1. I_1 = <u>0.50 A</u> (The current is equal in the same branch)

   I_2 = 0.50 A - 0.20 A = <u>0.30 A</u> (The total current splits at the junction)

   $I_3 = I_2$ = <u>0.30 A</u> (The current is equal in the same branch)

   I_4 = <u>0.20 A</u> (The current is equal in the same branch)

   $U_3 = U_0$ = <u>6.0 V</u> = U_1 + 4.5 V (In a parallel circuit the voltage is the same across all branches)

   U_1 + 4.5 V = 6.0 V ⇒ U_1 = <u>1.5 V</u> (In a series circuit the voltage is divided among the resistors)

   $R_1 = \frac{U_1}{I_2} = \frac{1.5\ \text{V}}{0.30\ \text{A}} = \underline{\underline{5.0\ \Omega}}$ $\quad R_2 = \frac{U_2}{I_2} = \frac{4.5\ \text{V}}{0.30\ \text{A}} = \underline{\underline{15\ \Omega}}$ $\quad R_3 = \frac{U_3}{I_4} = \frac{6.0\ \text{V}}{0.20\ \text{A}} = \underline{\underline{30\ \Omega}}$

2. a) In a series circuit the current through all lamps is the same: <u>78 mA</u>

   b) In a series circuit the total voltage is the sum of the individual voltages. All lamps are identical and the voltage is divided equally: $U_1 = U_2 = U_3 = \frac{U_{\text{total}}}{3} = \frac{4.5\ \text{V}}{3} = \underline{\underline{1.5\ \text{V}}}$

3. a) In a parallel circuit the total current is the sum of the individual currents. All lamps are identical and the current is divided equally: $I_1 = I_2 = I_3 = \frac{I_{\text{total}}}{3} = \frac{78\ \text{mA}}{3} = \underline{\underline{26\ \text{mA}}}$

   b) In a parallel circuit the voltage is the same over all branches.

4. I_1 = 0.24 A (equal current in the same branch)

   I_3 = 0.40 A (total current is the same on both sides)

   $I_2 = I_3 - I_1$ = 0.4 A - 0.24 A = 0.16 A (the total current splits at the junction)

   $U_3 = R_3 \cdot I_3 = 12\ \Omega \cdot 0.4\ \text{A} = 4.8\ \text{V}$

   $U_1 = U_0 - U_3$ = 6 V - 4.8 V = 1.2 V (voltage is divided in a series circuit)

   $U_2 = U_1$ = 1.2 V (in a parallel circuit the voltage is the same across all branches)

   $$R_1 = \frac{U_1}{I_1} = \frac{1.2\ \text{V}}{0.24\ \text{A}} = 5\ \Omega$$

   $$R_2 = \frac{U_2}{I_2} = \frac{1.2\ \text{V}}{0.16\ \text{A}} = 7.5\ \Omega$$

   $P_1 = U_1 \cdot I_1 = 1.2\ \text{V} \cdot 0.24\ \text{A} = 0.288\ \text{W}$

   $P_2 = U_2 \cdot I_2 = 1.2\ \text{V} \cdot 0.16\ \text{A} = 0.192\ \text{W}$

   $P_3 = U_3 \cdot I_3 = 4.8\ \text{V} \cdot 0.4\ \text{A} = 1.92\ \text{W}$

5. a) The voltage across the resistor is 230 V – 12.0 V = 218 V

The same amount of current passes through the lamp and the resistor (series circuit): 2.50 A

Therefore $R = \frac{U}{I} = \frac{218\text{ V}}{2.50\text{ A}} = \underline{\underline{87.2\ \Omega}}$

b) $P_{lamp} = U_{lamp} \cdot I_{lamp} = 12.0\text{ V} \cdot 2.50\text{ A} = \underline{\underline{30.0\text{ W}}}$

$P_{resistor} = U_{resistor} \cdot I_{resistor} = 218\text{ V} \cdot 2.50\text{ A} = \underline{\underline{545\text{ W}}}$

The power consumed by the resistor is almost twenty times greater than the power consumed by the lamp

6. $U = R_1 \cdot I = 6.00\ \Omega \cdot 0.100\text{ A} = 0.600\text{ V}$

0.100 A are passing through R_1. The total current is 6.00 A, therefore the current through R_2 is
$I_2 = I_{total} - I_1 = 6.00\text{ A} - 0.100\text{ A} = 5.90\text{ A}$

The voltage is the same in both branches of the paralllel circuit:

$R_2 = \frac{U}{I_2} = \frac{0.600\text{ V}}{5.90\text{ A}} = \underline{\underline{0.102\ \Omega}}$

7. **A:** Series circuit: The equivalent resistance is the sum of the individual resistances, the total voltage is the sum of the individual voltages, the current is the same through all resistors.

$R_{total} = R_1 + R_2 + R_3 + R_4 = 10\ \Omega + 20\ \Omega + 50\ \Omega + 100\ \Omega = \underline{\underline{180\ \Omega}}$

The current is the same through all the resistors: $I = \frac{U}{R_{tot}} = \frac{24\ V}{180\ \Omega} = \underline{\underline{0.133\ A}}$

The individual voltages are: $U_1 = I \cdot R_1 = \underline{\underline{1.33\ V}}$ $U_2 = I \cdot R_2 = \underline{\underline{2.66\ V}}$

$U_3 = I \cdot R_3 = \underline{\underline{6.66\ V}}$ $U_4 = I \cdot R_4 = \underline{\underline{13.3\ V}}$

B: Parallel circuit: First calculate the equivalent resistance:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{10\ \Omega} + \frac{1}{20\ \Omega} + \frac{1}{50\ \Omega} + \frac{1}{100\ \Omega}\right)^{-1} = \underline{\underline{5.55\ \Omega}}$$

The voltage is the same in all the branches: $U_1 = U_2 = U_3 = U_4 = \underline{\underline{24\text{ V}}}$.

The individual currents are $I_1 = \frac{U}{R_1} = \frac{24\ V}{10\ \Omega} = \underline{\underline{2.4\ A}}$, $I_2 = \frac{U}{R_2} = \frac{24\ V}{20\ \Omega} = \underline{\underline{1.2\ A}}$,

$I_3 = \frac{U}{R_3} = \frac{24\ V}{50\ \Omega} = \underline{\underline{0.48\ A}}$, $I_4 = \frac{U}{R_4} = \frac{24\ V}{100\ \Omega} = \underline{\underline{0.24\ A}}$

C: Combination of series and parallel circuits. First calculate the equivalent resistances of R_1 and R_2, and of R_3 and R_4:

$R_{eq(1,2)} = R_1 + R_2 = 10\ \Omega + 20\ \Omega = 30\ \Omega$

$R_{eq(3,4)} = R_3 + R_4 = 50\ \Omega + 100\ \Omega = 150\ \Omega$

$R_{eq(1,2)}$ and $R_{eq(3,4)}$ are connected in parallel, therefore:

$$R_{eq(1,2,3,4)} = \frac{R_{eq(1,2)} \cdot R_{eq(3,4)}}{R_{eq(1,2)} + R_{eq(3,4)}} = \frac{30\ \Omega \cdot 150\ \Omega}{30\ \Omega + 150\ \Omega} = \underline{\underline{25\ \Omega}}$$

The current in the upper branch is $I_{12} = \frac{U}{R_{12}} = \frac{24\ V}{30\ \Omega} = \underline{\underline{0.8\ A}}$

The current in the lower branch is $I_{34} = \frac{U}{R_{34}} = \frac{24\ V}{150\ \Omega} = \underline{\underline{0.16\ A}}$

The voltage is the same in each of the branches of the parallel circuit. The individual voltages are

$U_1 = I \cdot R_{12} = \underline{\underline{8\ V}}$ $\qquad U_2 = I \cdot R_{12} = \underline{\underline{16\ V}}$

$U_3 = I \cdot R_{34} = \underline{\underline{8\ V}}$ $\qquad U_4 = I \cdot R_{34} = \underline{\underline{16\ V}}$

D: Combination of series and parallel circuits. First calculate the equivalent resistance of R_2, R_3 and R_4:

$$R_{eq(2,3,4)} = \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{20\ \Omega} + \frac{1}{50\ \Omega} + \frac{1}{100\ \Omega}\right)^{-1} = 12.5\ \Omega$$

R_1 and $R_{eq(2,3,4)}$ are in parallel, thus:

$R_{eq(1,2,3,4)} = R_1 + R_{eq(2,3,4)} = 10\ \Omega + 12.5\ \Omega = \underline{\underline{22.5\ \Omega}}$

The total current passes through I_1, thus $I_1 = I_{total} = \frac{U_{total}}{R_{eq(1,2,3,4)}} = \frac{24\ V}{22.5\ \Omega} = \underline{\underline{1.07\ A}}$

The total current passes through R_1, thus the voltage across R_1 is

$U_1 = R_1 \cdot I_{total} = 10\ \Omega \cdot 1.07\ A = \underline{\underline{10.7\ V}}$

The remaining voltage is applied across the three branches of the parallel circuit, therefore

$U_2 = U_3 = U_4 = U_{total} - U_1 = 24.0\ V - 10.7\ V = \underline{\underline{13.3\ V}}$

The individual currents through the resistors R_2, R_3 and R_4 are:

$I_2 = \frac{U_2}{R_2} = \frac{13.3\ V}{20\ \Omega} = \underline{\underline{0.66\ A}}$ $\qquad I_3 = \frac{U_3}{R_3} = \frac{13.3\ V}{50\ \Omega} = \underline{\underline{0.27\ A}}$

$I_4 = \frac{U_4}{R_4} = \frac{13.3\ V}{100\ \Omega} = \underline{\underline{0.13\ A}}$

8. a) R (60W-light bulb) = $\frac{U^2}{P} = \frac{(220\ \text{V})^2}{60\ \text{W}}$ = $\underline{\underline{807\ \Omega}}$

R (100W-light bulb) = $\frac{U^2}{P} = \frac{(220\ \text{V})^2}{100\ \text{W}}$ = $\underline{\underline{484\ \Omega}}$

$R_{total} = R_{60W} + R_{100W} = 807\ \Omega + 484\ \Omega = \underline{\underline{1291\ \Omega}}$

b) $I = \frac{U}{R} = \frac{220\ V}{1291\,\Omega} = \underline{\underline{0.17\ \text{A}}}$

c) U (60 W-ligth bulb) = $R_{60W} \cdot I = 807\ \Omega \cdot 0.17\ \text{A} = \underline{\underline{138\ \text{V}}}$

U (100 W-light bulb) = $R_{100W} \cdot I = 484\ \Omega \cdot 0.17\ \text{A} = \underline{\underline{82\ \text{V}}}$

d) P (60 W-light buld) = $U_{60W} \cdot I = 138\ \text{V} \cdot 0.17\ \text{A} = \underline{\underline{23.5\ \text{W}}}$

P (100 W-light bulb) = $U_{100W} \cdot I = 82\ \text{V} \cdot 0.17\ \text{A} = \underline{\underline{13.9\ \text{W}}}$