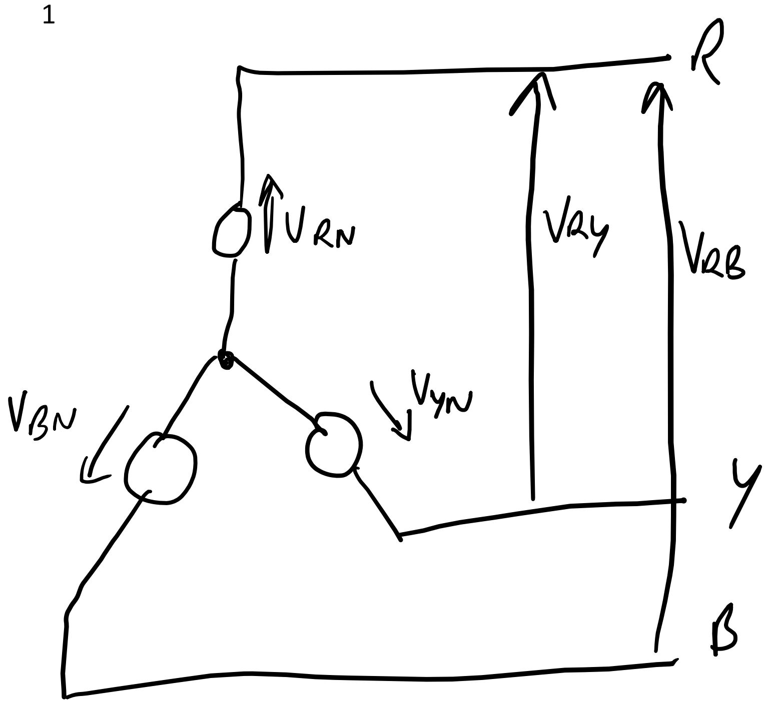
Solutions to Example Sheet 3

1



$V_{RN} = 200\angle 0^\circ$ V

$V_{YN} = 200\angle -120^\circ$ V

$V_{BN} = 200\angle 120^\circ$ V

[The key thing is the 120° phase shifts!]

$$V_{RY} = 200 - 200\angle -120^\circ$$
$$= 200(1 + 0.5 + j0.866) = 200(1.5 + j0.866)$$
$$\sqrt{3}\,200\angle 30^\circ = 346.4\angle 30^\circ \text{ V}$$

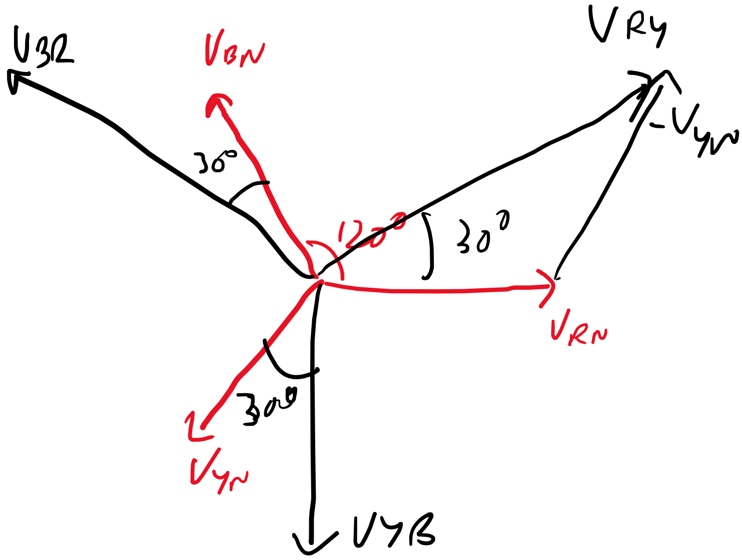
Note: Always give your final answer in phasor form. Always complete the calculation!

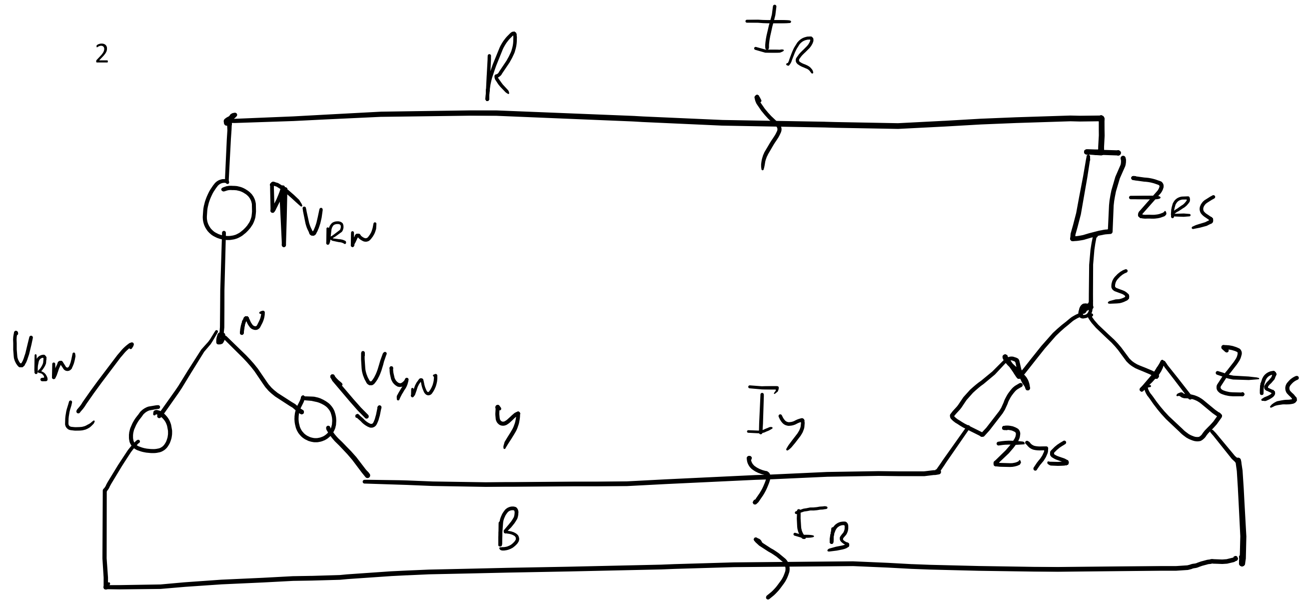
We do not need to do all the maths for V_{BR} and V_{YB}, just remember that the 120° phase shifts.

$V_{BR} = 346.4\angle 120^\circ$ V

$V_{YB} = 346.4\angle -90^\circ$ V

It is always a good idea to draw a phasor diagram.





$$V_{ph} = 240V \quad \therefore \quad V_{RN} = 240\angle 0^\circ \, V$$

Since it is balanced V_{RN} must be dropped across Z_{RS}.

$$I_R = \frac{V_{RN}}{Z_{RS}} = \frac{240}{12} = 20\angle 0^\circ \, A$$

Since there must be a 120° phase shift between R, Y and B:

$$I_y = 20\angle -120^\circ \, A \qquad I_B = 20\angle 120^\circ \, A$$

We can now find the power dissipated in each resistor:

$$P_R = |I|^2 R = 20^2 \times 12 = 4.8kW$$

So the total power is:

$$P_T = 3 \times P_R = \underline{14.4 \ kW}$$

3. This is similar to Q2 except that the loads now have an inductive element

$V_{ph} = 10\text{ kV}$ so $V_{RN} = 10\,000 \angle 0^\circ$ V

$V_{YN} = 10000 \angle -120^\circ$ V

$V_{BN} = 10000 \angle 120^\circ$ V

$Z_{RS} = 10 + j20\ \Omega$

So: $I_R = \dfrac{V_{RN}}{Z_{RS}} = \dfrac{10000 \angle 0^\circ}{10 + j20} = \dfrac{10000 \angle 0^\circ}{22.36 \angle 63.43^\circ}$

$= 447.3 \angle -63.43^\circ$ A

$\therefore I_Y = 447.3 \angle -63.43 - 120^\circ = 447.3 \angle -183.43$

$= 447.3 \angle 176.57^\circ$ A

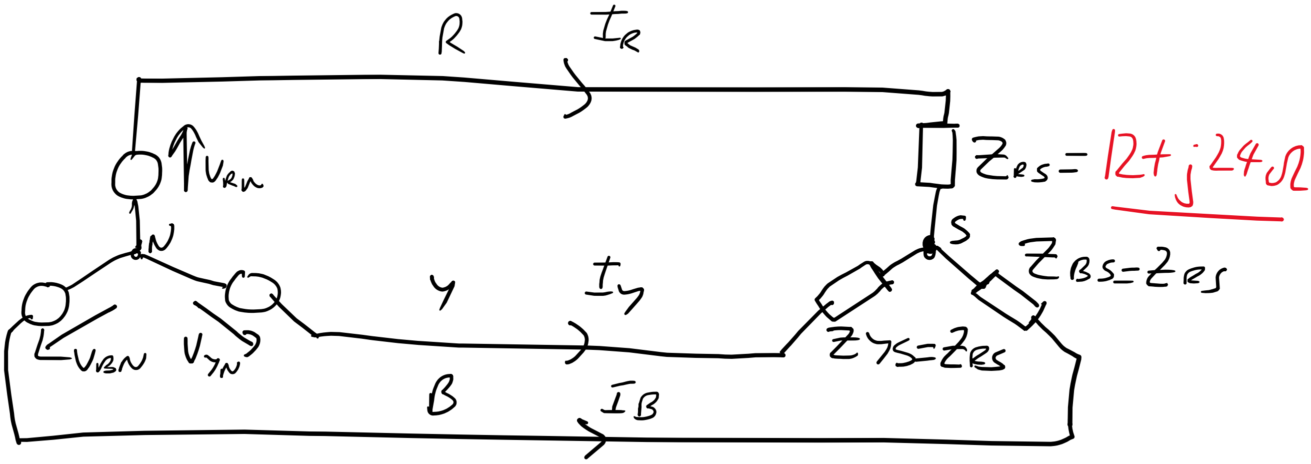
$I_B = 447.3 \angle 56.57^\circ$ A

We can calculate the power per phase by considering the magnitude of the current and the resistance (real part of impedance).

$P_r = 447.3^2 \times 10 = 2$ MW

$P_T = 3 \times P_r = \underline{6\text{ MW}}$

4.



First calculate the reactance: $X_L = 2\pi f L$

$$= 2\pi\, 60 \times 63.7 \times 10^{-3}$$

$$= 24\,\Omega$$

So $Z_{RS} = 12 + j24\,\Omega = 26.8\angle 63.43^\circ\,\Omega$

Line voltages $= \sqrt{3}$ Phase Voltages with 30° phase shift.

So! $V_{RY} = \sqrt{3} \times 10000\angle 30^\circ = 17320\angle 30^\circ\,V$

$V_{BR} = 17320\angle (30+120)^\circ = 17320\angle 150^\circ\,V$

$V_{YB} = 17320\angle (30-120)^\circ = 17320\angle -90^\circ\,V$

To find I_R:

$$I_R = \frac{V_{RN}}{Z_{RS}} = \frac{10000\angle 0^\circ}{26.8\angle 63.43^\circ} = 373\angle -63.43^\circ A$$

$$I_B = 373\angle{-63.43+120^\circ} = 373\angle{56.57^\circ}\ A$$

$$I_Y = 373\angle{-63.43-120^\circ} = 373\angle{176.57^\circ} A$$

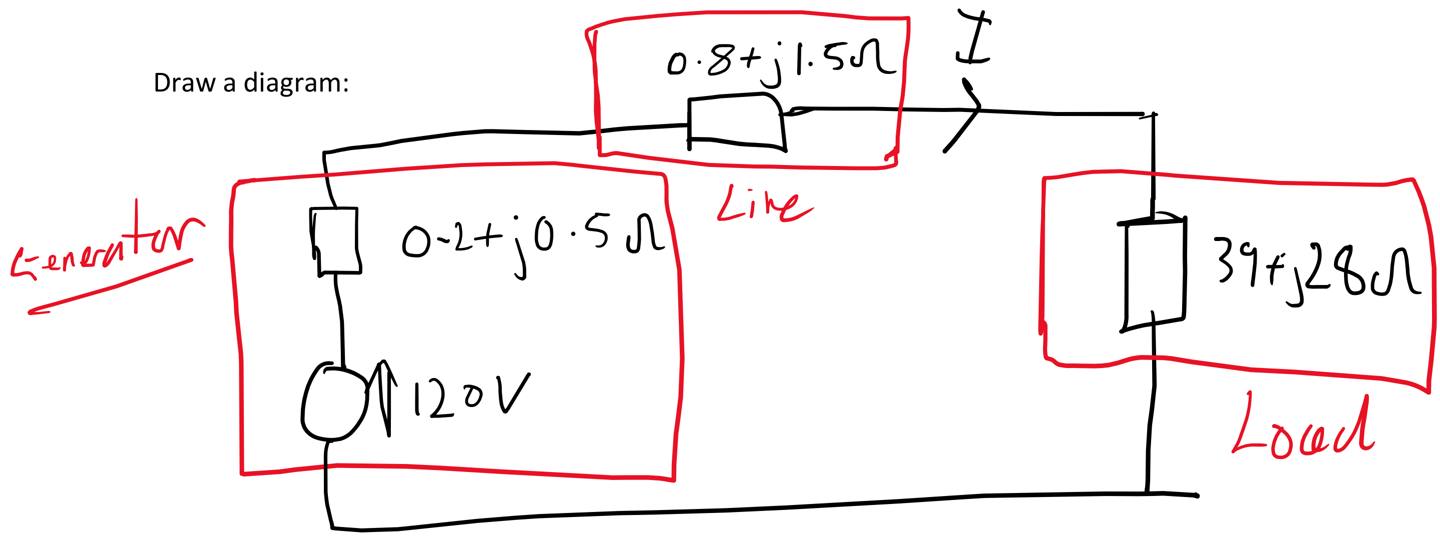
To find total power:

$$P_R = 373^2 \times 12 = 1.67\ MW$$

So: $P_T = 3 \times P_R = \underline{5\ MW}$

5. Solving Y load balanced 3-phase problems with a single phase equivalent circuit is a good idea.

Draw a diagram:



$$I = \frac{120\angle 0^\circ}{0.2+j0.5+0.8+j1.5+39+j28} = \frac{120\angle 0^\circ}{40+j30}$$

$$= \frac{120\angle 0^\circ}{50\angle 36.9^\circ} = 2.4\angle -36.9^\circ \text{ A}$$

So we can now work out the line currents:

$$I_R = 2.4\angle -36.9^\circ \text{ A}$$

$$I_Y = 2.4\angle -156.9^\circ \text{ A}$$

$$I_B = 2.4\angle 83.1^\circ \text{ A}$$

We can find Voltage across the loads:

$$V_{RL} = I_R \times Z_{RS} = 2.4\angle{-36.9^\circ} \times (39 + j28)$$

$$= 2.4\angle{-36.9^\circ} \times 48\angle{35.7^\circ}$$

$$= 115.2\angle{-1.2^\circ}\ V$$

$$V_{YL} = 115.2\angle{-121.2^\circ}\ V$$

$$V_{BL} = 115.2\angle{118.8^\circ}\ V$$

Line voltages = $\sqrt{3}$ phase voltage with 30 degree phase shift.

$$V_{RY(LOAD)} = \sqrt{3} \times 115.2\angle{-1.2 + 30^\circ} = 200\angle{28.8^\circ}\ V$$

$$V_{BR(LOAD)} = 200\angle{148.8^\circ}\ V$$

$$V_{YB(LOAD)} = 200\angle{-91.2}\ V$$

6. This question relates to a load which is a 3-phase motor. The first thing you should do is calculate the power in Watts.

$$100\,HP = 100 \times 746 = 74600\ W$$
$$= 74.6\ kW$$

You should note that the motor (load) is in a delta configuration.

You can write down for total power that:

$$P_T = \sqrt{3}\, I_{Line} V_{Line} \quad \therefore I_{Line} = \frac{74600}{460 \times \sqrt{3}} = 93.63A$$

Note this is the magnitude of the current. You cannot find the phase from the information given.

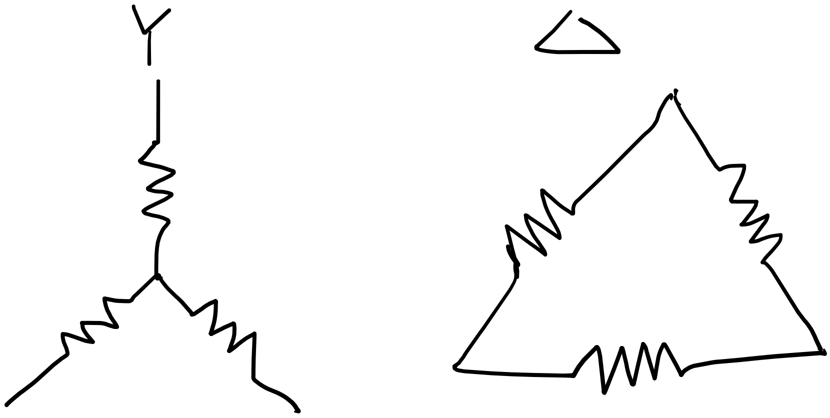
To find the phase current we need to realise that in a delta configuration the line and phase currents are different:

$$I_{PH} = \frac{I_{LINE}}{\sqrt{3}} = \frac{93.63}{\sqrt{3}} = \underline{54A}$$

Alternatively, you can work this out from a single phase:

$$P = IV, \quad \therefore \quad I = \frac{7460}{3} \times \frac{1}{460} = \underline{\underline{54A}}$$

7.



Each resistor must dissipate 5 kW. In a delta configuration each resistor sees to full line voltage so:

$$R = \frac{V_L^2}{P} = \frac{480^2}{5000} = 46.08\,\Omega$$

In a Y connection each resistor sees the phase voltage:

$$R = \frac{V_{PH}^2}{P} = \frac{\left(\frac{480}{\sqrt{3}}\right)^2}{5000} = \frac{277^2}{5000} = 15.36\,\Omega$$