1

(a) By varying the resistance of the variable resistor R from its maximum resistance to zero

(b) **(i)** False. To test Ohm's law, the same resistance value must be used throughout the experiment. Here, the variable resistor is set to different values at each measurement, so we cannot conclude it doesn't obey Ohm's law from this data.

(ii) False. The battery does not supply electrons - the electrons are already in the conductor. Instead, the battery acts as an electrical 'pump' that provides e.m.f./electric field to make these existing free electrons drift through the circuit, producing current.

(c) **(i)** The graph is a plot of $V = E - Ir$
Hence, the V-intercept is $E = 3.00\ V$.

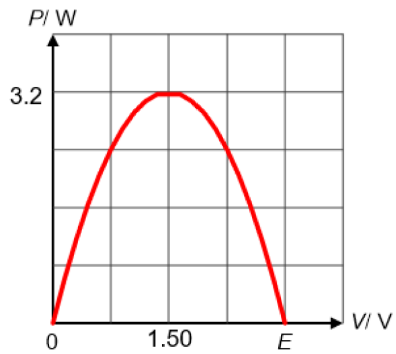
(ii) Gradient $= -r = \frac{3.00-0.20}{0.0-4.0} = \frac{2.80}{-4.0} = -0.70\ \Omega$

So, $r = 0.70\ \Omega$

(d) **(i)** Power output is maximum when $R = r = 0.70\ \Omega$.
Using potential divider rule, $V = 1.5\ V$

(ii) $P_{max} = \frac{V^2}{R} = \frac{1.5^2}{0.70}$
$= 3.2\ W$

(iii)



(e) **(i)** $\eta = \frac{IV}{IE} = \frac{V}{E} = \frac{1.50}{3.00} = 50\%$

(ii) Maximum efficiency is achieved when value of R is maximum, i.e., 10 Ω.

$$\eta = \frac{I^2R}{IE} = I\frac{R}{E} = \left(\frac{E}{r+R}\right)\left(\frac{R}{E}\right) = \frac{R}{r+R} = \frac{1}{\frac{r}{R}+1}$$

(iii) Maximum power transfer is more desirable because the goal is to produce the loudest sound, which requires maximum power delivered to the loudspeaker.

High efficiency (R >> r) minimises energy waste but reduces the actual power delivered to the speaker, whilst maximum power transfer (R = r) provides the loudest sound despite being less efficient.

2

(a) $R_{eff} = \left(\frac{1}{R} + \frac{1}{R} + \frac{1}{2R}\right)^{-1} = 0.4R$

$0.4R = 2.4$

$R = 6.0\ \Omega$

(b) **(i)** Total resistance $= 2.4 + 0.6 = 3.0\ \Omega$

Current in $A_1 = \frac{E}{R} = \frac{1.5}{3.0} = 0.50\ A$

(ii) Terminal potential difference between X and Y

$$\frac{2.4}{3.0} \times 1.5 = 1.2\ V$$

Current through resistor $R_1 = \frac{V}{R} = \frac{1.2}{6.0} = 0.20\ A$

Thus, current in $A_2 = 0.50 - 0.20 = 0.30\ A$

(iii) Potential difference across $R_4 = \frac{6.0}{6.0+6.0} \times 1.2 = 0.60\ V$

Potential at $Z = 0 - 0.60 = -0.60\ V$

(iv) As reading is zero, the potential difference across S is 0.6 V.

The potential difference across $S = \frac{S}{S+0.60} \times 1.5 = 0.60\ V$

Hence $S = 0.4\ \Omega$

3

(a) **(i)**

$$R_{total} = R_{//} + r$$
$$= \left(\frac{1}{600} + \frac{1}{3000}\right)^{-1} + 30 = 530\ \Omega$$
$$V_{LDR} = V_{terminal} = \epsilon - Ir$$
$$= 12 - \left(\frac{12}{530}\right)(30) = 11.3\ V$$
$$I_{LDR} = \frac{V_{LDR}}{R_{LDR}}$$
$$= \frac{11.3}{3000} = 3.77 = 3.8\ mA$$

(ii)

$$P_{LDR} = I_{LDR}^2 R_{LDR}$$
$$= (3.8 \times 10^{-3})^2(3000)$$
$$= 0.043\ W$$

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(b) Resistance of LDR decreases in bright light, thus resistance of the combination of parallel resistors decreases. By potential divider rule, potential difference (p.d.) across parallel resistors decreases. Since terminal p.d. is the same as p.d. across parallel resistor, terminal p.d. decreases.

4

(a) **(i)** Capacitance is defined as the ratio of charge stored to the potential difference across the capacitor

(ii) DC block, timing delay and smoothing of electrical signals

(b) capacitors in series have combined capacitance = $8\ \mu F$

Capacitance $= 8 + 24 = 32\ \mu F$

5

(b) **(i)**
$$I = \frac{Q}{t} = \frac{CV}{T}$$
$$f = \frac{1}{T}$$
$$I = fCV$$

(ii)
$$4.8 \times 10^{-6} = 150 \times 60 \times C$$
$$C = 530\ p\ F$$

(c) Since capacitors are connected in series, the total capacitance is halved. f and V are constants, so current is proportional to capacitance.

Current $= 2.4\ \mu A$

6

(a) **(i)**
$$R_{eff} = \left(\frac{1}{6.0 \times 10^3} + \frac{1}{8.0 \times 10^3}\right)^{-1}$$
$$= 3.4286\ k\Omega$$

$$I_{A1} = \frac{E}{R_T}$$
$$= \frac{9.0}{(3.4286 + 4.0) \times 10^3} = 1.21 \times 10^{-3}\ A$$

(ii)
$$V_{eff} = \frac{R_{eff}}{R_{eff} + R_p} \times E$$
$$= \frac{3.4286}{3.4286 + 4.0} \times 9.0$$
$$= 4.1539\ V$$
$$I_{A2} = \frac{V_{LDR}}{R_{LDR}}$$
$$= \frac{4.1539}{8.0 \times 10^3}$$
$$= 5.19 \times 10^{-4}\ A$$

(b) **(i)** Resistance of the LDR increases when light intensity is lowered. The effective resistance of Q and the LDR increases. Since the potential difference across P and Q is the same at $9.0\ V$, by the potential divider principle, the potential difference across Q is a larger proportion of the $9.0\ V$. Hence the potential difference across Q increases.

(ii) Since the potential difference across Q increases, the current through Q increases for the same resistance of Q. Total current in the circuit is the sum of the current through Q and the LDR. Since the total current from the battery decreases due to overall increase in resistance, and the current in Q increases, this means the current through the LDR decreases. Hence the current reading on ammeter A2 decreases.

7

(a) $R_{diode} = \frac{V}{I} = \frac{0.56}{6.0 \times 10^{-3}} = 93\ \Omega$

(b) $E = V_{diode} + V_{R3}$
$1.2 = 0.56 + (6.0 \times 10^{-3})R_3$
$R_3 = 110\ \Omega$

(c) $I = \frac{E}{R_1 + R_2}$
$= \frac{1.2}{50 + 200}$
$= 4.8 \times 10^{-3}\ A$

(d) $I_{total} = 6.0 \times 10^{-3} + 4.8 \times 10^{-3} = 1.1 \times 10^{-2}\ A$
$P = I_{total}E = (1.1 \times 10^{-2})(1.2)$
$= 1.3 \times 10^{-2}\ W$

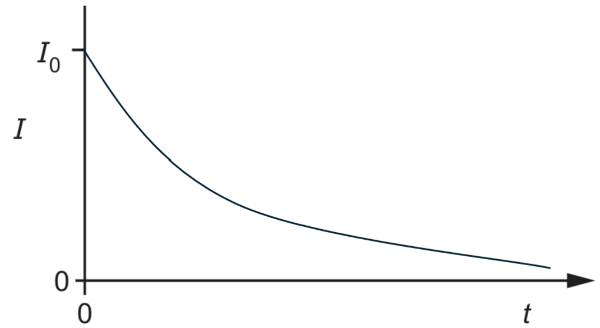
8

(a) **(i)** Q=CV
$Q_0 = 24 \times 470 \times 10^{-6}$
$= 0.011\ C$

(ii) $I_0 = \frac{24}{5600}$
$= 4.3 \times 10^{-3}\ A$

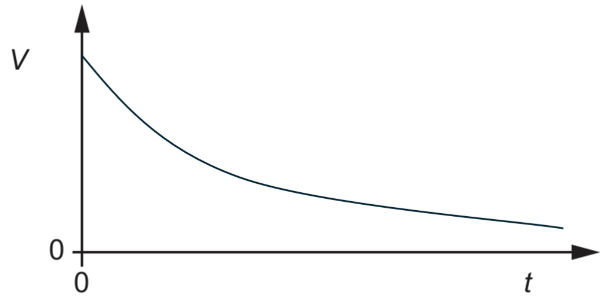
(iii) $\tau = RC$
$= 5600 \times 470 \times 10^{-6}$
$= 2.6\ s$

(iv)



(b) **(i)** The current flowing through resistor P generates magnetic fields around it. As current decreases, there is a decrease in flux and the rate of change of magnetic flux causes an induced emf across wire Q by Faraday's Law.

(ii)



9

(a) The p.d. across the resistor is the same as the p.d. across the capacitor. The charge on the capacitor is proportional to the p.d. across the capacitor thus p.d. decreases. The rate of change of p.d. decreases as p.d. decreases

(b) $Q_0 = 0.90\ mC$ and at $t = one\ time\ constant$, $Q = Q_0 e^{-1}$
$Q = 0.33\ \ mC$ at $one\ time\ constant$
$t = 5.5\ s$ from graph

(c) **(i)**

$$C = \frac{Q}{V}$$
$$= \frac{0.90 \times 10^{-3}}{7.5} = 1.2 \times 10^{-4} = 120 \times 10^{-6} = 120\ \mu F$$

(ii)

$$R = \frac{\tau}{C}$$
$$= \frac{5.5}{1.2 \times 10^{-4}}$$
$$= 46\ k\Omega$$

10

(a) If the p.d. across each light bulb is $12\ V$, the current through each bulb is $12/3.0\ =\ 4.0\ A$
Current through resistor $R\ =\ 4.0\ +\ 4.0\ =\ 8.0\ A$
p.d. across $R\ =\ 14.0\ -\ 12.0\ =\ 2.0\ V$
resistance of $R\ =\ 2.0\ /\ 8.0\ =\ 0.25\ \Omega$

(b) Since the potential difference across R_1 remains at $12\ V$, same amount of current will flow through R_1 and no current will flow through R_2. Hence, the current through the $14\ V$ generator and resistor R will reduce to $4.0\ A$. Since the p.d. across R remains the same at $2.0\ V$, the value of R should be adjusted to a lower value of $\frac{2.0}{4.0} = 0.5\ \Omega$

(c) There will be emf across the lamps even if either the generator or the battery is defective.

The light bulbs will light up longer since energy is delivered from both generator and battery.