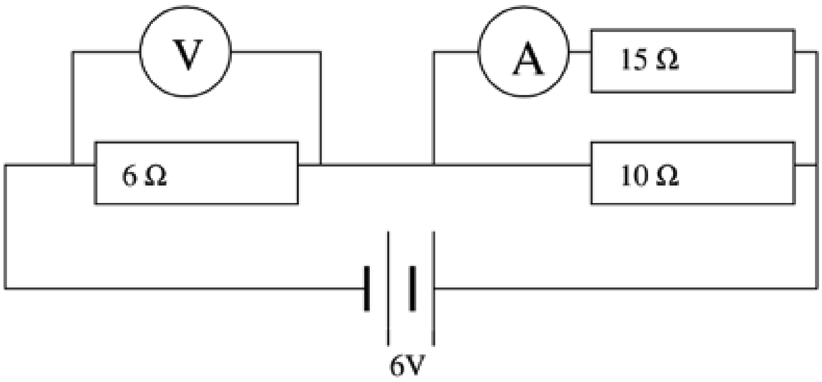
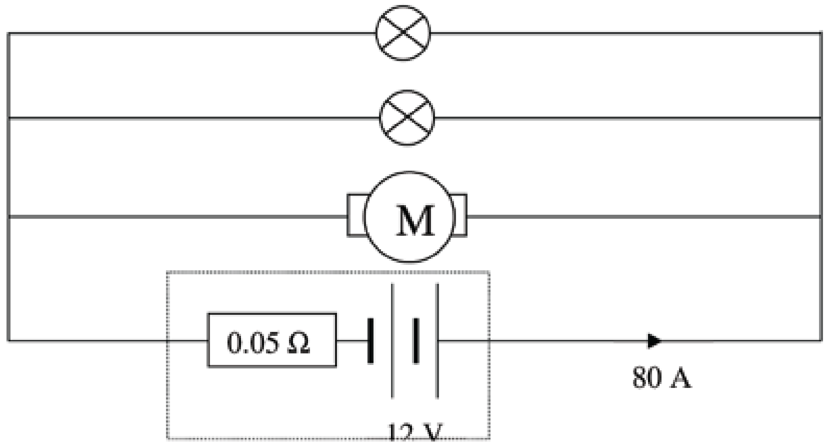
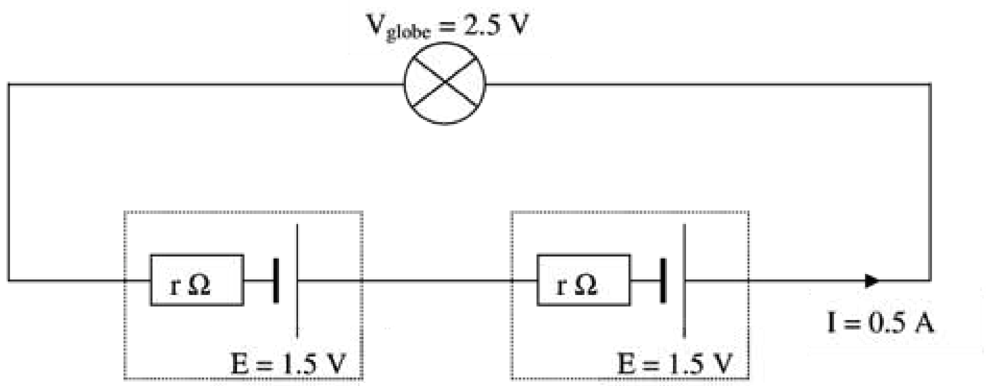
Set 17: Parallel and Series Circuits

17.1		The appliances are connected in parallel with each other, since if one device blows the others keep working (a property of parallel circuits). Also, if are independent of each other so that if you turn one on or off, it does not affect other appliances. This would not happen if they were connected in series.
17.2		$R_{total} = 12 \times 30\ \Omega = 360\ \Omega$
17.3	(a)	$V_{total} = V_1 + V_2 = 12\text{ V} + 12\text{ V} = 24.0\text{ V}$
	(b)	$R_{total} = R_1 + R_2 + R_3 = 20\ \Omega + 20\ \Omega + 20\ \Omega = 60\ \Omega$ $I = \frac{V_{total}}{R_{total}} = \frac{24\text{ V}}{60\ \Omega} = 0.40\text{ A or }400\text{ mA}$
	(c)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{3}{20\Omega}$ gives $R_t = 6.67\ \Omega$
	(d)	A smaller resistance means that from the same power supply, the parallel arrangement will draw a larger current than the series lights, so the situation in part c). will be more intense (brighter).
17.4		The series resistor must account for 20 V of the electricity supply and since it is to be connected in series with the radio, 4 A will also flow through it. Its resistance, $R = \frac{V}{I} = \frac{20\text{ V}}{4\text{ A}} = 5.0\ \Omega$
17.5	(a)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{2}{2\ \Omega}$ gives $R_t = 1.0\ \Omega$ for the parallel section of the circuit so $R_{total} = R_{parallel} + R_{buzzer} = 1\ \Omega + 3\ \Omega = 4.0\ \Omega$
	(b)	$I = \frac{V_{total}}{R_{total}} = \frac{(2 \times 9\text{ V})}{4\ \Omega} = 4.5\text{ A}$
	(c)	The buzzer will be loudest when both switches are closed. If only one was closed, then the circuit is effectively a series circuit and the new current, $I = \frac{V}{(R_2 + R_3)} = \frac{18\text{ V}}{(2\ \Omega + 3\ \Omega)} = 3.6\text{ A}$ (almost 1 A less). If both switches are open, the buzzer will not work at all since there will not be a closed circuit.
	(d)	At its softest setting, the current = 3.6 A (see part c). above). $E = V \times I \times t = 18\text{ V} \times 3.6\text{ A} \times (3\text{ min} \times 60\text{s}) = 11.7\text{ kJ}$
17.6	(a)	$R_{ammeter} = 2.0\ \Omega$ $R_{min} = 300\ \Omega$, so $I_{max} = \frac{V}{(R_{min} + R_{ammeter})} = \frac{12\text{ V}}{(300\ \Omega + 2.0\ \Omega)} = 0.0397\text{ A}$

		$R_{max} = (300\ \Omega + 150\ \Omega)$, so $I_{min} = \frac{V}{(R_{max} + R_{ammeter})} = \frac{12\ V}{(450\ \Omega + 2.0\ \Omega)} = 0.0265\ A$ Heath can achieve current values from 26.5 mA to 39.7 mA
	(b)	$\frac{1}{R_{min}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{300\ \Omega} + \frac{1}{150\ \Omega} = \frac{3}{300\ \Omega}$ gives $R_{min} = 100\ \Omega$ so $I_{max} = \frac{V}{(R_{min} + R_{ammeter})} = \frac{12\ V}{(100\ \Omega + 2.0\ \Omega)} = 0.118\ A$ or $118\ mA$ $R_{max} = 150\ \Omega$, so $I_{min} = V \div (R_{max} + R_{ammeter}) = 12V \div (150\Omega + 2.0\ \Omega) = 0.0789\ A$ (or 78.9 mA) Jenni can achieve current values from 78.9 mA to 118 mA
	(c)	$R_{min} = 0\ \Omega$, so $I_{max} = \frac{V}{(R_{min} + R_{ammeter})} = \frac{12\ V}{(0 + 2.0\ \Omega)} = 6.0\ A$ $R_{max} = 150\ \Omega$, so $I_{min} = \frac{V}{(R_{max} + R_{ammeter})} = \frac{12\ V}{(150\ \Omega + 2.0\ \Omega)} = 0.0789\ A$ or $78.9\ mA$ Shani can achieve current values from 78.9 mA to 6.0 A
17.7	(a)	
	(b)	$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10\ \Omega} + \frac{1}{15\ \Omega} = \frac{10}{60\ \Omega}$ gives $R_{parallel} = 6.0\ \Omega$ $I_{total} = \frac{V_{total}}{(R_{parallel} + R_6)} = \frac{6\ V}{(6\ \Omega + 6\ \Omega)} = 0.50\ A$ Voltmeter reading, $V = I_{total} \times R_6 = 0.5\ A \times 6\ \Omega = 3.0\ V$
	(c)	The voltage across the parallel arrangement = 3.0 V also. Ammeter reading, $I = \frac{V}{R_{15}} = \frac{3\ V}{15\ \Omega} = 0.2\ A$ or $200\ mA$

17.8	(a)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ so $\frac{1}{R_t} = \frac{1}{4\,\Omega} + \frac{1}{8\,\Omega} + \frac{1}{40\,\Omega} = \frac{16}{40\,\Omega}$ gives $R_t = 2.5\ \Omega$
	(b)	Voltage across all resistors is the same, so $V = I_4 \times R_4 = 2\text{ A} \times 4\ \Omega = 8.0\text{ V}$
	(c)	$I_8 = \frac{V}{R_8} = \frac{8\text{ V}}{8\,\Omega} = 1.0\text{ A}$
	(d)	$I_{40} = \frac{V}{R_{40}} = \frac{8\text{ V}}{40\,\Omega} = 0.2\text{ A or } 200\text{ mA}$
17.9	(a)	parallel
	(b)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{1440\,\Omega} + \frac{1}{960\,\Omega} = \frac{5}{2880\,\Omega}$ gives $R_t = 576\ \Omega$
	(c)	$I_{total} = \frac{V}{R_{total}} = \frac{240\text{ V}}{576\,\Omega} = 0.417\text{ A or } 417\text{ mA}$
17.10	(a)	$I_{microwave} = \frac{P_{microwave}}{V} = \frac{600\text{ W}}{240\text{ V}} = 2.50\text{ A}$ $I_{toaster} = \frac{P_{toaster}}{V} = \frac{450\text{ W}}{240\text{ V}} = 1.88\text{ A}$ $I_{kettle} = \frac{P_{kettle}}{V} = \frac{1000\text{ W}}{240\text{ V}} = 4.17\text{ A}$ gives $I_{total} = (2.50\text{ A} + 1.88\text{ A} + 4.17\text{ A}) = 8.55\text{ A}$
	(b)	$I_{grinder} = \frac{P_{grinder}}{V} = \frac{150\text{ W}}{240\text{ V}} = 0.625\text{ A}$ The total current would therefore increase to 9.18 A if the coffee grinder was turned on.
17.11	(a)	$R_{total} = R_1 + R_2 = 100\ \Omega + 100\ \Omega = 200\ \Omega$
	(b)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{100\Omega} + \frac{1}{100\Omega} = \frac{2}{100\Omega}$ gives $R_t = 50\ \Omega$
	(c)	Connect in parallel since this offers the least resistance and will therefore result in a greater current so a shorter heating time.
17.12	(a)	Two identical resistors in parallel provide half the effective resistance of a single resistor. Therefore, circuit A will have double the resistance of circuit B.
	(b)	Since the resistance has halved, the total current will double. Also, the current through the globes will be the same and their value will be half of the total. So, $A_1 = 12.0\text{ A}$, $A_2 = 6.0\text{ A}$, $A_3 = 6.0\text{ A}$
	(c)	Each globe is receiving a current of 6 A, so they will all glow with the same intensity (brightness).

17.13	(a)	Since the internal resistance of the battery is effectively connected in series with the external resistance, the current through each must be the same.
	(b)	When starting the motor, voltage drop across the battery, v = I x r = 80 A x 0.05 Ω = 4.0 V
	(c)	Since the starter motor current needs to be huge (between 80 A to 100 A), then this can only be achieved from a battery with a very low internal resistance.
	(d)	At start up, the voltage dropped across the car battery is 4.0 V (see part (b), above). Therefore, although the car battery is rated at 12.0 V, only 8.0 V of this will be available to the headlights. Assuming they normally operate at 12 V, they will appear dim, at least until the motor is running and the current from the battery drops to a much lower value.  Car battery, EMF = 12.0 V and r = 0.050 Ω
17.14	(a)	P_{total} = 60 W + 60 W + 10 W + 10 W = 140 W
	(b)	$R_{total} = \frac{V^2}{P} = \frac{(12\text{ V})^2}{140\text{ W}} = 1.03\,\Omega$
	(c)	$R_{60} = \frac{V^2}{P} = \frac{(12\text{ V})^2}{60\text{ W}} = 2.40\,\Omega$
	(d)	$R_{10} = \frac{V^2}{P} = \frac{(12\text{ V})^2}{10\text{ W}} = 14.4\,\Omega$
	(e)	$I_{total} = \frac{P}{V} = \frac{140\text{ W}}{12\text{ V}} = 11.7\text{ A}$
17.15	(a)	The type A lamps are connected in series so if one burns out then there is no longer a complete circuit and all the lamps will fail to light. However, the type B lamps are connected

		in parallel so if one of them burns out then as they are all independent of each other, the other 14 lamps continue working normally, with no difference to their brightness.
	(b)	For the series (A) lamps, each lamp takes an equal share $\left(\frac{1}{15}\right)$ of the power supply voltage to which they are attached, so $R_A = \frac{V^2}{P} = \frac{\left(\frac{240\ V}{15}\right)^2}{4\ W} = 64\ \Omega$
	(c)	For the parallel (B) lamps, each lamp receives the full power supply voltage available, so $R_B = \frac{V^2}{P} = \frac{(240\ V)^2}{4\ W} = 14.4\ k\Omega$
	(d)	If a B type globe was mistakenly swapped for one of the A type lamps in the series circuit, then the effective resistance of the circuit would be huge, resulting in a much smaller current flow. The fourteen remaining A type lamps would light very dimly, if at all and may give the impression that they are not working. However, the B lamp, which uses a very small operating current, would light, with perhaps a small loss in intensity. If an A type lamp was mistakenly swapped for one of the B type lamps in the parallel circuit, then the effective resistance of the circuit would fall dramatically, resulting in a much greater current flow from the power supply. There would be no apparent change to the existing 14 type B lamps since they are all independent of each other and the new lamp. However, this A type lamp would now be operating from the whole 240 V supply (as opposed to its fifteenth share of this supply), therefore receive a massive current flow which would probably light extremely brightly and then almost instantly burn out. So, overall, no change to this circuit – there will still be a dead lamp.
17.16	(a)	
	(b)	Once the cells are connected to a load and a current is then drawn from them, their internal resistances come into play and some voltage will be dropped within them. This means that the external circuit, in this case the 2.5 V globe, will experience the combined EMF of the cells minus the dropped voltage.

	(c)	$E_{total} = I \times (r_{int} + R_{ext}) = (I \times r_{int}) + (I \times R_{ext}) = (I \times r_{int})$ + external voltage so $(1.5V + 1.5V) = (0.5A \times r_{int}) + 2.5V$ gives $r_{int} = \frac{\text{voltage drop}}{\text{current}} = \frac{0.5\text{ V}}{0.5\,\Omega} = 1.0\,\Omega$ - this is the internal resistance provided by both cells and since they are connected in series and they are identical, then their individual internal resistance = 0.50 Ω
17.17	(a)	The difference is due to the internal resistance of the solar cell, causing a small voltage drop within the cell itself once a load is connected and a current is being drawn.
	(b)	The EMF of the cell (as measured by the very high resistance voltmeter), E = 1.2 V Once the lower resistance voltmeter is connected (which effectively acts as a 1000 Ω load), a current, I flows and a voltage reading of 1.0 V is measured. This current, $I = \frac{V}{R} = \frac{1\text{ V}}{1000\,\Omega} = 0.001\text{ A}$ The voltage drop across the cell = E – V = 1.2V – 1.0V = 0.2 V So, the internal resistance of the solar cell, $r_{int} = \frac{\text{voltage drop}}{\text{current}} = \frac{0.2\text{ V}}{0.001\,\Omega} = 200\,\Omega$