Unit 3: Electricity
3.2 Circuits

1. 6J of energy is given to each coulomb of charge that passes through the battery.

2. $V = 1.5V$
$Q = 12C$
$W = ?$

$W = QV$
$W = 12 \times 1.5$
$W = 18J$

3. $V = 12V$
$Q = 1.6 \times 10^{-19} C$
$W = ?$

$W = QV$
$W = 1.6 \times 10^{-19} \times 12$
$W = 1.92 \times 10^{-18} J$.

4. $W = 480J$
$Q = 16C$
$V = ?$

$W = QV$
$480 = 16 \times V$
$V = 30V$.

5(a) $W = 24J$
$Q = 0.8C$
$V = ?$

$W = QV$
$24 = 0.8V$
$V = 30V$

(b) $Q = 12 \times 10^{-6} C$
$W = 7.2J$.
$V = ?$

$W = QV$
$7.2 = 12 \times 10^{-6} \times V$.
$V = 600,000V$
$V = 600kV$ or $6 \times 10^5 V$.

6(a) $Q = 48\times10^{-3}\,C$
$V = 6V$
$W = ?$

$W = QV$
$W = 48\times10^{-3} \times 6$
$W = 0.288J$
$W = 0.29J$

(b) $Q = 500\times10^{-6}\,C$
$V = 1.5V$
$W = ?$

$W = QV$
$W = 500\times10^{-6} \times 1.5$
$W = 7.5\times10^{-4}\,J$

(c) $V = 3V$
$Q = 1.6\times10^{-19}\,C$
$W = ?$

$W = QV$
$W = 1.6\times10^{-19} \times 3$
$W = 4.8\times10^{-19}\,J$

7. $Q = ?$
$V = 12V$
$W = 4800J$

$W = QV$
$4800 = Q \times 12$
$Q = 400C$

8 $I = 5A$
$t = 10 minutes$
$= 600s$
$Q = ?$

$Q = It$
$Q = 5 \times 600$
$Q = 3000C$

9. $t = ?$
$I = 25\times10^{-3}A$
$Q = 96,500C$

$Q = It$
$96,500 = 25\times10^{-3}\,t$
$t = 3.86\times10^{6}\,s$
$= 6.4\times10^{4}$ minutes
$= 1072$ hours
$= 45$ days.

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10. $Q = 240C$
$t = 3$ minutes
$= 180s$
$I = ?$

$Q = It$
$240 = I \times 180$
$I = 1.3A$

11(a) $V = 24V$
$I = 2.5A$
$t = 20$ minutes
$= 1200s$
$Q = ?$

$Q = It$
$Q = 2.5 \times 1200$
$Q = 3000C$

(b) $W = QV$
$W = 3000 \times 24$
$W = 72,000J$

(c) $P = IV$
$P = 2.5 \times 24$
$P = 60W$

12(a) $I = 2.4A$
$V = 12V$
$W = 288 \times 10^3 J$
$Q = ?$

$W = QV$
$288 \times 10^3 = Q \times 12$
$Q = 24,000C$

(b) $Q = It$
$24000 = 2.4t$
$t = 10,000s$
$= 1 \times 10^4 s$

13(a) $R_T = R_1 + R_2$

$R_T = 12 + 20$

$R_T = 32\,\Omega$

(b) $R_T = R_1 + R_2 + R_3$

$R_T = 12 + 8 + 16$

$R_T = 36\,\Omega$

(c) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{20} + \frac{1}{20}$

$\frac{1}{R_T} = \frac{2}{20}$

$R_T = 10\,\Omega$

(d) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{20} + \frac{1}{5}$

$\frac{1}{R_T} = 0.25$

$R_T = 4\,\Omega$

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13e) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{10} + \frac{1}{15}$.

$\frac{1}{R_T} = 0.17$.

$\underline{R_T = 6\,\Omega}$.

f) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_T} = \frac{1}{20} + \frac{1}{20} + \frac{1}{20}$.

$\frac{1}{R_T} = \frac{3}{20}$.

$\underline{R_T = 6.7\,\Omega}$

g) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_T} = \frac{1}{20} + \frac{1}{5} + \frac{1}{4}$

$\frac{1}{R_T} = \frac{1}{2}$

$R_T = 2\,\Omega$

h) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_T} = \frac{1}{12} + \frac{1}{6} + \frac{1}{12}$

$\frac{1}{R_T} = 0.33$

$R_T = 3\,\Omega.$

(i) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{40} + \frac{1}{10}.$

$\frac{1}{R_T} = 0.125$

$R_T = 8\,k\Omega$

$R_T = R_1 + R_2$
$= 10 + 8$
$= 18\,k\Omega.$

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13 j) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{48} + \frac{1}{16}$

$\frac{1}{R_T} = 0.083$

$R_T = 12\,\Omega$

$R_T = R_1 + R_2 + R_3$

$R_T = 24 + 12 + 36$

$R_T = 72\,\Omega$

13 k) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{15} + \frac{1}{5}$

$\frac{1}{R_T} = 0.267$

$R_T = 3.75\,k\Omega$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{100} + \frac{1}{25}$

$\frac{1}{R_T} = 0.05$

$R_T = 20\,k\Omega$

$R_T = R_1 + R_2$

$R_T = 3.75 + 20$

$R_T = 23.75\,k\Omega$

i) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$= \frac{1}{12} + \frac{1}{36}$

$\frac{1}{R_T} = 0.111$

$R_T = 9\,\Omega$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$= \frac{1}{15} + \frac{1}{10} + \frac{1}{12}$

$\frac{1}{R_T} = 0.25$

$R_T = 4\,\Omega$

$R_T = R_1 + R_2$

$R_T = 9 + 4$

$R_T = 13\,\Omega$

M) $R_T = R_1 + R_2$

$= 24 + 12$

$= 36\,\Omega$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{36} + \frac{1}{9}$

$\frac{1}{R_T} = 0.139$

$R_T = 7.2\,\Omega$

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13n) $R_T = R_1 + R_2$
$= 100 + 400$
$= 500\Omega$

$R_T = R_1 + R_2$
$= 200 + 300$
$= 500\Omega$.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_T} = \frac{1}{500} + \frac{1}{500} + \frac{1}{500}$$

$$\frac{1}{R_T} = 6 \times 10^{-3}$$

$$R_T = 167\Omega$$

14a) $R_T = R_1 + R_2$
$= 16 + 8$
$= 24\Omega$

b) $R = 24\Omega$
$V = 12V$
$I = ?$

$I = \frac{V}{R}$

$I = \frac{12}{24}$

$I = 0.5A$

c) 16Ω

$V = IR$
$V = 0.5 \times 16$
$V = 8V$

8Ω.

$V = IR$
$V = 0.5 \times 8$
$V = 4V$.

15. $V = 6V$

$R = 10 \times 10^3 \Omega$

$V_R = V_{supply} - V_{thermister}$.

$= 6 - 0.5$

$= 5.5V$.

$I = \frac{V}{R}$

$= \frac{5.5}{10 \times 10^3}$

$= 5.5 \times 10^{-4} A$.

$R_{therm} = \frac{V_{therm}}{I}$

$= \frac{0.5}{5.5 \times 10^{-4}}$

$= 909 \Omega$

16. $I = 0.2A$

(a) $R_T = 20 + 30$

$= 50 \Omega$

Emf = ?

$V = IR$

$V = 0.2 \times 50$

$V = 10V$.

(b) $V = IR$

$= 0.2 \times 20$

$= 4V$

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17. $P = IV$

$24 = I \cdot 6$

$I = 4A$

Voltage across resistor $= 12 - 6 = 6V$.

$V = IR$

$6 = 4R$

$R = 1.5\Omega$

18(a) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{12} + \frac{1}{4}$

$\frac{1}{R_T} = 0.33$

$R_T = 3\Omega$

(b) $I = \frac{V}{R}$

$I = \frac{24}{3}$

$I = 8A$.

(c) $I = \frac{V}{R}$

$I = \frac{24}{12}$

$I = 2A$

$I = \frac{V}{R}$

$I = \frac{24}{4}$

$I = 6A$.

19(a) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{40} + \frac{1}{10}$

$\frac{1}{R_T} = 0.125$

$R_T = 8\Omega$

$R_T = R_1 + R_2$

$R_T = 16 + 8$

$R_T = 24\Omega$

(b) $I = \frac{V}{R}$

$I = \frac{12}{24}$

$I = 0.5A$.

c) R_1 $V = IR$.

$V = 0.5 \times 16$

$V = 8V$

$12 - 8 = 4V$

Voltage across R_2 & $R_3 = 4V$.

(d) R_2 $I = \frac{V}{R}$

$I = \frac{4}{40}$

$I = 0.1A$

R_3 : $I = \frac{V}{R}$

$I = \frac{4}{10}$.

$I = 0.4A$.

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20. $\frac{1}{R_T} = \frac{1}{20} + \frac{1}{30}$

$\frac{1}{R_T} = 0.083$

$R_T = 12\Omega$ $\qquad R_T = 24 + 12 + 36 = 72\Omega.$

$I_{TOTAL} = \frac{V}{R}$

$= \frac{18}{72}$

$= 0.25A.$

$V_{across\ 24\Omega} = IR$
$= 0.25 \times 24$
$= 6V$

$V_{across\ 36\Omega} = IR$
$= 0.25 \times 36$
$= 9V.$

$V_{parallel} = 18 - 6 - 9 = 3V.$

$I = \frac{V}{R}$
$= \frac{3}{20}$
$= 0.15A.$

$I = \frac{V}{R}$
$= \frac{3}{30}$
$= 0.1A.$

I through $24\Omega = 0.25A.$
I through $36\Omega = 0.25A$
I through $20\Omega = 0.15A$
I through $30\Omega = 0.1\Omega.$

21) $\frac{1}{R_T} = \frac{1}{3.3} + \frac{1}{4.7}$

$\frac{1}{R_T} = 0.516$

$R_T = 1.9\text{k}\Omega$

$R_T = 2.2 + 1.9 = 4.1\text{k}\Omega$

$I = \frac{V}{R}$

$I = \frac{1.5}{4.1 \times 10^3}$

$I = 3.7 \times 10^{-4}\text{A}$ (Reading on Ammeter - total current)

Voltage across 2.2kΩ: $V = IR$

$V = 3.7 \times 10^{-4} \times 2200$

$V = 0.8\text{V}$

Voltage of Parallel component: $1.5 - 0.8 = 0.7\text{V}$

Ammeter (3.3kΩ): $I = \frac{V}{R}$

$I = \frac{0.7}{3300}$

$I = 2.1 \times 10^{-4}\text{A}$

Ammeter (4.7kΩ): $I = \frac{V}{R}$

$I = \frac{0.7}{4700}$

$I = 1.5 \times 10^{-4}\text{A}$

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22. $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$= \frac{1}{15} + \frac{1}{10}$

$\frac{1}{R_T} = 0.17$

$R_T = 6\Omega$

$R_T = \frac{V}{I}$

$R_T = \frac{9}{0.25}$

$R_T = 36\Omega.$

$R = 36 - 6 = 30\Omega.$

23(a) use ratio : 12 : 4

3 : 1

$3 \times 2 = 6$

therefore 6A flows through 4Ω.

(b) current in 6Ω = 6 + 2 = 8A.

(c) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$= \frac{1}{12} + \frac{1}{4}$

$\frac{1}{R_T} = 0.33$

$R_T = 3\Omega.$

$V = IR$

$= 8 \times 9$

$= 72V$

24(a) $\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$\frac{4}{8} = \frac{R}{250}$

$R = \frac{4 \times 250}{8}$

$R = 125\Omega.$

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24(b) $\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$\frac{5}{19} = \frac{3.3}{R}$

$R = \frac{3.3 \times 19}{5}$

$R = 12.5 k\Omega$

25(a) $V_1 = \left(\frac{R_1}{R_1 + R_2}\right) V_s$

$V_1 = \frac{10}{(10+15)} \cdot 5.$

$V_1 = 2V$

(b) $V_1 = \frac{R_1}{(R_1+R_2)} \cdot V_s$

$V_1 = \frac{470}{(470+330)} \cdot 12$

$V_1 = 7V$

(c) $V_1 = \left(\frac{R_1}{R_1+R_2}\right) V_s$

$V_1 = \left(\frac{1000}{1000+100}\right) 5$

$V_1 = 4.5V$

(d) $V_1 = \left(\frac{R_1}{R_1+R_2}\right) V_s$

$V_1 = \left(\frac{10000}{10 \times 10^3 + 1.2 \times 10^6}\right) 5$

$V_1 = 0.04V$

25(e) $V_1 = \left(\frac{R_1}{R_1+R_2}\right)V_S$

$V_1 = \left(\frac{5}{5+15}\right)5$

$V_1 = 1.25V$.

(f) $\frac{1}{R_T} = \frac{1}{56} + \frac{1}{22}$

$\frac{1}{R_T} = 0.06$

$R_T = 15.8k\Omega$.

$V_1 = \left(\frac{R_1}{R_1+R_2}\right)V_S$

$V_1 = \left(\frac{15.8}{15.8+33}\right)12$

$V_1 = 3.9V$.

(g) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$= \frac{1}{10} + \frac{1}{470}$

$\frac{1}{R_T} = \frac{24}{235}$

$R_T = 9.8\Omega$

$V_1 = \left(\frac{R_1}{R_1+R_2}\right)V_S$

$V_1 = \left(\frac{9.8}{9.8+330}\right)5$

$V_1 = 0.14V$

(h) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{68} + \frac{1}{56}$

$\frac{1}{R_T} = \frac{31}{952}$

$R_T = 30.7k\Omega$

$V_1 = \left(\frac{R_1}{R_1+R_2}\right)V_S$

$V_1 = \left(\frac{47}{47+30.7}\right)5$

$V_1 = 3V$

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Internal Resistance

27

(a) $I = \frac{E}{R+r}$

$I = \frac{12}{(7.5+0.5)}$

$I = 1.5A$

(b) t.p.d = IR
= 1.5 × 7.5
= 11.25V

(c) 'lost volts' = 12 − 11.25 = 0.75V

28a) t.p.d = IR
= 6 × 3
= 18V

(b) 'lost Volts' = Emf − t.p.d
= 24 − 18
= 6V

'lost volts' = Ir

6 = 6r

r = 1Ω

29(a) $E = 1.5V$

$r = 0.6\Omega$

$R = 3.3\Omega$

$I = ?$

$$I = \frac{E}{R + r}$$

$$I = \frac{1.5}{(3.3 + 0.6)}$$

$$I = 0.38A.$$

(b) $t.p.d = IR$

$= 0.38 \times 3.3$

$= 1.27V.$

(c) short circuit:

$$I = \frac{E}{r}$$

$$I = \frac{1.5}{0.6}$$

$$I = 2.5A.$$

30. $E = 12.4V$

$r = 0.06\Omega$

$I_s = ?$

$$I_s = \frac{E}{r}$$

$$I_s = \frac{12.4}{0.06}$$

$$I_s = 207A.$$

31. $E = 6V$

$I = 24A.$

$r = ?$

$$r = \frac{E}{I}$$

$$r = \frac{6}{24}$$

$$r = 0.25\Omega.$$

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3.2. $E = 15V$
$r = 0.5\Omega$
$R = 4.5\Omega$.

(a) $I = \frac{E}{R+r}$

$I = \frac{1.5}{4.5 + 0.5}$

$I = 0.3A$.

$P = I^2R$
$= .3^2 \times 4.5$
$= 0.405W$

(b) $P = I^2R$
$= .3^2 \times 5$
$= 0.045W$

33. $E = 1.6V$
$r = 0.25\Omega$
$I = 2.4A$.

$E = IR + Ir$
$1.6 = 2.4R + (2.4 \times 0.25)$
$1.6 = 2.4R + 0.6$
$2.4R = 1$
$R = 0.4\Omega$.

$t.p.d = IR$
$= 2.4 \times 0.4$
$= 1V$.

34.

$E = 12V$

$t.p.d = 10.5V$.

$R = 2.8\Omega$.

$r = ?$

$t.p.d = IR$

$10.5 = I \times 2.8$

$I = 3.75A$.

'lost volts' $= 12 - 10.5$

$= 1.5V$.

'lost volts' $= Ir$

$1.5 = 3.75r$.

$r = 0.4\Omega$

35. $E = 1.53V$

$t.p.d = 1.32V$

$I = 0.42A$

$r = ?$

'lost volts' $= 1.53 - 1.32$

$= 0.21V$

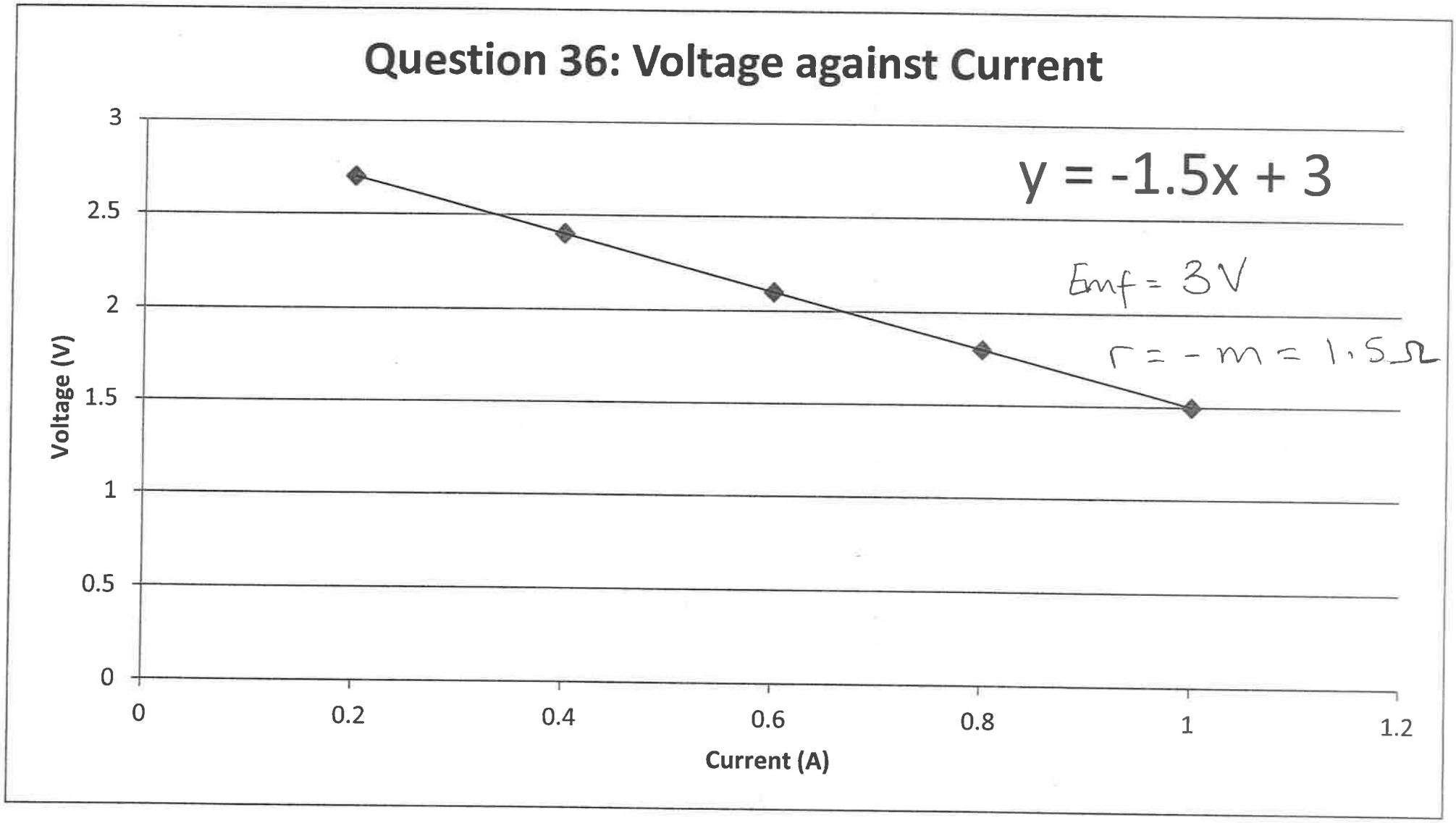
$$r = \frac{\text{'lost Volts'}}{I}$$

$$r = \frac{0.21}{0.42}$$

$r = 0.5\Omega$

36. $a + b$ = see graph.

(c) $I = \frac{E}{r} = \frac{3}{1.5} = 2A$.


Question 36: Voltage against Current
y = -1.5x + 3
Emf = 3V
r = - m = 1.5Ω
Voltage (V)
3
2.5
2
1.5
1
0.5
0
0
0.2
0.4
0.6
0.8
1
1.2
Current (A)

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37. When the switch is closed the overall load resistance will decrease.
This will lead to an increase in the current.
since E & r are constant in the equation:

$$E = IR + Ir$$

Ir (the lost volts) must increase which in turn means IR (the t·p·d) must decrease. Since the t·p·d is lower the lamp will get dimmer.

38. $E = 9V$
$r = 2\Omega$

$$I = \frac{V}{R}$$

$$I = \frac{5}{16}$$

$$I = 0.31A$$

'lost volts' = Ir
$= 0.31 \times 2$
$= 0.62V$

Emf = t·p·d + 'lost Volts'

therfore, t·p·d = $9 - 0.62$
$= 8.38V$

$V_R = 3.38V$
$I = 0.31A$
$R = ?$

$$R = \frac{V}{I} = \frac{3.38}{0.31}$$

$= 11\Omega$.

39(a)

(i) $E = 6V$
$R = 1.5\Omega$
$I = 3A$

t·p·d = IR
= 1.5 × 3
= 4.5V

'lost Volts' = 6 − 4.5
= 1.5V

(ii) 'lost Volts' = Ir
1.5 = 3r
$r = 0.5\Omega$

(b) If R increases the current will decrease. The Emf (E) of the cell is fixed as is the internal resistance (r). This means that the lost volts will decrease as $E = IR + Ir$ with 'Ir' representing the 'lost volts'.