# Wallace Hall Academy

CfE Higher Physics

Electricity

Exam Questions: Solutions

# Solutions to Electricity Exam Questions

Pages 1. – 4

## Measuring and Monitoring a.c.

1. (a) $V_{pk}$ = amplitude on screen × Y gain

$\therefore V_{pk} = 3 \times 0.5 \times 10^{-3}$

$\therefore V_{pk} = 1.5 \times 10^{-3}$ Peak voltage is $\underline{\underline{1.5\,mV}}$.

(b) $V_{RMS} = V_{pk}/\sqrt{2}$

$\therefore V_{RMS} = 1.5 \times 10^{-3}/\sqrt{2}$

$\therefore V_{RMS} = 1.06 \times 10^{-3}$ R.m.s. voltage is $\underline{\underline{1.1\,mV}}$.

(c) frequency $= \frac{1}{T}$

Period = width of 1 cycle × timebase

$= 4.0 \times 1.0 \times 10^{-3}$

$= 4.0 \times 10^{-3}$.

$f = 1/T$

$\therefore f = \frac{1}{4 \times 10^{-3}}$

$\therefore f = 0.25 \times 10^{3}$ Frequency is $\underline{\underline{250\,Hz}}$

2. (a) width of 1 cycle is 4 divisions

Period $T = 4 \times 1 \times 10^{-3}$

$\therefore T = 4.0 \times 10^{-3}$

$f = \frac{1}{T}$

$\therefore f = \frac{1}{4 \times 10^{-3}}$

$\therefore f = 250$ Frequency is $\underline{\underline{250\,Hz}}$

(b) $V_{pk}$ = ampl. on screen × Y-gain.

$= 2.0 \times 5.0$

$= 10.0$ Peak voltage is $\underline{\underline{10.0\,V}}$

3. (a) $V_{pk}$ = Y-gain × ampl. on screen

$\therefore$ Y-gain = $V_{pk}$ / ampl. on screen.

$\therefore$ Y-gain = $15/3$

$\therefore$ Y-gain = 5 Y-gain setting is 5 volts/div.

(b) 2 cycles spread 5 div on screen.

$\therefore$ 1 cycle " 2·5 div.

Period = width of 1 cycle × timebase.

$= 2{\cdot}5 \times 1{\cdot}0 \times 10^{-3}$

$= 2{\cdot}5 \times 10^{-3}$

$f = \frac{1}{T}$

$\therefore f = \frac{1}{2{\cdot}5 \times 10^{-3}}$

$\therefore f = 0{\cdot}4 \times 10^{3}$ frequency is 400 Hz

4. (a) Period = no of div for 1 cycle × timebase

$= 4 \times 2{\cdot}5 \times 10^{-3}$

$= 10 \times 10^{-3}$

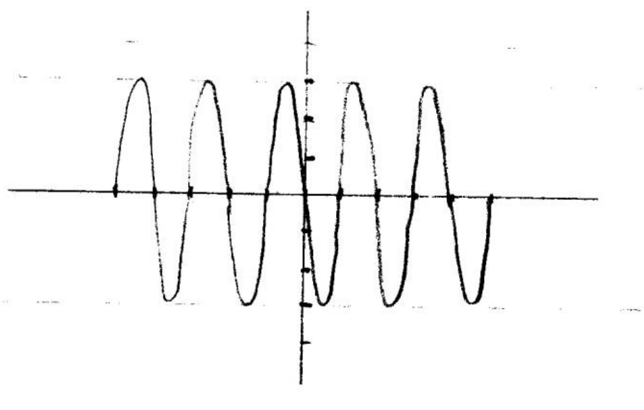
$= 10^{-2}$

$f = 1/T$

$\therefore f = \frac{1}{10^{-2}}$

$\therefore f = 10^{2}$ Frequency is 100 Hz

(b) new trace looks like



Twice as many cycles are seen on the screen now.

5. (a) $V_{rms} = V_{pk}/\sqrt{2}$

$\therefore V_{rms} = 12/\sqrt{2}$

$\therefore V_{rms} = 8.4853$ r.m.s voltage is $\underline{\underline{8.5\,V}}$

(b) $P = V^2/R$.

$\therefore P = 12^2/4.0$

$\therefore P = 144/4.0$

$\therefore P = 36$ Power dissipated is $\underline{\underline{36\,W}}$

# Current Voltage Power & Resistance

Pages 5 - 7.

1. Inner $\parallel^{el}$ part.

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$\therefore \frac{1}{R_p} = \frac{1}{6} + \frac{1}{3}$$
$$\therefore \frac{1}{R_p} = \frac{1+2}{6}$$
$$\therefore R_p = 6/3$$
$$\therefore R_p = 2.$$

upper branch. $R_s = R_1 + R_2$
$$\therefore R_s = 2 + 2$$
$$\therefore R_s = 4.$$

Whole circuit

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$\therefore \frac{1}{R_p} = \frac{1}{4} + \frac{1}{4}$$
$$\therefore 1/R_p = 2/4$$
$$\therefore R_p = 4/2$$
$$\therefore R_p = 2.$$

Total resistance is $2\,\Omega$.

$$V_s = I_s R_T$$
$$\therefore I_s = V_s / R_T$$
$$\therefore I_s = 12/2$$
$$\therefore I_s = 6.$$

Current is **6 A.**

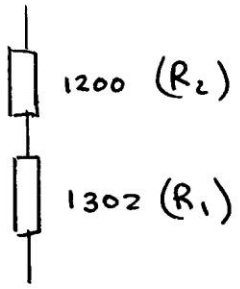
2. (a)(i)

$$V_o = \left(\frac{R_1}{R_1+R_2}\right) V_s.$$
$$\therefore 6 = \left(\frac{R_1}{R_1+1200}\right) \times 10$$
$$\therefore 6 = \frac{10R_1}{R_1+1200}$$
$$\therefore 6R_1 + 7200 = 10R_1$$
$$\therefore 4R_1 = 7200$$
$$\therefore R_1 = 1800$$

Resistance is **1.8 kΩ.**

(ii) With Z in parallel with Y the combined resistance is less than that of Y alone. Hence $R_1$ in the above expression is reduced thus reducing value of $V_o$ below 6V.

(iii)
$$\frac{1}{R_p} = \frac{1}{R_1} + 1/R_2$$
$$\therefore 1/R_p = \frac{1}{1800} + \frac{1}{4700}$$
$$\therefore 1/R_p = 7.68 \times 10^{-4}$$
$$\therefore R_p = 1302.$$




$$V_1 = \left(\frac{R_1}{R_1+R_2}\right) V_s.$$
$$\therefore V_1 = \left(\frac{1302}{1302+1200}\right) \times 10.$$
$$\therefore V_1 = \frac{13020}{2502}$$
$$\therefore V_1 = 5.2.$$

Voltage across Z is **5.2V.**

(b)
$$R_A/R_B = R_C/R_D.$$

3. (a) $V_o = \left(\frac{R_1}{R_1+R_2}\right)V_s$

$\therefore V_o = \left(\frac{6}{6+6}\right)\times 10$

$\therefore V_o = 6/12 \times 10$

$\therefore V_o = 5$ Voltmeter reading is $\underline{\underline{5V}}$

(b) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

$\therefore \frac{1}{R_p} = \frac{1}{3} + \frac{1}{6}.$

$\therefore \frac{1}{R_p} = \frac{2+1}{6}$

$\therefore 1/R_p = 3/6$

$\therefore R_p = 2.$

$V_o = \left(\frac{R_1}{R_1+R_2}\right)V_s$

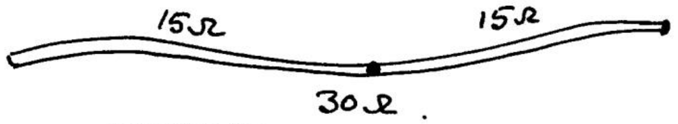
$\therefore V_o = \left(\frac{2}{2+6}\right)\times 10$

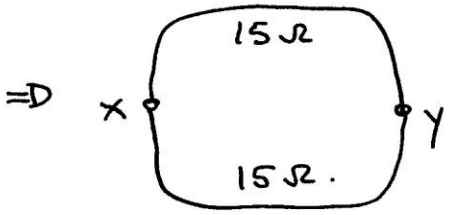
$\therefore V_o = \frac{2}{8}\times 10$

$\therefore V_o = 20/8$

$\therefore V_o = 2.5$ Voltmeter reading is $\underline{\underline{2.5V}}$

4. (a) Total resistance of wire $= 30\Omega$.




Effectively a parallel resistance combination.

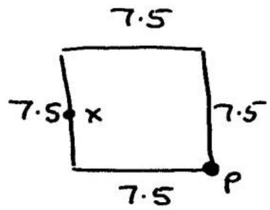
$\frac{1}{R_{xy}} = \frac{1}{R_1} + \frac{1}{R_2}$

$\therefore \frac{1}{R_{xy}} = \frac{1}{15} + \frac{1}{15}$

$\therefore \frac{1}{R_{xy}} = \frac{2}{15}$

$\therefore R_{xy} = 15/2$

$\therefore R_{xy} = 7.5$




Ohmmeter reads $\underline{\underline{7.5\,\Omega}}$

(b) Ω reads a smaller value. The shorter path on the bottom has now a lower resistance than 15 Ω in fact (7.5+3.75) ohms. The longer path XP has a resisistance of. (7.5 + 7.5 + 3.75) ohms. Hence

$\frac{1}{R_{xp}} = \frac{1}{R_1} + \frac{1}{R_2}$

$\therefore \frac{1}{R_{xp}} = \frac{1}{11.25} + \frac{1}{18.75}$

$\therefore \frac{1}{R_{xp}} = 0.1422\dot{2}$

$\therefore R_{xp} = 7.03$

This value of 7.03 Ω is $\underline{\underline{\text{less than } 7.5\,\Omega}}$.

# Electrical Sources & Internal Resistance

Pages 8 – 17

1. (a)(i) This means that every coulomb of charge passing through the supply gains 10 J of electrical energy.

(ii) $V = E - Ir$

$\therefore IR = E - Ir$

$\therefore 1.25 \times 6.0 = 10.0 - 1.25r$

$\therefore 7.50 = 10.0 - 1.25r$

$\therefore 1.25r = 2.5$

$\therefore r = 2.5/1.25$

$\therefore r = 2.0$ Internal resistance is $\underline{\underline{2.0\,\Omega}}$.

(b)(i) As a greater current now flows from the battery a greater p.d. is dropped across $r$. ($Ir$) increases as $I\uparrow$. This reduces the p.d. available at the terminals.

(ii) $E = IR_{TOTAL}$

$\therefore E = I\left(r + \left(\frac{1}{6.0} + \frac{1}{R}\right)^{-1}\right)$

$\therefore 10 = 2\left(r + \left(\frac{1}{6.0} + \frac{1}{R}\right)^{-1}\right)$

$\therefore r + \left(\frac{1}{6.0} + \frac{1}{R}\right)^{-1} = 5$

$\therefore \left(\frac{1}{6.0} + \frac{1}{R}\right)^{-1} = 3$

$\therefore \frac{1}{6.0} + \frac{1}{R} = \frac{1}{3}$

$\therefore \frac{1}{R} = \frac{1}{6.0}$

$\therefore R = 6.0$ Resistance of $R$ = $\underline{\underline{6.0\,\Omega}}$.

2. (a)(i) From graph, when $R$ is $1.5\,\Omega$, (A) reads 3.0 A.

p.d. across $R = IR$
$= 3.0 \times 1.5$
$= 4.5$

p.d. across $r = E - V$
$= 6.0 - 4.5$
$= 1.5$ "Lost volts" = $\underline{\underline{1.5\,V}}$.

(ii) $V = Ir$

$\therefore r = V/I$

$\therefore r = 1.5/3.0$

$\therefore r = 0.5$ Internal resistance is $\underline{0.5\,\Omega}$.

(b) When $R$ is increased the current drawn decreases. Hence the current in $r$ is less. Hence the p.d. across $r$ is less. Lost volts are reduced.

3. (a)(i) $R_S = R_1 + R_2 + R_3$

$\therefore R_S = 0.20 + 0.20 + 3.6$

$\therefore R_S = 0.40 + 3.6$

$\therefore R_S = 4.0$ Total resistance is $\underline{\underline{4.0\ \Omega}}$.

(ii) $E_T = IR_T$

$\therefore I = E_T/R_T$

$\therefore I = 3.0/4.0$

$\therefore I = 0.75$ Current is $\underline{\underline{0.75\ A}}$.

(iii) $P = I^2R$

$\therefore P = 0.75^2 \times 3.6$

$\therefore P = 2.025$ Power is $\underline{\underline{2.03\ W}}$.

(b) The power decreases since the current I decreases with increasing 'r'. R is constant so only $I^2$ decreases, decreasing P in turn.

4. (a) The e.m.f. is $\underline{\underline{12\ V}}$.

(b)(i) P.d. across r is $12.0 - 9.6 = 2.4$ V.

$r = 2.0\ \Omega$.

$V = Ir$.

$\therefore I = V/r$

$\therefore I = 2.4/2.0$.

$\therefore I = 1.2$ Current is $\underline{\underline{1.2\ A}}$.

b (ii) $V = IR$

$\therefore R = V/I$

$\therefore R = 9.6/1.2$

$\therefore R = 8.0$ Resistance is $\underline{\underline{8.0\ \Omega}}$.

(c) New $R_T = 2.0 + (8.0^{-1} + 8.0^{-1})^{-1}$

$= 2.0 + 4.0$

$= 6.0$

New $I = V/R_T$

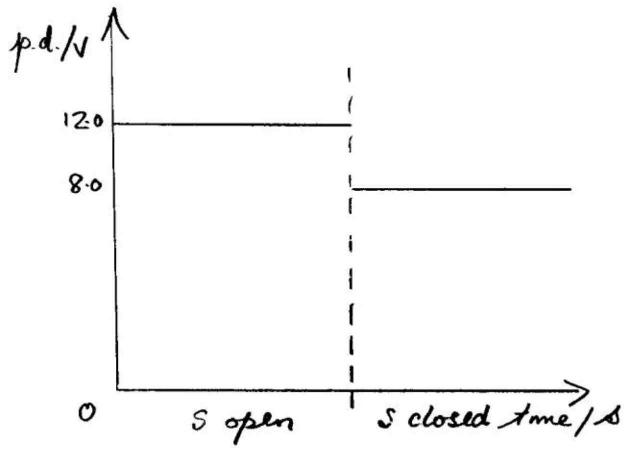
$= 12/6.0$

$= 2$

New Terminal p.d $= IR_p$

$= 2 \times 4.0$

$= 8.0$ V



5. (a) e.m.f. or electro-motive force is the energy gained by each coulomb of charge which passes through the source.

(b)(i) (A) e.m.f is $\underline{\underline{6.0V}}$ (y-intercept)

(B) internal resistance is $\underline{\underline{5.0\ \Omega}}$. (from gradient)

$$\text{grad} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\therefore -r = \frac{V_2 - V_1}{I_2 - I_1}$$

$$\therefore -r = \frac{1.0 - 5.0}{1.0 - 0.2}$$

$$\therefore -r = \frac{-4}{0.8}$$

$$\therefore r = 5$$

(ii) From graph, at 0.30 A the terminal p.d. is 4.5V (from graph)

$$V = IR$$

$$\therefore R = V/I.$$

$$\therefore R = 4.5/0.30$$

$$\therefore R = 15$$

Variable resistor set at $\underline{\underline{15\ \Omega}}$

(c) $R_{TOTAL} = r + R_P.$

$$\therefore R_T = r + \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$$

$$\therefore R_T = 5 + \left(\frac{1}{15} + \frac{1}{30}\right)^{-1}$$

$$\therefore R_T = 5 + \left(3/30\right)^{-1}$$

$$\therefore R_T = 5 + 30/3$$

$$\therefore R_T = 5 + 10.$$

$$\therefore R_T = 15$$

$$I = E/R_T$$

$$\therefore I = 6.0/15$$

$$\therefore I = 0.4$$

New ammeter reading is $\underline{\underline{0.4\,A}}$.

6\. (a) $r$ = gradient magnitude

$\therefore r = \dfrac{V_2 - V_1}{I_2 - I_1}$

$\therefore r = \left(\dfrac{1-4}{3-1}\right)$

$\therefore r = \dfrac{-3}{2}$

$\therefore r = -1.5$ Internal resistance is $\underline{\underline{1.5\ \Omega}}$

(b) $I_{max} = \dfrac{E}{r}$ $\underline{\underline{\text{or}}}$ intercept on current axis.

$\therefore I = \underline{\underline{(3.4 \pm 0.1)\,A}}$. " " " "

7 (a) $E = I(R + r)$

$\therefore E = IR + Ir$

$\therefore IR = E - Ir$

$\therefore \underline{\underline{R = E/I - r}}$

(b)(i) Internal resistance is |intercept| on vert. axis $= \underline{\underline{2.5\,\Omega}}$.

(ii) The gradient is $E$ $= \dfrac{6-0}{0.5-0.15}$

$= 6/0.35$

$= 17.14$. Emf. is $\underline{\underline{17.1\,V}}$

(c) $I_{max} = E/r$.

$= 17.1/2.5$

$= 6.84$

$\underline{\text{OR}}$ $I_{max}$ = intercept on horiz axis inverted.

$= \dfrac{1}{0.15}$

$= 6.7$

Max current is $\underline{\underline{(6.8 \pm 0.1)}}\,A$.

8\. (a)(i) $Q = It$

$\therefore Q = 0.5 \times 1 \times (60 \times 60)$

$\therefore Q = 1800$ Charge is $\underline{\underline{1.8 \times 10^3\,C}}$.

(ii) $E_w = QV$

$\therefore E_w = 1.8 \times 10^3 \times 1.2$

$\therefore E_w = 2.16 \times 10^3$ Energy supplied is $\underline{\underline{2.16 \times 10^3\,J}}$.

(b)(i) e.m.f is the work done on each coulomb of charge passing through cell.

(ii) emf is the Y-intercept. $= \underline{\underline{(1.41 \pm 0.02)\,V}}$.

$r$ = gradient $= \dfrac{V_2 - V_1}{I_2 - I_1}$

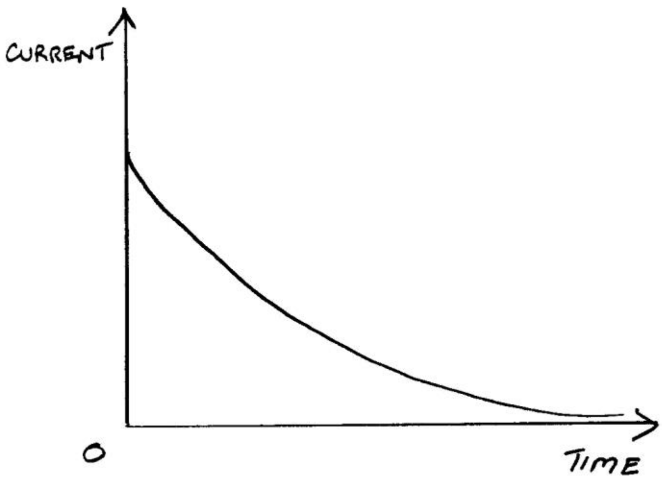
$= \left(\dfrac{1.2 - 0.6}{2.0 - 0.52}\right)$

$= -0.405$ Internal resistance is $\underline{\underline{0.41\,\Omega}}$.

# Capacitors

Pages 18 - 28.

1. (a)




(b) Series circuit $\Rightarrow I_R = I_C =$ A reading

$V_R = I_R R$

$\therefore V_R = 5.0 \times 10^{-3} \times 500$

$\therefore V_R = 2.5$

$V_S = V_R + V_C$

$\therefore V_C = V_S - V_R$

$\therefore V_C = 12 - 2.5$

$\therefore V_C = 9.5$

Reading on voltmeter is $\underline{\underline{9.5V}}$

(c) $E_{max} = \frac{1}{2} C V_{max}^2$

$\therefore E_{max} = \frac{1}{2} \times 47 \times 10^{-6} \times 12^2$

$\therefore E_{max} = 0.5 \times 47 \times 10^{-6} \times 144$

$\therefore E_{max} = 3.384 \times 10^{-3}$

Max energy stored is $\underline{\underline{3.4 \times 10^{-3} J}}$ $(3.4 mJ.)$

(d) It has no effect on the value of the energy, as the final p.d. across the plates of the capacitor is still 12V so equation $E = \frac{1}{2} C V^2$ gives same value (It just takes longer to build up that energy).

2.(a) Capacitance is a measure of the ability to store charge. It is defined as the ratio $Q/V$ ie $\frac{\text{charge}}{\text{p.d.}}$

(b)(i) $V_S = V_C + V_R$

$\therefore 12 = 8.6 + V_R$

$\therefore V_R = 12 - 8.6$

$\therefore V_R = 3.4$ p.d. is $\underline{\underline{3.4V}}$

b(ii) $V = IR$

$\therefore R = V/I$

$\therefore R = \frac{3.4}{1.6 \times 10^{-3}}$

$\therefore R = 2.13 \times 10^3$

Resistance is $2.13 \times 10^3 \Omega$

$\underline{\underline{2.13 k\Omega}}$.

(iii) Energy $= \frac{1}{2} C V^2$

$\therefore 10.8 \times 10^{-3} = \frac{1}{2} C \times 12^2$

$\therefore 21.6 \times 10^{-3} = C \times 144$

$\therefore C = \frac{21.6 \times 10^{-3}}{144}$

$\therefore C = 1.5 \times 10^{-4}$ Capacitance is $\underline{\underline{150 \times 10^{-6} F}}$

$\underline{150 \mu F}$

(c) The resistance is halved so the charging time will be halved so the time to charge is less. The smaller resistance allows a larger current to flow so charge will accumulate on the capacitor plates quicker.

3. (a) $V = IR$

$\therefore I = V/R$

$\therefore I = \frac{12.0}{480 \times 10^3}$

$\therefore I = 2.5 \times 10^{-5}$

Initial current is <u>25μA.</u>

(b) $V_S = V_C + V_R$

$\therefore V_C = V_S - V_R$

$\therefore V_C = 12 - 3.8$

$\therefore V_C = 8.2$

$Q = CV$

$\therefore Q = 2200 \times 10^{-6} \times 8.2$

$\therefore Q = 0.01804$

Charge is <u>18 mC.</u>

(c) $E_{max} = \frac{1}{2} C V_{max}^2$

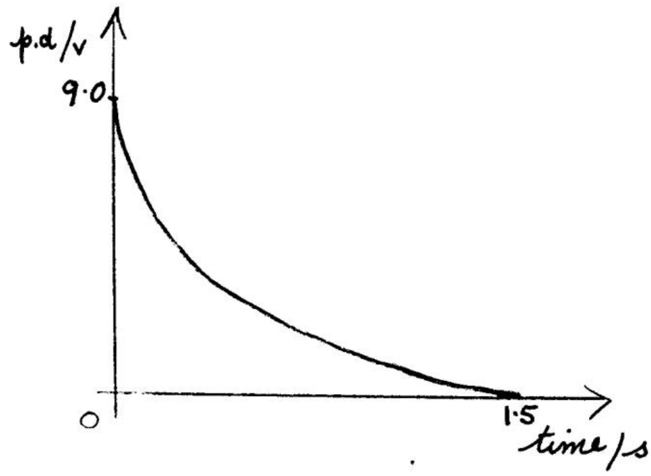
$= \frac{1}{2} \times 2200 \times 10^{-6} \times 12.0^2$

$= 72 \times 2200 \times 10^{-6}$

$= 0.1584$

Max energy stored is <u>158 mJ</u>

4. (a)(i)




(ii) This increases the time to charge. The larger resistance reduces the charging current, hence the time taken for a fixed amount of charge to build up on the plates is increased $Q = It$

as $Q$ is same value and $I \downarrow$ then $t \uparrow$

(iii) $V_R = 4.0V$

$\therefore V_C = V_S - V_R$

$\therefore V_C = 9.0 - 4.0$

$\therefore V_C = 5.0$

$Q = CV$

$\therefore Q = 2.2 \times 10^{-3} \times 5.0$

$\therefore Q = 11 \times 10^{-3}$

Charge stored is <u>11 mC.</u>

(b) (i) $E_{max} = \frac{1}{2} C V_{max}^2$

$\therefore E_{max} = \frac{1}{2} \times 2200 \times 10^{-6} \times 9^2$

$\therefore E_{max} = 1100 \times 10^{-6} \times 81$

$\therefore E_{max} = 0.0891$

Max energy is <u>89.1 mJ</u>

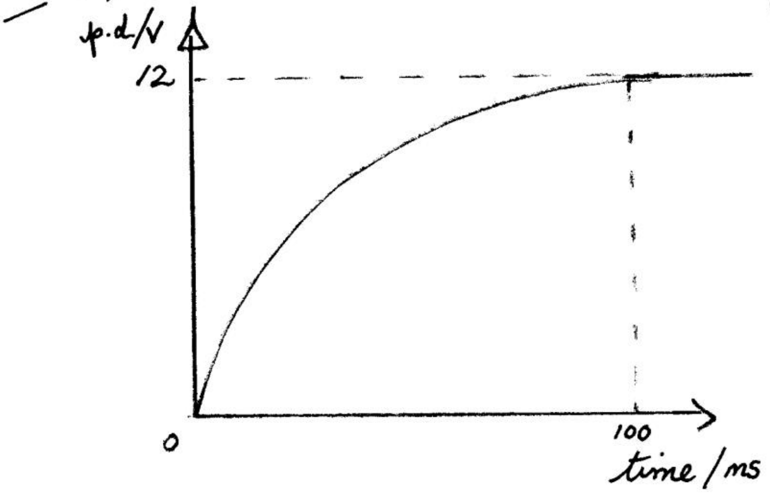
(ii) $V_s = IR$

$\therefore I = V_s/R$

$\therefore I = \frac{9.0}{10^5}$

$\therefore I = 9 \times 10^{-5}$ Max current is <u>90μA</u>

5. (a)




(b)(i) $V_R = IR$

$\therefore V_R = 20\times10^{-3} \times 400$

$\therefore V_R = 8$

$V_C = V_S - V_R$

$\therefore V_C = 12 - 8$

$\therefore V_C = 4$

Voltage across capacitor is $\underline{\underline{4V}}$

b(ii) $E = \frac{1}{2}CV^2$

$\therefore E = \frac{1}{2} \times 100\times10^{-6} \times 4^2$

$\therefore E = 50\times10^{-6} \times 16$

$\therefore E = 800\times10^{-6}$

$\therefore E = 8\times10^{-4}$ Energy stored is $\underline{\underline{8\times10^{-4}\,J}}$ $(0.8\,mJ)$

(c) Use a resistor of value less than $\underline{\underline{400\,\Omega}}$

(d) The new capacitor has a smaller value than $100\,\mu F$. (just over half the value). The charging time is smaller indicating that less charge was needed to fully charge the capacitor and since $Q = CV$ with $V$ constant when $Q\downarrow$ then $C$ must be less.

6. (a)(i) 6 V

(a)(ii) $E = \frac{1}{2}CV^2$

$\therefore E = \frac{1}{2} \times 2000\times10^{-6} \times 6^2$

$\therefore E = 1000\times10^{-6} \times 36$

$\therefore E = 36000\times10^{-6}$

$\therefore E = 0.036$

Energy stored is $\underline{\underline{0.036\,J}}$

(a)(iii) $V = IR$

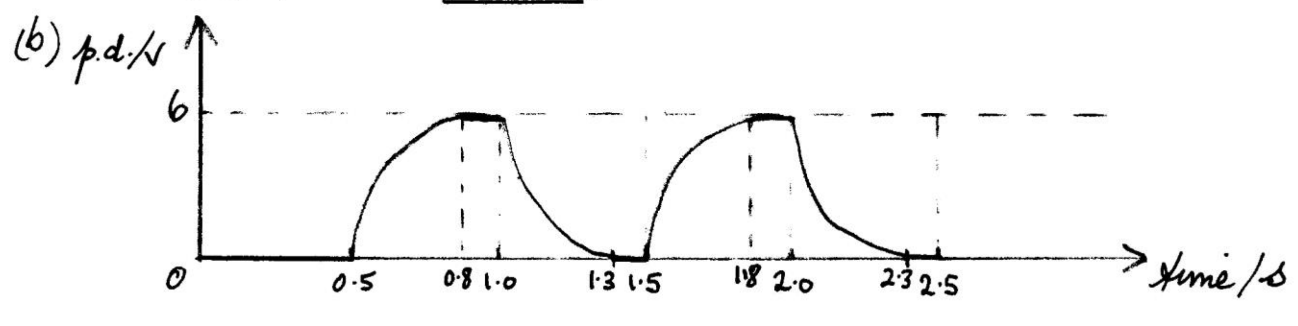
$\therefore R = V/I$

$\therefore R = \frac{6}{4.5\times10^{-3}}$

$\therefore R = 800$

Resistance is $\underline{\underline{800\,\Omega}}$.

(b)



7 (a)(i) $V = IR$

$\therefore I = V/R$

$\therefore I = \frac{6.0}{1500}$

$\therefore I = 4 \times 10^{-3}$. Initial current is $\underline{\underline{4\ mA}}$.

(ii) Energy $= \frac{1}{2}CV^2$

$= \frac{1}{2} \times 470 \times 10^{-6} \times 6^2$

$= 0.00846$ Energy stored is $\underline{\underline{8.46}}$ mJ.

(iii) The supply p.d. must be increased beyond 6.0V.

(b) Photon energy $= hf$.

$= 6.63 \times 10^{-34} \times 5.80 \times 10^{14}$

$= 3.845 \times 10^{-19}$.

No of photons required for $6.35 \times 10^{-3}$ J $= \frac{6.35 \times 10^{-3}}{3.845 \times 10^{-19}}$

$= \underline{\underline{1.65 \times 10^{16}}}$ photons.

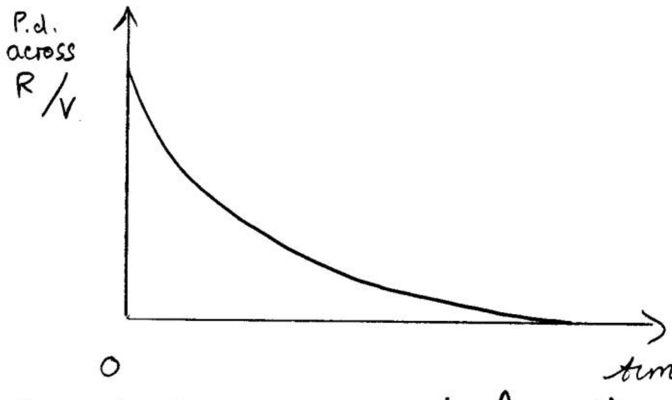
8 (a)(i) P.d. is 6 V.

(ii) $I_{max} = V/R$

$\therefore I_{max} = 6/800$

$\therefore I_{max} = 7.5 \times 10^{-3}$ Max current is $\underline{\underline{7.5\ mA}}$

(iii)



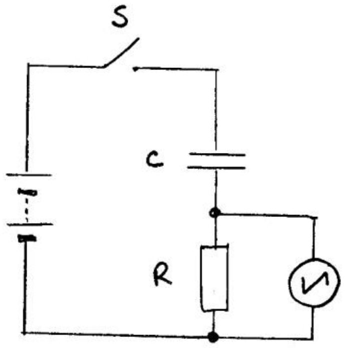

(b) The discharge time is less than the charging time. Since the capacitance is the same the discharge resistance must be smaller than the charging resistance.

(c) Energy stored $= \frac{1}{2}CV^2$

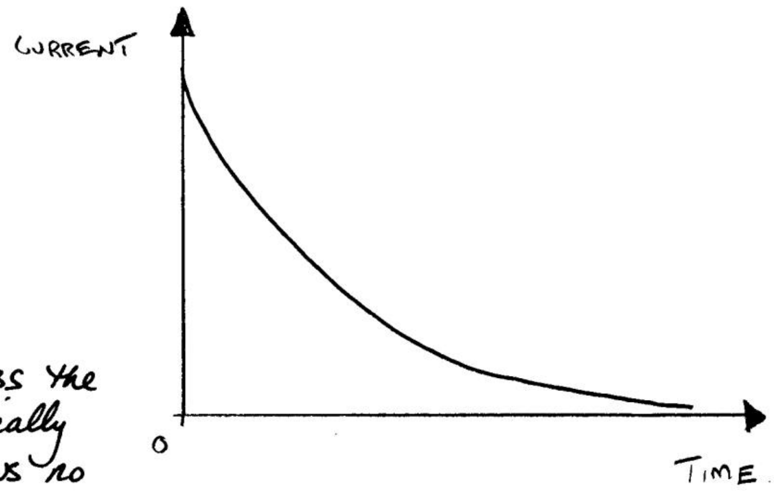
$= \frac{1}{2} \times 10\,000 \times 10^{-6} \times 6^2$

$= 0.18$ Energy stored is $\underline{\underline{0.18J}}$

9. (a)



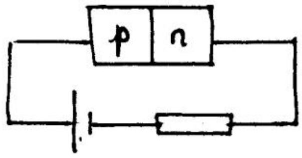

( The CRO must be across the resistor as it is basically a voltmeter which draws no current itself)



# Electrons at Work.

## Pages 29 - 35

1\. (a)




(b) At the junction electrons move ← towards junction and holes move → towards junction. These holes and electrons meet in the junction region and recombine and the energy released as an electron 'falls' into a hole is released as light, one photon for each recombining electron-hole pair.

(c) (i)

$E = hf$.

$E = h\,c/\lambda$

$c/\lambda = E/h$.

$\lambda/c = h/E$

$\lambda = ch/E$

$= \dfrac{3.0\times10^{8}\times 6.63\times10^{-34}}{3.68\times10^{-19}}$

Wavelength. = 540 nm.

(ii) $E_W = qV$.

$\Rightarrow$ $3.68\times10^{-19} \times 1.6\times10^{-19}\ V$

$\Rightarrow$ $V = 2.3$.

Minimum p.d. is 2.3 V

2 (a)(i) Diode is in PHOTOVOLTAIC MODE.

(ii) As photons enter the semiconductor junction their energy is used to separate holes and electrons. This charge separation is consistent with the generation of a small e.m.f..

(iii) The reading increases slightly

(b) (i) e.m.f. is 0·508 volts.

(ii) Term pd. = $E - Ir$

$\Rightarrow 0{\cdot}04 = 0{\cdot}508 - (2\times10^{-3}\,r)$

$\Rightarrow 2\times10^{-3}\,r = 0{\cdot}508 - 0{\cdot}04$

$\Rightarrow r = \frac{0{\cdot}508 - 0{\cdot}04}{2\times10^{-3}}$

$\Rightarrow r = 234$ Internal resistance is <u>234 Ω</u>

(c) Since a greater current is drawn with a smaller total resistance the 'Ir' term has a greater value so the terminal pd. is now less than 0·04 V.

3. (a) (i) One complete cycle occurs in 4 divisions

" " " " " $4 \times 2.5ms$

$= 10ms$

$\Rightarrow$ PERIOD $= 10ms$

Now $f = \frac{1}{T}$

$\Rightarrow f = \frac{1}{10 \times 10^{-3}}$

$\Rightarrow f = \frac{1}{10^{-2}}$

$\Rightarrow f = 100$. Frequency is $\underline{\underline{100\ Hz}}$.

(ii) Peak voltage $= 2 \times 5$
$= 10V$.

R.M.S. VOLTAGE $= {}^{10}/_{\sqrt{2}}$
$= 7.07$.

$V = IR$

$\Rightarrow I_{RMS} = V_{rms}/R$

$\Rightarrow I_{rms} = 7.07/200$

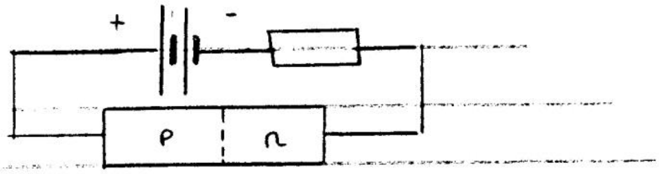
$\Rightarrow I_{rms} = 0.035$ r.m.s current is $\underline{\underline{0.035A}}$.

(b) The disappearance of the negative half cycles is explained by the fact that when the diode is reverse biased it does not conduct so no current flows in R hence no -ve p.d. appears across R.

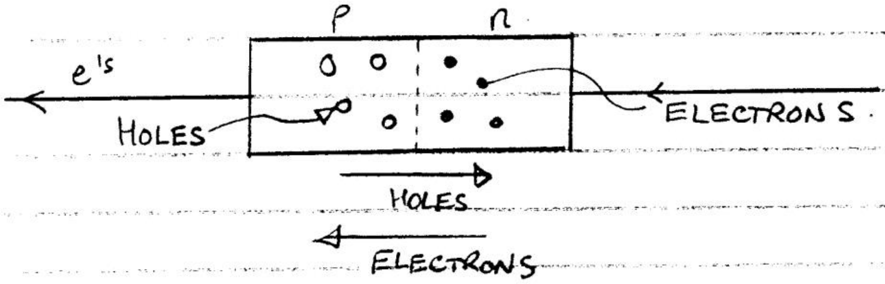
The peak positive values as less than before because even when the diode is forward biased there is a potential drop across the diode of ~0.6, 0.7 V.

4. The voltmeter reading increases very slightly. The no. of photons incident on the photodiode per second has increased but the energy delivered to holes & electrons individually is the same. (definition of e.m.f.). As more & more holes & electrons are separated the layers of charge carriers move a little further apart increasing the measured p.d. slightly.

5. (a) (i)




(ii)




(iii) When an electron "lands in a hole" in the junction region the energy of recombination is emitted in the form of light.

(b)(i) The voltage must be greater than 0.5 V

(ii) The resistance of the diode decreases as the p.d is increased. The resistance is V/I and the gradient of the graph is I/V so as I/V increases; V/I decreases

6 (a) Photons of light enter the junction region of the diode and create electron hole pairs which allow conduction to take place.

(b) The diode is operating in the photoconductive mode.

(c) $I_{nt} \propto \frac{1}{d^2}$ and the current is proportional to the intensity of the light.

$\Rightarrow I \propto \frac{1}{d^2}$

$\Rightarrow I = k/d^2$

$\Rightarrow k = Id^2$

$\Rightarrow I_1 d_1^2 = I_2 d_2^2$

$\Rightarrow 3 \times 10^{-6} \times 1^2 = I_2 \times (0.75)^2$

$\Rightarrow I_2 = \frac{3 \times 10^{-6}}{(0.75)^2}$

$\Rightarrow I_2 = 5.33 \times 10^{-6}$

The current is $\underline{\underline{5.33 \mu A}}$

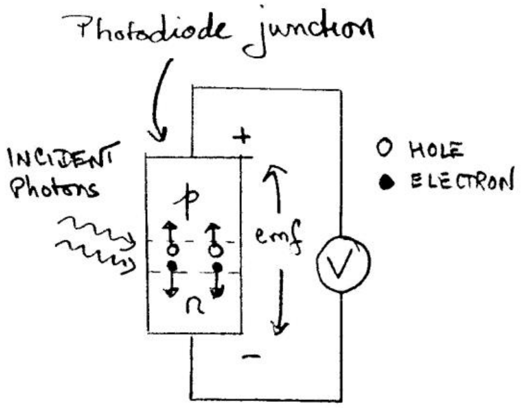
7. (a) $P = IV$

$\therefore I = P/V$

$\therefore I = \frac{150}{34}$

$\therefore I = 4.41$ Current is $\underline{4.4 A}$

(b) In the photovoltaic mode, photons reaching the junction region separate holes & electrons. The electrons move into the n-type material (cathode) and holes move into the p-type material (anode). Since emf is defined as the energy gained per unit charge, the separated holes & electrons constitute an e.m.f.




(c) Assuming the Sun can be considered as a point source, the inverse-square law for light applies "$I \propto \frac{1}{d^2}$". If $d \to 2d$ then denominator becomes $4d^2$ making the irradiance I one quarter of the original value.

# Uncertainties (page 36)

1. % error in $V = \left(\frac{0.03}{30.0}\right) \times \frac{100}{1}$

$= \frac{3}{30}$

$= 0.1\%$

% error in $I = \left(\frac{0.01}{2.00}\right) \times \frac{100}{1}$

$= \frac{1}{2}$

$= 0.5\%$

The larger contribution is $\pm 0.5\%$ from current hence $\pm 0.5\%$ used in final value.

$V = IR$

$\therefore R = V/I$

$\therefore R = 30/2$

$\therefore R = 15.0$

$0.5\%$ of $15.0$

$= \frac{0.5}{100} \times \frac{15}{1}$

$= 0.075$

Resistance is $(15.0 \pm 0.1)\ \Omega$.
$(15.00 \pm 0.08)\ \Omega$. } Two acceptable answers.

## Open Ended Question. (page 37)

1\. During charging the current flows through the 5Ω int. res. of the battery. Some electrical energy will be converted to heat.

During use with MP3 player the current again passes through the 5Ω int. resistance. More energy will be converted to heat.

The power loss in both cases is $I_c^2 R = 5 I_c^2$ where $I_c$ is the charging current.

Hence the total energy recovered in the MP3 player will be less than that supplied by the 12V supply.