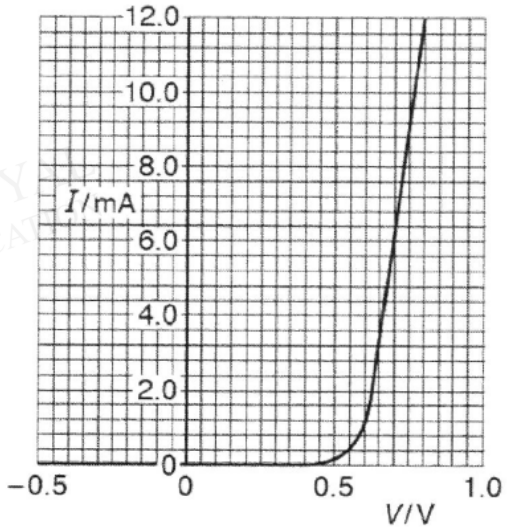
O Level Pure Physics Structured

Current and DC Circuits Test 4.0

Q1

The variation with potential difference (p.d.) V of current I for a semiconductor diode is shown in the figure below.

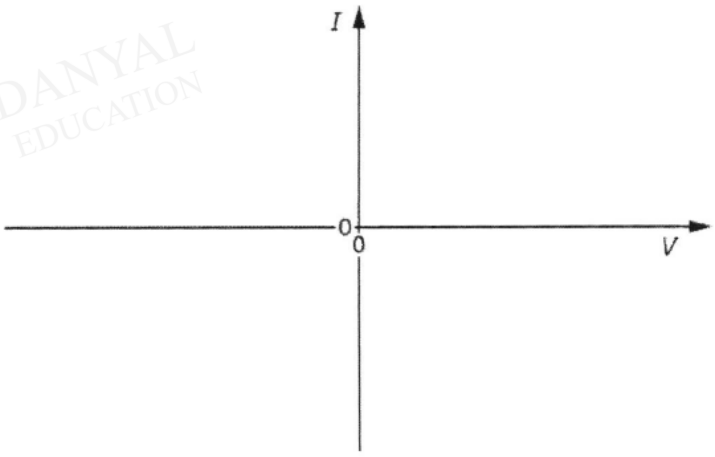


a. Use the figure provided to describe the variation of the resistance of the diode between V = - 0.5 V and V = 0.8 V.

[2]

b. On the figure below, sketch the variation with p.d. V of current I for a filament lamp. Numerical values are not required.

[1]

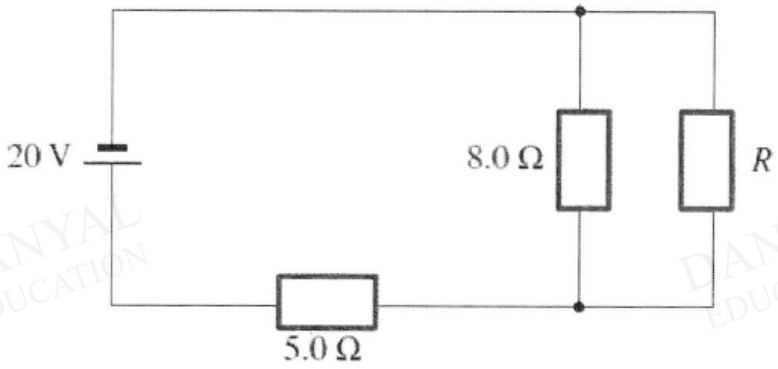


c. What is the name given to such an electrical conductor as described in (b)?

[1]

Q2

The 8.0 Ω resistor in the circuit shown below dissipates 45 J of heat energy in 5.0 s.



a. Calculate the potential difference across the 8.0 Ω resistor.

[2]

b. Calculate the current flowing through the 5.0 Ω resistor.

[3]

c. Calculate the total resistance of the circuit.

[2]

d. Determine the value of the resistor R.

[3]

Q3

Fig. 10.1 shows the properties of 3 rods, **X**, **Y** and **Z**, which are made of different materials. These rods have an identical length of 0.40 m and a diameter of 1.0 cm.

Rod	Material	Density (kg/m^3)	Resistivity (Ω m)
X	copper	8960	1.7×10^{-8}
Y	lead	11 340	2.2×10^{-7}
Z	plastic	1200	1.6×10^{16}

Fig. 10.1

(a) Calculate the resistance of the copper rod.

resistance = _____ [2]

(b) An experiment is carried out for each of these rods.
Fig. 10.2 shows the setup of the experiment where the copper rod **X** is used. **X** hangs from a spring balance and is connected to a circuit containing a battery supply.

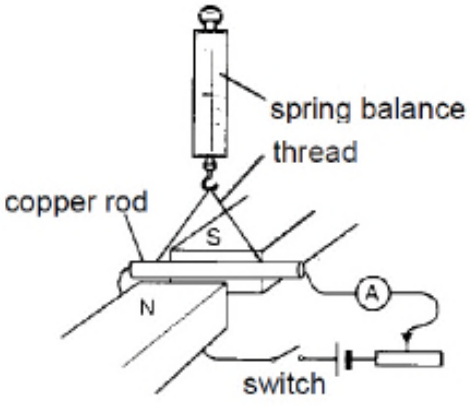


Fig. 10.2

The initial spring balance reading is recorded as N_1. The switch is then closed, and the new reading is recorded as N_2. The ammeter reading is recorded as I.

(i) Compare the value of N_1 and N_2 in Fig. 10.2. Explain your answer.

[2]

(ii) Rod **X** is replaced with **Y** and **Z**, and the experiment is repeated in each case.

For each of the following cases, identify the rod (**X**, **Y** or **Z**) that produces the observation and explain your answer.

1. Largest value of N_1 recorded,

[2]

2. No change in value of N_1 and N_2,

[2]

3. Largest ammeter reading I.

[2]

Q4

Fig. 11.1b shows the relay connected in a circuit to a 12 V battery and a thermistor. The bell is initially not ringing.

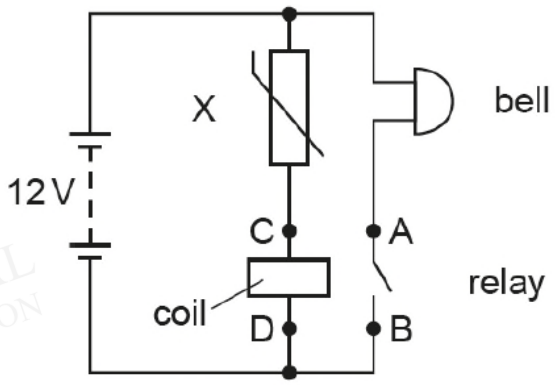


Fig. 11.1b

(i) Explain why the bell rings when the temperature of the thermistor rises.

[2]

(ii) When the resistance of the thermistor is 2000 Ω, the current in the coil is 1.5 mA. This causes the contacts in the relay to close.
The resistance of the bell is 200 Ω.

Calculate

1. the current passing through the bell,

current = _____ [1]

2. the potential difference (p.d.) across the coil.

p.d. across coil = _____ [2]

(iii) Suggest an advantage of using a relay in this circuit.

_____

_____ [1]

Q5

(a) During a thunderstorm, a lightning strike has an average current of 1.5×10^4 A. The charge transferred to the ground is 32 C.

Calculate the duration of the lightning strike.

duration = ... [2]

(b) Fig. 11.1 shows a circuit.

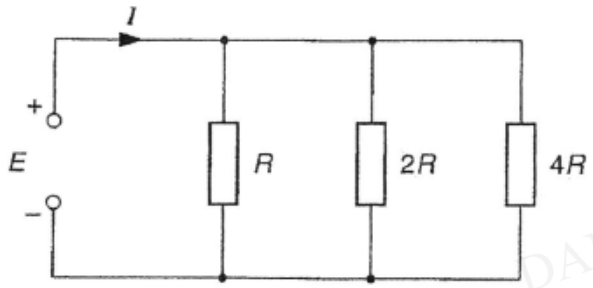


Fig. 12.1

The resistances of the resistors are R, $2R$ and $4R$. The supply has electromotive force, E.

(i) Define the *electromotive force* of the supply.

.....

..... [1]

(ii) Calculate

1. the total resistance of the circuit in terms of R,

resistance = ... [2]

2. the current from the supply in terms of E and R.

current = ... [1]

(c) Fig. 12.2 shows a circuit consisting of two resistors connected in series to a d.c. supply.

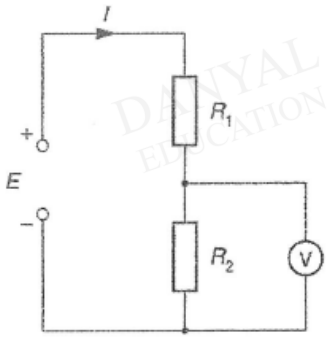


Fig. 12.2

The resistors have resistances R_1 and R_2. The supply has electromotive force, E. The current from the supply is I.

(i) Show that the voltmeter reading V is given by the relation

$$V = \left(\frac{R_2}{R_1 + R_2} \right) E .$$

[2]

(ii) Fig. 12.3 shows a circuit that includes a thermistor.

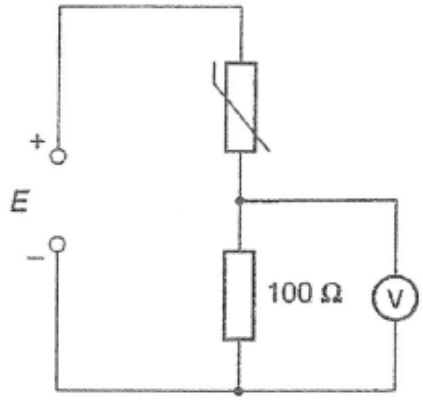


Fig. 12.3

Describe and explain how the voltmeter reading changes as the temperature of the thermistor is increased.

.....

.....

.....

.....

.....

..... [2]

Answers

Current and DC Circuits Test 4.0

Q1

a. Use the figure provided to describe the variation of the resistance of the diode between V = - 0.5 V and V = 0.8 V.

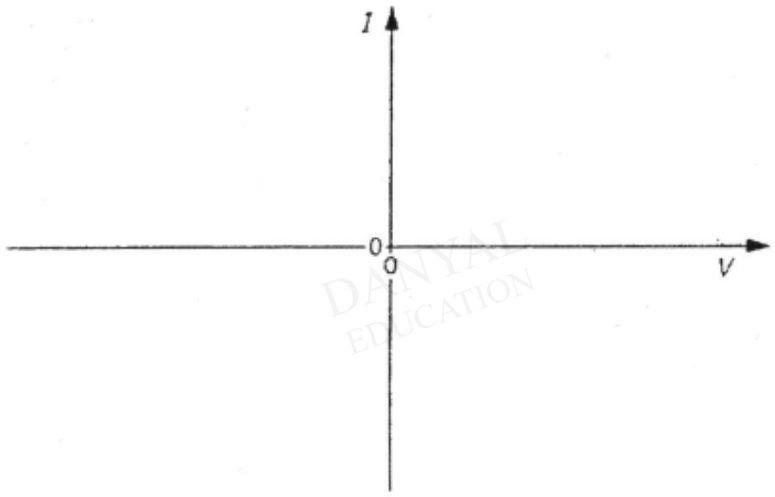
[2]

From -0.5 V to 0.4 V, the resistance of the diode is very high and no current can flow. A1

From V = 0.4 V onwards, the resistance of the diode decreases significantly and large amount of current can now flow. A1

b. On the figure below, sketch the variation with p.d. V of current I for a filament lamp. Numerical values are not required.

[1]



c. What is the name given to such an electrical conductor as described in (b)?

[1]

Non Ohmic Conductor A1

Q2

a. Calculate the potential difference across the 8.0 Ω resistor.

[2]

Power = $V^2 \div R$

$45 \div 5 = V^2 \div 8$ A1
V = 8.49 V A1

b. Calculate the current flowing through the 5.0 Ω resistor.

[3]

EMF = V1 + V2

20 = 8.485 + V2
V2 = 11.51 V A1

V = IR

11.51 = I x 5 A1
I = 2.30 A A1

c. Calculate the total resistance of the circuit.

[2]

EMF = IR

20 = 2.302 x R A1
R = 8.69 Ω A1

d. Determine the value of the resistor R.

[3]

Total R = R1 + R2

8.688 = 5 + R2
R2 = 3.688 A1

R2 = (8 x R) ÷ (8 + R)

3.688 = (8 x R) ÷ (8 + R) A1
R = 6.84 A1

Q3

(a)	$R = \rho l / A$ $= 1.7 \times 10^{-8} \times 0.40 / (\pi \times 0.005^2)$ $= \underline{8.7 \times 10^{-5}\ \Omega\ (2\ s.f.)}$	[1] [1]	**Deduct [1] if wrong sig fig or unit.** Max [1] for application of formula if area is incorrectly calculated.
(b) (i)	N_2 has a <u>lower value than N_1</u>. When the switch is closed, a current flows in the copper rod. By <u>Fleming's Left-Hand Rule</u>, where the thumb, index finger and second finger represents the direction of the force, magnetic field and current respectively, an <u>upward force will act on the rod</u>. This <u>decreases the spring balance reading</u>.	[1] [1]	Accept: Interaction of the magnetic field of the current and that of the magnet produces an upward force.
(ii)	1. <u>Rod Y</u>. It has the <u>highest density of 11340 kg/m^3</u> and hence the <u>largest mass and weight.</u>	[1] [1]	**No credit if each rod is identified without any explanation.** Accept: Plastic is a poor conductor of electricity if low resistivity is mentioned in 3. **Deduct [1] from whole of part (ii) if candidate did not quote <u>any</u> value from table in the explanation.**
	2. <u>Rod Z</u>. Plastic has the <u>highest resistivity of 1.6×10^{16} Ωm</u>. When the switch is closed, <u>no current flows through it</u> and it <u>will not experience any force</u>.	[1] [1]	
	3. <u>Rod X.</u> Copper has the <u>lowest resistivity of 1.7×10^{-8} Ωm</u> and hence the <u>lowest resistance</u>. It will produce the <u>largest current</u>.	[1] [1]	

Q4

(i)	When the temperature of the thermistor rises, its resistance decreases. This will cause a larger current to flow through the coil. The soft iron will be magnetised and the relay switch will be closed, causing the bell to ring.	[1] [1]	
(ii)	1. I = V / R = 12 / 200 = 0.060 A	 [1]	
	2. p.d. of thermistor = RI = 2000 x 1.5 x 10^{-3} = 3.0 V p.d. across coil = 12 – 3.0 = 9.0 V	 [1] [1]	
(iii)	Only a small current of 1.5 mA is required to switch on the bell using the relay. Without the relay, the user needs to handle a higher and more dangerous current of 60 mA.	 [1]	Candidate is required to relate to the context of the question.

Q5

(a)

Q = It [1]

$32 = 1.5 \times 10^4 \times t$ [1]

$t = 2.13 \times 10^{-3}$ s [1]

Marker's comments:
This question was generally well answered.

(bi)

Electromotive force is the work done by the supply in driving a unit charge around a complete circuit.

Marker's comments:
Some candidates knew the definition but weaker candidates failed to use the term "unit charge". Many candidates failed to use the term "complete" but no marks were deducted.

(bii)
1.
$1/R_{eff} = 1/R_1 + 1/R_2 + 1/R_3$
$1/R_{eff} = 1/R + 1/2R + 1/4R$ [1]
$1/R_{eff} = 7/(4R)$
$R_{eff} = 4R/7$ [1]

Marker's comments:
This part was generally well answered. But weaker candidates used complex mathematics to get the answer.

2.
$V = IR$
$E = I \times 4R/7$
$I = 7E/(4R)$

Marker's comments:
Error carried forward was allowed for this question. This part was generally well answered.

(ci)
$V = IR$
$I = V/R$
$= E/(R_1 + R_2)$ ---------- Equation 1

voltmeter reading, $V = IR_2$
$I = V/R_2$ ---------- Equation 2

Equate 1 to 2

$V/R_2 = E/(R_1+R_2)$
$V = [R_2/(R_1 + R_2)] \times E$
(shown)

Marker's comments:
Only some candidates obtained full credit for this question. Many tried to use the given equation in their proof and thus gained no credit.

(cii)
As the temperature increases, the resistance of the thermistor decreases and the potential difference across the thermistor thus decreases. [1]
As the thermistor and the fixed resistor are arranged in series, this results in the potential difference across the fixed resistor to increase. [1]

Marker's comments:
Few candidates gave the correct change in potential difference with the correct reason.
CER should be applied to improve quality of answers.