recorded in the experiment.



With reference to the graph,

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

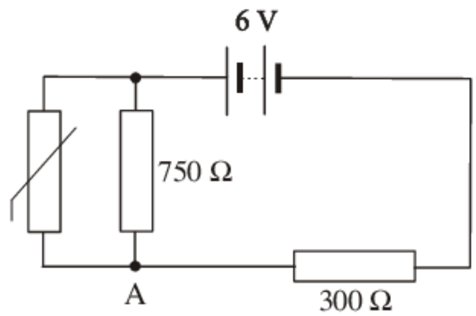
(ii) calculate the change in resistance of the filament bulb as the potential difference increases from 1 V to 5 V. (18)

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

Question 40

9. Define (i) potential difference, (ii) resistance. (12)

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)



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;
(ii) the current flowing through the 750 Ω resistor. (18)

As the temperature of the room increases, explain why

(iii) the resistance of the thermistor decreases;
(iv) the potential at A increases. (14)

Question 41

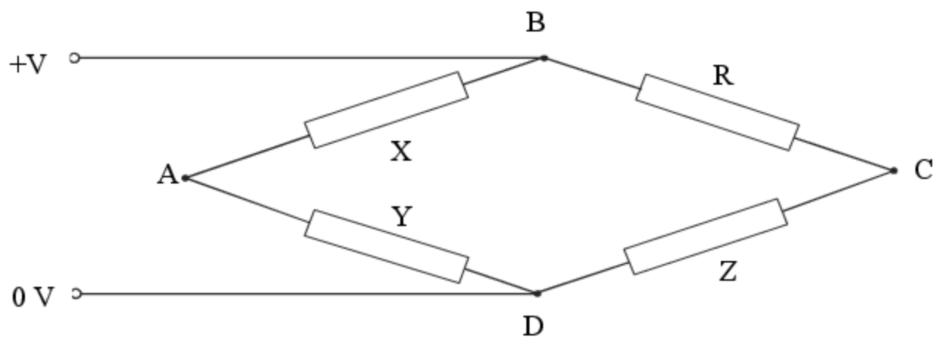
9. Define resistance.

(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. (18)

(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. (9)

(iii) A fuse is a resistor used as a safety device in a circuit. How does a fuse operate? (11)

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? (6)

(v) What is the resistance of the unknown resistor R? (6)

(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? Give a use for this type of resistor. (6)