3. (a) $R_{Wire} = \rho \frac{L}{A}$

$$3.50\ \Omega = \left(1.7 \times 10^{-8}\ \Omega \cdot \text{m}\right) \frac{L}{3.5 \times 10^{-9}\ \text{m}^2}$$

$\boxed{L = 0.72\ \text{m}} = 72\ \text{cm}$

$V = IR$ or $R_{Total} = \frac{V}{I} = \frac{16\ \text{V}}{4.0\ \text{A}} = 4.0\ \Omega$

$R_{Total} = R_{Internal} + R_{Wire}$

$4.0\ \Omega = 0.5\ \Omega + R_{Wire}$

$R_{Wire} = 3.5\ \Omega$

(b)

_X_ Upward ___Downward

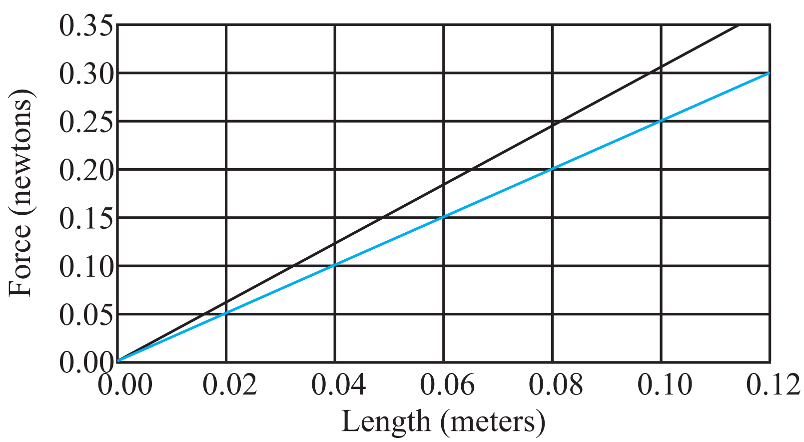
Using the right-hand rule to show the direction of the force from a magnetic field on a current-carrying wire, the fingers point in the direction of the current and the wrist is rotated (keeping the fingers in the direction of the current) until the palm is facing the magnetic field (so the fingers can curl in the direction of the magnetic field), then the direction the thumb is facing shows the direction of this force on the wire which is down in this instance. According to Newton's third law, the reaction force on the magnet from the wire will be in the opposite direction which is upward.

(c) $\boldsymbol{F} = I\boldsymbol{lB}\sin\theta$

$$0.060\ \text{N} = (4.0\ \text{A})(0.020\ \text{m})B\sin(90)$$

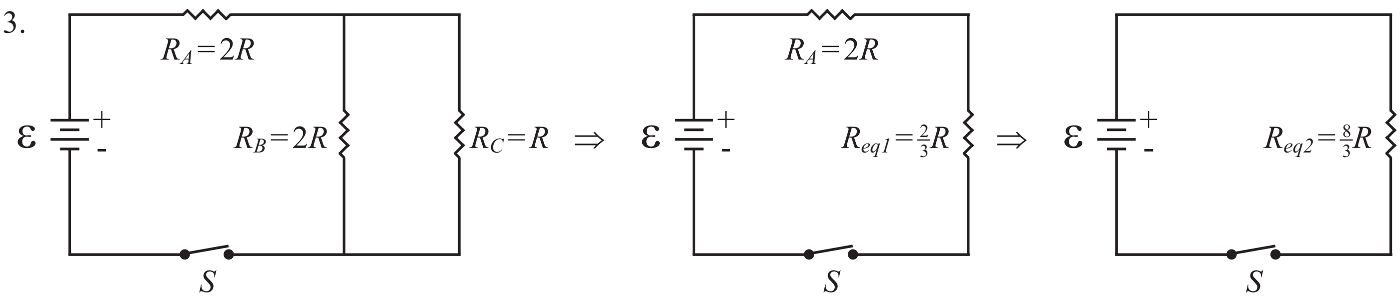
$\boxed{B = 0.75\ \text{T}}$

(d)




(e) The magnetic field is not constant between the two pole faces. The strength of magnetic field decreases as the location of the wire moves away from the center of the pole faces and towards the edges. Similarly, the direction of the magnetic field becomes less perpendicular to the pole faces as the location of the wire moves away from the center of the pole faces and towards the edges, therefore, the angle, θ, between the direction of the field and the length of wire segment in the field becomes smaller. There is significant fringing of the field at the edges of the pole faces. The longer the segment of wire between the two pole faces, the more of it is exposed to the fields near the edges of the poles where the field is weaker and less perpendicular to the pole faces. Since, $F = IlB\sin\theta$, the force on the wire segment will become increasingly less than expected as the length of the segment is increased.

3.




$$I_B = \frac{V_B}{R_B} = \frac{\frac{1}{4}\varepsilon}{2R}$$
$$I_B = \frac{1}{8}\frac{\varepsilon}{R}$$

$$I_C = \frac{V_B}{R_C} = \frac{\frac{1}{4}\varepsilon}{R}$$
$$I_C = \frac{1}{4}\frac{\varepsilon}{R}$$

$$\frac{1}{R_{eq1}} = \frac{1}{R_B} + \frac{1}{R_C}$$
$$\frac{1}{R_{eq1}} = \frac{1}{2R} + \frac{1}{R}$$
$$\frac{1}{R_{eq1}} = \frac{1}{2R} + \frac{2}{2R} = \frac{3}{2R}$$
$$R_{eq1} = \tfrac{2}{3}R$$

$$V_B = I_A R_{eq1} = \left(\frac{3}{8}\frac{\varepsilon}{R}\right)\left(\tfrac{2}{3}R\right)$$
$$V_B = \tfrac{1}{4}\varepsilon = V_C$$

$$R_{eq2} = R_A + R_{eq1}$$
$$R_{eq2} = 2R + \tfrac{2}{3}R = \tfrac{6}{3}R + \tfrac{2}{3}R$$
$$R_{eq2} = \tfrac{8}{3}R$$

$$V = IR$$
$$I_A = \frac{V}{R_{eq2}} = \frac{\varepsilon}{\frac{8}{3}R}$$
$$I_A = \frac{3}{8}\frac{\varepsilon}{R}$$

$$V_A = I_A R_A = \left(\frac{3}{8}\frac{\varepsilon}{R}\right)(2R)$$
$$V_A = \frac{3}{4}\varepsilon$$

(a) i.

__1__ $I_A$ __3__ $I_B$ __2__ $I_C$

ii. See calculations above for mathematical values of $I_A$, $I_B$, $I_C$. Conceptually, $I_A = I_B + I_C$ because the current comes out of the battery, through resistor $R_A$ and splits into the two branches containing resistors $R_B$ and $R_C$, respectively. When the current splits, more of the original current will flow through resistor $R_C$ than resistor $R_B$ because resistor $R_C$ ($R$) has less resistance than resistor $R_B$ ($2R$).

(b) i.

__1__ $V_A$ __2__ $V_B$ __2__ $V_C$

ii. See calculations above for mathematical values of $V_A$, $V_B$, $V_C$. Conceptually, $V_B = V_C$ because the two resistors are in parallel and voltage is common in parallel. The voltage across a resistor depends on the current passing through it and the size of its resistance. $V_A$ will be greater than $V_B$ and $V_C$ because it has a greater current running through it and has a resistance of $2R$, which is as large as the resistance of resistor $R_B$ and greater than the resistance of resistor $R_C$ which has a resistance of $R$.

(c) $R_{eq2} = \tfrac{8}{3}R = \tfrac{8}{3}(200\ \Omega) = \boxed{533\ \Omega = R_{eq2}}$ - See calculations above.

(d) $I_C = \frac{1}{4}\frac{\varepsilon}{R} = \frac{1}{4}\frac{(12\text{ V})}{(200\ \Omega)} = \boxed{0.015\text{ A} = I_C}$ - See calculations above.

(e) At equilibrium, there is no current through the capacitor, so it is as if that branch is not there. Therefore, $I = \frac{\varepsilon}{R_{total}} = \frac{\varepsilon}{R_A + R_C} = \frac{\varepsilon}{2R + R} = \frac{\varepsilon}{3R} = \frac{12\text{ V}}{3(200\ \Omega)} = 0.020$ A is the current through both registers $R_A$ and $R_C$. Thus, the voltage across resistor $R_C$ is $V_C = IR_C = (0.020A)(200\ \Omega) = 4.0$ V. Since this resistor is in parallel with the capacitor that is also the voltage across the capacitor. The charge across this capacitor will be $Q = CV = (2.0 \times 10^{-6}\text{ F})(4.0\text{ V}) = \boxed{8.0 \times 10^{-6}\text{ C} = Q}$

2. (a) $\frac{1}{C_T} = \frac{1}{(12 \times 10^{-6}\ F)} + \frac{1}{(6 \times 10^{-6}\ F)}$

$C_T = 4 \times 10^{-6}$ F = 4 μF

(b) After the circuit has been connected for a long time, there is no current flow to the branch with the capacitors because they already contain a full charge-it is as if there is an open circuit in that branch. So, the circuit consists, essentially, of one battery and two resistors all in series with one another. The total resitance in the circuit, $R_T$, is $R_T = 10\ \Omega + 20\ \Omega = 30\ \Omega$.

$V = IR_T$

$6\ V = I(30\ \Omega)$

$I = 0.2$ A

(c) $V_{ab} = IR_2 = (0.2\ A)(20\ \Omega)$ **<u>OR</u>** $V_{ab} = \varepsilon - IR_1 = 6\ V - (0.2\ A)(10\ \Omega) = 4\ V$

$V = 4$ V

(d) $Q = C_TV = (4 \times 10^{-6}\ F)(4\ V)$

$Q = 1.6 \times 10^{-5}$ C = 0.16 μC

Since charge on capacitors in series is common, the charge on the 6 μF capacitor is the same as that on the equivalent capacitor in the calculation above.

(e)

____ increase ____ decrease __**X**__ remain the same

The potential difference between points *A* and *B* will remain the same because once the capacitors are fully charged, the branch containing those capacitors can be treated like an open portion of the circuit. Cutting the wire between the two capacitors (point *P*) just makes the circuit truly open in that branch so the circuit will behave just as it did before.

3. (a) i. $P_1 = \frac{V^2}{R_1}$

$30\ W = \frac{(120\ V)^2}{R_1}$

$R_1 = 480\ \Omega$

$V = IR_T$

$120\ V = I(480\ \Omega)$

$I_1 = 0.25\ A$

ii. $P_2 = \frac{V^2}{R_2}$

$40\ W = \frac{(120\ V)^2}{R_2}$

$R_2 = 360\ \Omega$

$V = IR_T$

$120\ V = I(360\ \Omega)$

$I_2 = 0.33\ A$

(b) i. $R_1 = 4.0\ \Omega$ - The resistance does not change.

$R_T = R_1 + R_2 = 480\ \Omega + 360\ \Omega = 840\ \Omega$

$V = IR_T$

$120\ V = I(840\ \Omega)$

$I_1 = 0.14\ A$

ii. $R_2 = 3.0\ \Omega$ - The resistance does not change.

$R_T = R_1 + R_2 = 480\ \Omega + 360\ \Omega = 840\ \Omega$

$V = IR_T$

$120\ V = I(840\ \Omega)$

$I_1 = 0.14\ A$

(c) Parallel

$P_1 = I_1^2 R_1$

$P_1 = (0.25\ A)^2(480\ \Omega) = 30\ W$

$P_2 = I_2^2 R_2$

$P_1 = (0.33\ A)^2(360\ \Omega) = 40\ W$

Series

$P_1 = I_1^2 R_1$

$P_1 = (0.14\ A)^2(480\ \Omega) = 9.4\ W$

$P_2 = I_2^2 R_2$

$P_1 = (0.14\ A)^2(360\ \Omega) = 7.1\ W$

2 30 W bulb in parallel circuit
1 40 W bulb in parallel circuit
3 30 W bulb in series circuit
4 40 W bulb in series circuit

(d) i. Parallel

$P_T = P_1 + P_2 = 30\ W + 40\ W$

$P_T = 70\ W$

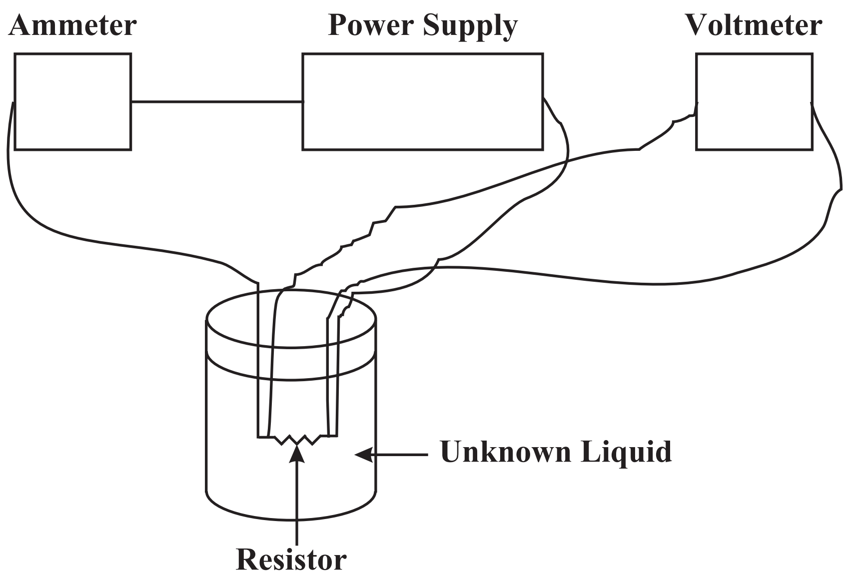
ii. Series

$P_T = P_1 + P_2 = 9.4\ W + 7.1\ W$

$P_T = 16.5\ W$

5. Connect the resistor to a power supply in series with an ammeter. Connect the voltmeter in parallel with the resistor. A line can be drawn on the graph that shows the pattern of resistance as a function of temperature and extrapolated into the 50 °C to 75 °C region. Or more data can be collected using the boiling-water bath and the ice-water bath for temperatures between 50 °C and 75 °C. Start with the boiling-water bath, take away the heat source and allow to cool by slowly adding cold water from the ice-water bath until the temperature is 75 °C. Measure the resistance and continue to cool at 5 °C intervals.

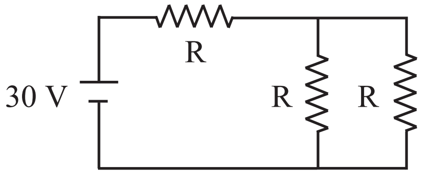
(a)

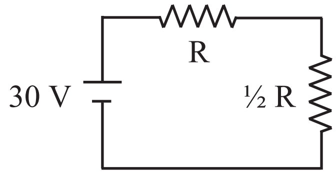


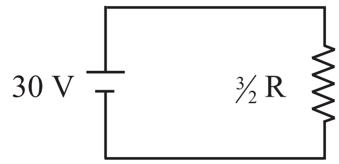

(b) Measure the voltage and the current and use ohm's law to get the resistance of this platinum resistor ( $R = \frac{V}{I}$ ). From the graph read the temperature that would give this resistance.

(c) As current flows, the resistor will get warmer and affect its own resitance. To minimize this effect, leave the resistor in the unknown liquid for several minutes so it reaches thermal equilibrium with the unknown liquid before turning on the power supply and take the readings (particularly current) as quickly as possible after the power supply has been turned on.

3. (a)




$V = IR$

$I = \dfrac{V}{R_{eq2}} = \dfrac{30V}{\frac{3}{2}R}$

$I = 20\dfrac{V}{R}$

$V_{eq3} = IR = 20\dfrac{V}{R}$

$V_{eq3} = 20\text{ V}$

$\dfrac{1}{R_{eq1}} = \dfrac{1}{R} + \dfrac{1}{R}$

$\dfrac{1}{R_{eq1}} = \dfrac{2}{R}$

$R_{eq2} = \frac{1}{2}R$

$R_{eq2} = R + R_{eq1}$

$R_{eq2} = R + \frac{1}{2}R$

$R_{eq2} = \frac{3}{2}R$

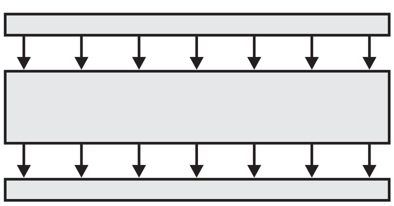
(b) $Q = CV = (1.0 \times 10^{-9}\text{ F})(30\text{ V})$

$Q = 3.0 \times 10^{-8}\text{ C}$

(c) i. 30 V

ii. 0

iii.



iv. $E = \dfrac{V}{d} = \dfrac{30V}{0.0005m}$

$E = 6.0 \times 10^{4}\text{ V/m}$