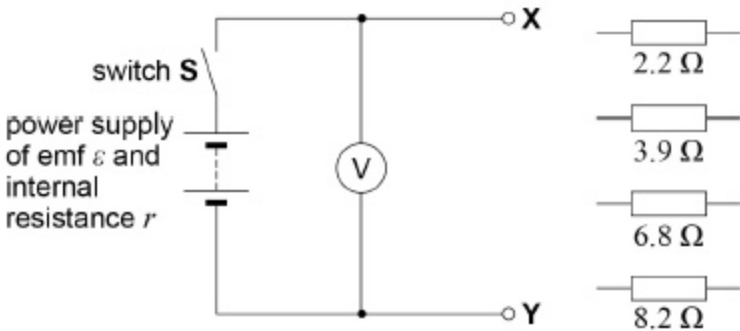


7

This question is about an experiment to determine the internal resistance of a power supply.

A student is given the circuit and the four resistors of known resistance shown in **Figure 1**.

Figure 1



The student can change the external resistance R of the circuit between terminals **X** and **Y**. This is done by connecting different combinations of **two** resistors in series or in parallel between **X** and **Y**.

This method can produce **12 different values** for R .

(a) Calculate the largest value of R that the student can obtain using **two** resistors.

$$8.2 + 6.8 = 15$$

largest value of $R =$ _____ Ω

(1)

(b) Calculate the smallest value of R that the student can obtain using **two** resistors.

$$\frac{1}{R} = \frac{1}{2.2} + \frac{1}{3.9} \quad R = 1.4$$

smallest value of $R =$ _____ Ω

(2)

(c) With switch **S** closed (in the on position) and no resistors connected between **X** and **Y** the voltmeter reading V is 1.62 V.

The student concludes that this voltmeter reading equals the emf ϵ of the power supply.

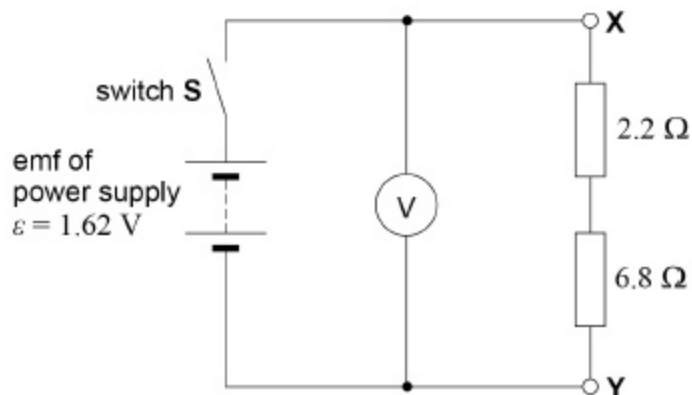
State why the student's conclusion that $\epsilon = 1.62 \text{ V}$ was correct.

(V) has a very high R
 meaning I is very small
 so lost voltage over internal
 resistance is ≈ 0

(1)

- (d) **Figure 2** shows one particular combination and arrangement of two resistors that the student could use.

Figure 2



When **S** is closed the voltmeter reading V is 1.14 V.

Explain why V is less than 1.62 V when **S** is closed.

current is flowing through the cell so some voltage is dropped over the internal resistance

(1)

- (e) It can be shown that

$$\begin{matrix} 1.62 & & 1.14 \\ \swarrow & & \swarrow \\ \epsilon - V = r \times \frac{V}{R} \end{matrix}$$

where r is the internal resistance of the power supply.

Determine $(\epsilon - V)$ and $\frac{V}{R}$ for this circuit using the data given in part (d).

$$(\epsilon - V) = \frac{1.62 - 1.14}{V} = 0.48$$

$$\frac{V}{R} = \frac{1.14}{2.2 + 6.8} = 0.13 \text{ V } \Omega^{-1}$$

$$2.2 + 6.8 = 0.13$$

(1)

(f) The student obtains values of V for five further different values of R .

These data were used to produce the graph of $(\varepsilon - V)$ against $\frac{V}{R}$ in **Figure 3**.

Plot the point you determined in part (e) on **Figure 3** and add a suitable best-fit line.

(1)

(g) Use **Figure 3** to determine r .

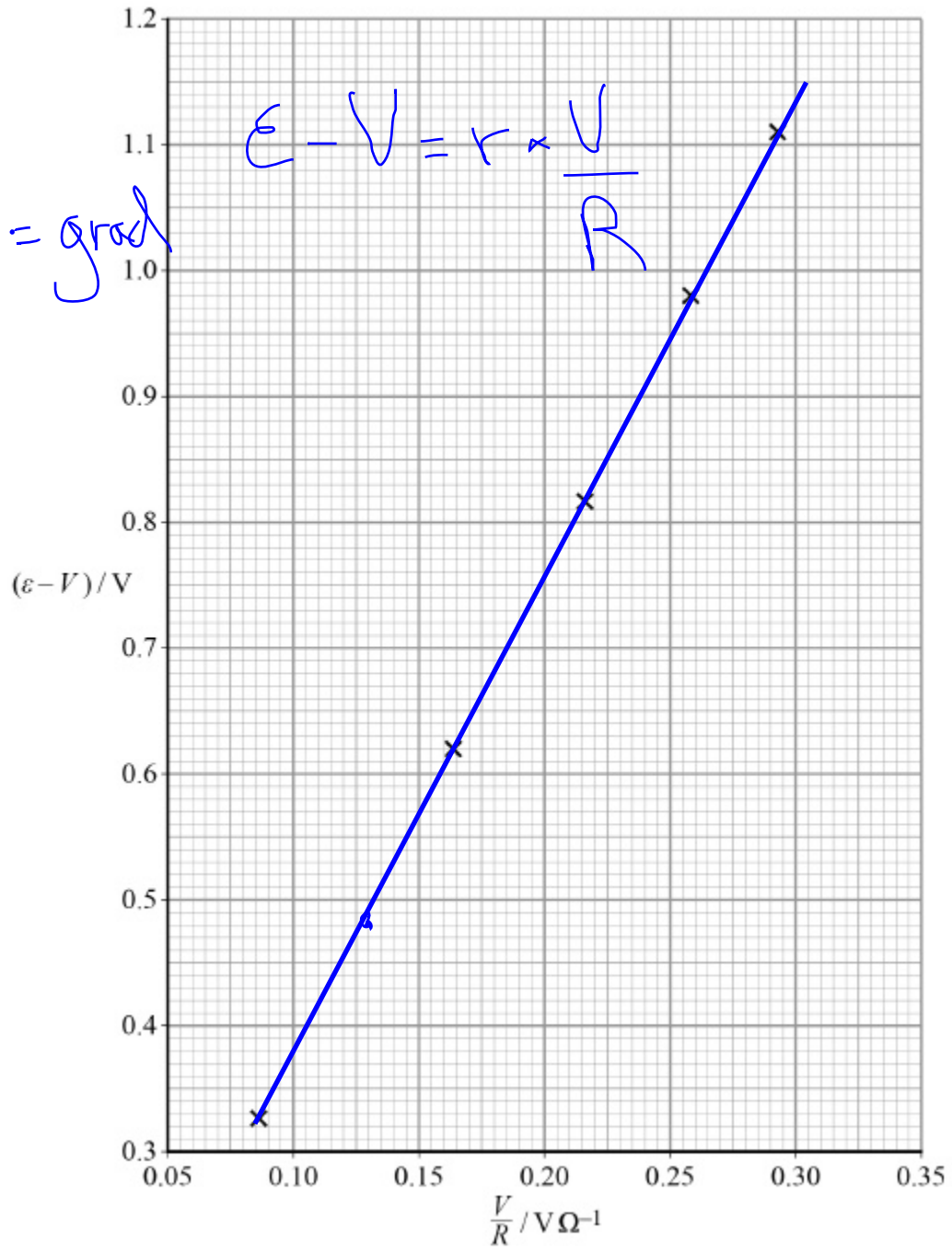
$$r = 3.49 \rightarrow 3.95$$

$$r = \underline{\hspace{10em}} \Omega$$

(2)

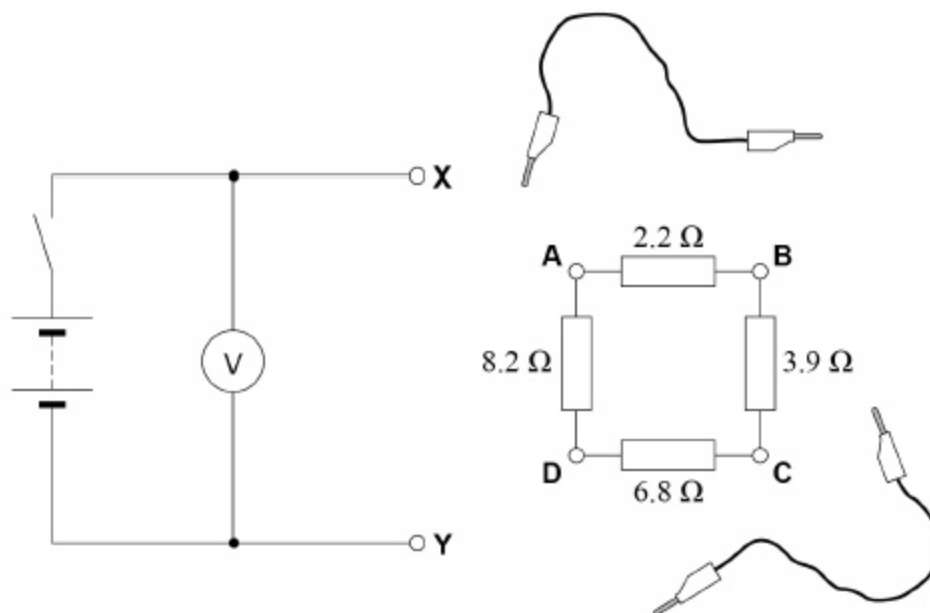
Figure 3

$$\therefore \frac{\Delta Y}{\Delta X} = \text{grad}$$



(h) **Figure 4** shows a different method for varying the resistance R described in part (a).

Figure 4



The four resistors are connected in a loop with sockets **A**, **B**, **C** and **D** at each junction. Two leads are used to connect the resistor loop to **X** and **Y**.

Discuss whether this method is an improvement over the method described in part (a). In your answer, you should refer to the number of different values that can be obtained for R .

This new solution has 6 possible combinations: AB, AC, AD, BC, BD, CD

The original method is better because question tells us there are 12 possible combinations

(2)

(Total 11 marks)

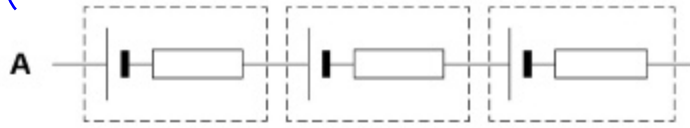


8

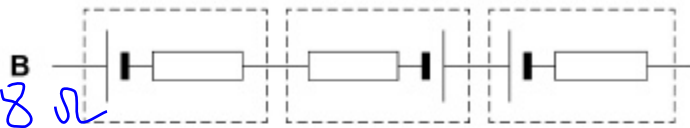
Three cells each have an emf $\epsilon = 1.5 \text{ V}$ and an internal resistance $r = 0.6 \Omega$.

Which combination of these cells will deliver a total emf of 1.5 V and a maximum current of 7.5 A ?

*r add as usual
r = 1.8 Ω*

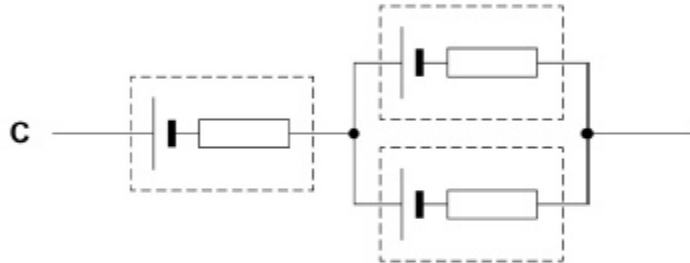


X E = 4.5 V



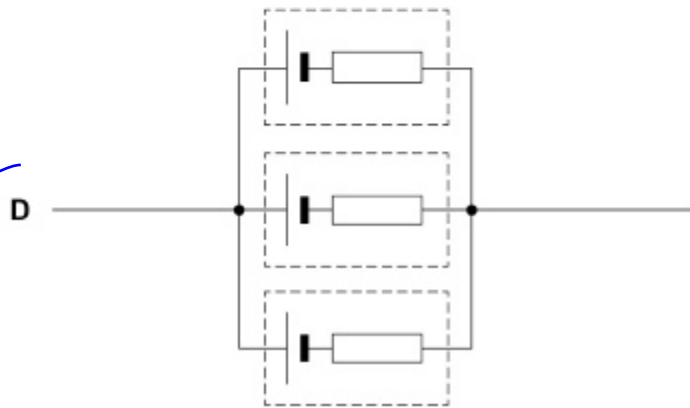
E = 1.5 V

r = 0.9 Ω



E = 3 V

r = 0.2 Ω



X E = 1.5

- A
- B
- C
- D**

use V/R = I

0.6 D

(Total 1 mark)

- (c) Solar cells convert solar energy to useful electrical energy in the road sign with an efficiency of 4.0%.

The solar-cell supply used by the engineer has a total surface area of 32 cm².

Calculate the minimum intensity, in W m⁻², of the sunlight needed to provide the minimum current of 75 mA to the road sign when it has a resistance of 6.0 Ω.

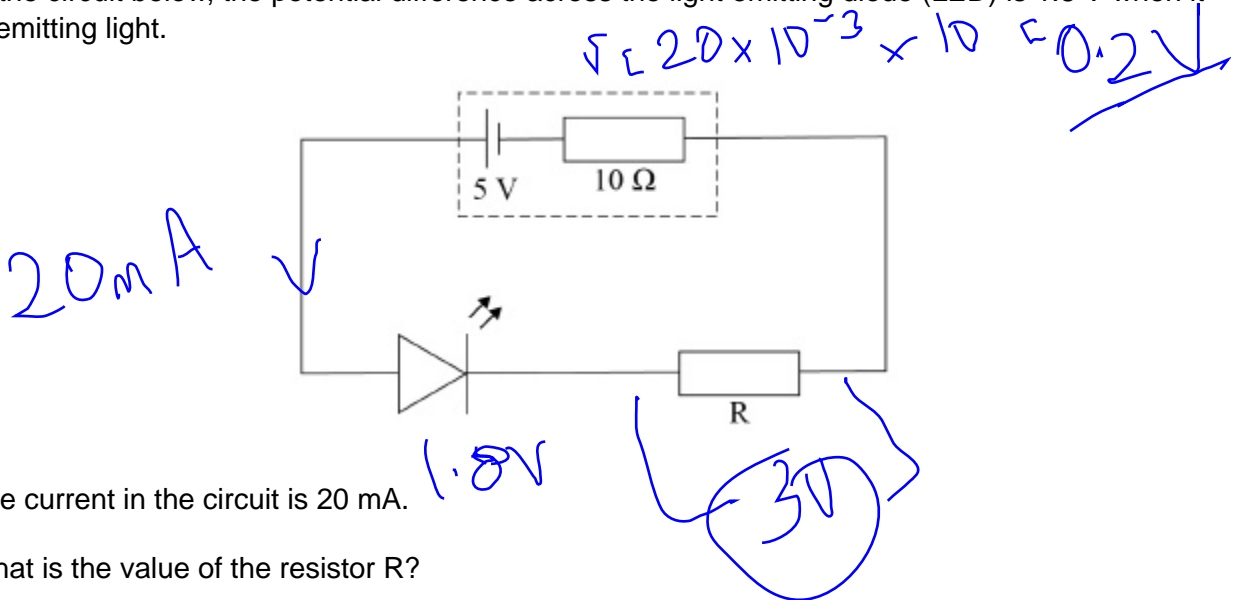
intensity = _____ W m⁻²

(3)

(Total 9 marks)

10

In the circuit below, the potential difference across the light emitting diode (LED) is 1.8 V when it is emitting light.



The current in the circuit is 20 mA.

What is the value of the resistor R?

- A 80 Ω
- B 90 Ω
- C 150 Ω
- D 160 Ω

Handwritten calculation:

$$R = \frac{V}{I} = \frac{30}{20\text{mA}} = 150\ \Omega$$

(Total 1 mark)