Refrigeration and Air conditioning Engineering.

3rd year – refrigeration and Air conditioning Course

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Pumps selection part 2

Lecture -13 -

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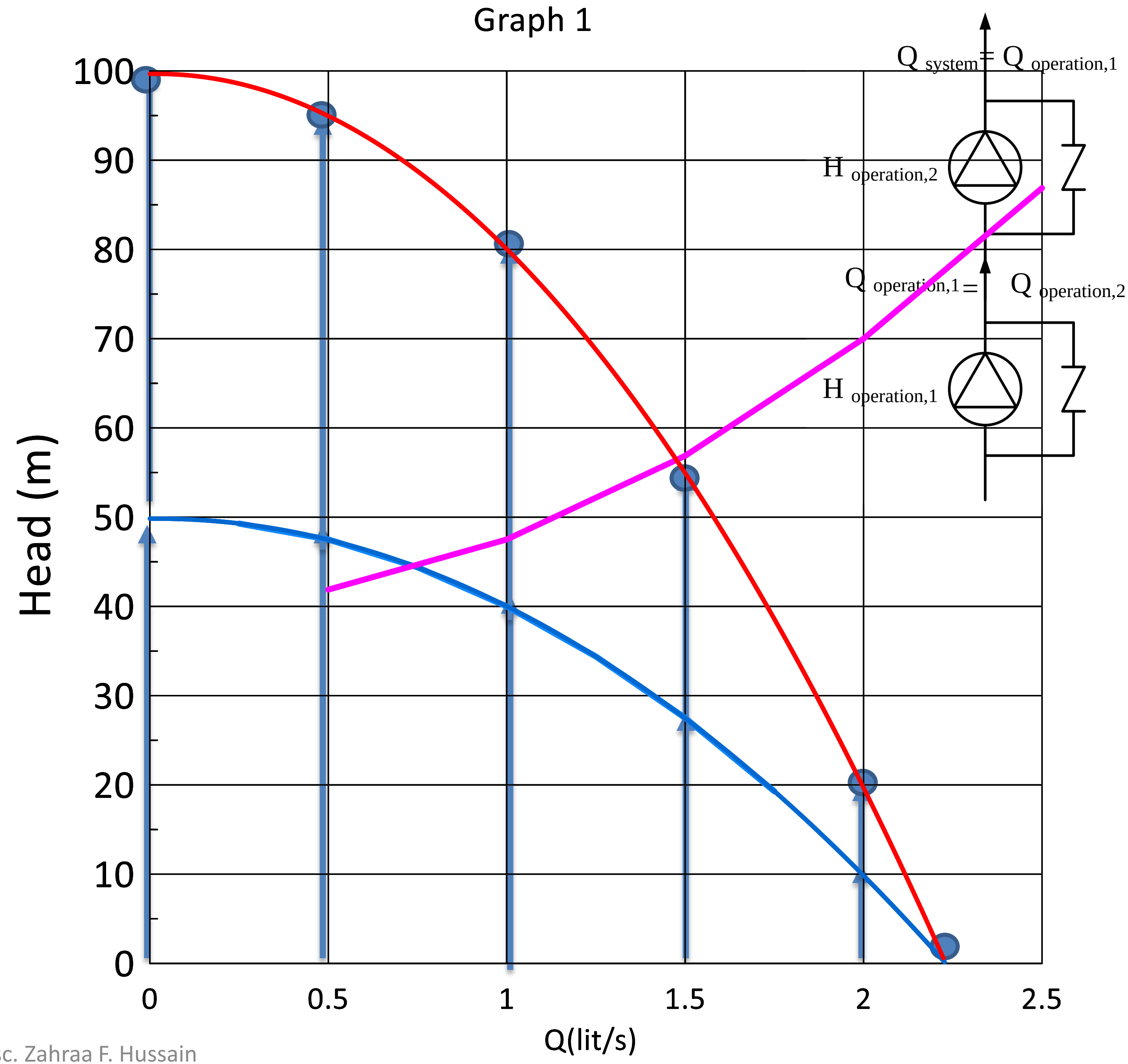
Pumps operated in series:

- Centrifugal pumps are **rarely** connected in serial, but a multi-stage pump can be considered as a serial connection of single-stage pumps.
- However, single stages in multistage pumps cannot be uncoupled. If one of the pumps in a serial connection is not operating, it causes a considerable resistance to the system.
- To avoid this, a bypass with a non-return valve could be build-in, see figure 8. The head at a given flow for a serial-connected pump is found by adding the single heads vertically.



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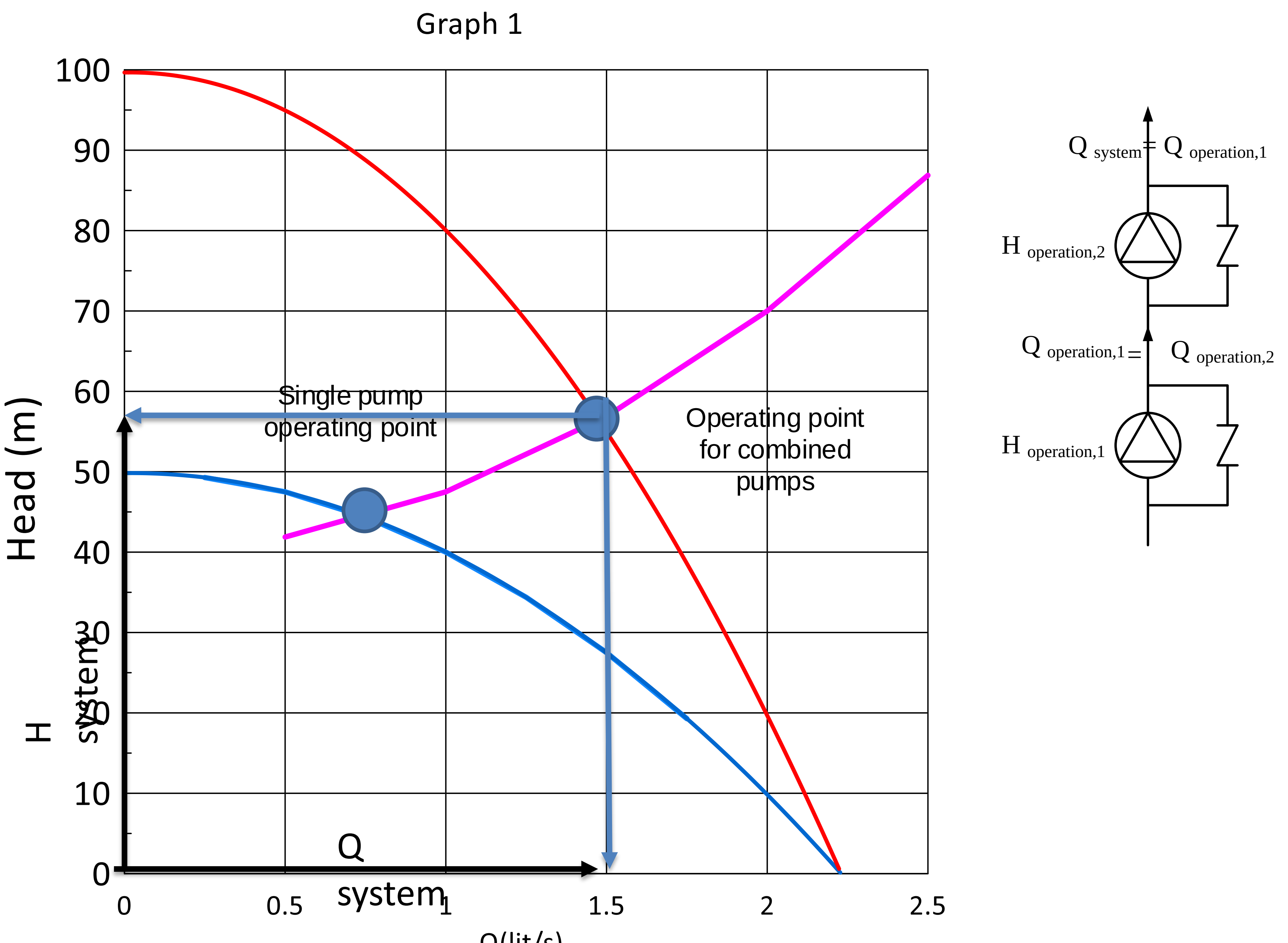

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Pump laws

- Various pump laws show the relationships between pressure, flow rate, efficiency and power. These can be used to calculate each factor:

$$\frac{\mathbf{Q_2}}{\mathbf{Q_1}} = \frac{\mathbf{rpm_2}}{\mathbf{rpm_1}} \qquad \textbf{(5-7)}$$

$$\frac{\mathbf{p_2}}{\mathbf{p_1}} = \left(\frac{\mathbf{rpm_2}}{\mathbf{rpm_1}}\right)^{\mathbf{2}} \qquad (5\text{-}8)$$

$$\frac{\mathbf{P_2}}{\mathbf{P_1}} = \left(\frac{\mathbf{rpm_2}}{\mathbf{rpm_1}}\right)^{\mathbf{3}} \qquad (5\text{-}9)$$

$$\frac{\mathbf{p_2}}{\mathbf{p_1}} = \frac{\boldsymbol{\rho_2}}{\boldsymbol{\rho_1}} \qquad (5\text{-}10)$$

$$\frac{\mathbf{Q_2}}{\mathbf{Q_1}} = \left(\frac{\mathbf{D_2}}{\mathbf{D_1}}\right)^{\mathbf{3}} \qquad (5\text{-}11)$$

$$\frac{\mathbf{p_2}}{\mathbf{p_1}} = \left(\frac{\mathbf{D_2}}{\mathbf{D_1}}\right)^{\mathbf{2}} \qquad (5\text{-}12)$$

$$\frac{P_2}{P_1} = \left(\frac{D_2}{D_1}\right)^{5} \qquad (5\text{-}13)$$

- Where:
- Q = volume flow rate (m^3/s)
  rpm= revolution speed (r
  P = pressure developed (Pa.)
  W = power (W)
  D = diameter of the impeller (m)
  p = density. (kg/m^3)

Pump Sizing

- **Key design inputs:**
- Details of fluid, for example water, glycol solution or oil.
- Design flow and return temperatures (°C)
- System mass flow rates (kg/s)
- System pressure drops (Pa)
- Ambient conditions including the surrounding air temperature (°C)

Design outputs:

- Schematic of pump layout installation, mounting and pipework connections
- Schedule of pump types, flow rates, pressure and efficiencies including motor requirements, drive type and adjustment, speed control and stand by provision
- Media details, such as water/refrigerant, and temperature.
- A schedule of electricity supply requirements

Calculation procedure:

- **Step I.** Calculate the index run pressure drop and total system mass flow rate.
- **Step 2.** Convert mass flow rate to volume flow rate in 1/s.
- **Step 3.** Determine system equations constant R. This can be done by substituting the required $\Delta p$and Q into the equation $\Delta p = R.Q^2$ and then solving for R.
- **Step 4** Select a pump that will operate within the required parameters and plot the system and pump characteristics on the same graph.
- **Step 5.** Determine the operating point. Identify operating pressure and flow rate.
- **Step 6.** Calculate pump speed to achieve required values or select another pump.
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- **Design tip:** With belt-driven pumps it is easy to vary the speed by changing the pulleys. If the pump is inverter- driven this can be done automatically.
- **Design tip:** If you use an additional margin with the required pressure drop to allow for differences between design pipe work layout and physical installations on site, do so carefully, as over sizing a pump will only result in excess energy usage.

Example

- A system has a volume flow rate requirement of 1 lit/s with an index run $\Delta p = 30$kPa. Find an appropriate pump from the A manufacturer's catalogue gives the following information for a centrifugal pump operating at 12 rev/s:

P	49·38	47·5	44·38	40	34·38	27·5	19·38
Q	0·25	0·5	0·75	1	1·25	1·5	1·75

- Step 1 and step 2: Pressure drop and volume flow rate are available in the units required.
  Step 3. The constant R in the system characteristic curve equation can be calculated as shown below:
- $\Delta p = R.Q^2$
- $30 = R.1^2$
- R=30
- Then rewrite the equation above.
- $\Delta p = 30.Q^2$

Q	0·25	0·5	0·75	1	1·25	1·5	1·75

$$\Delta p = 30.Q^2$$

$$\Delta p = 30.\times 0.25^2 = 1.875$$

$$\Delta p = 30.\times 0.5^2 = 7.5$$

$$\Delta p = 30.\times 0.75^2 = 16.875$$

$$\Delta p = 30.\times 1^2 = 30$$

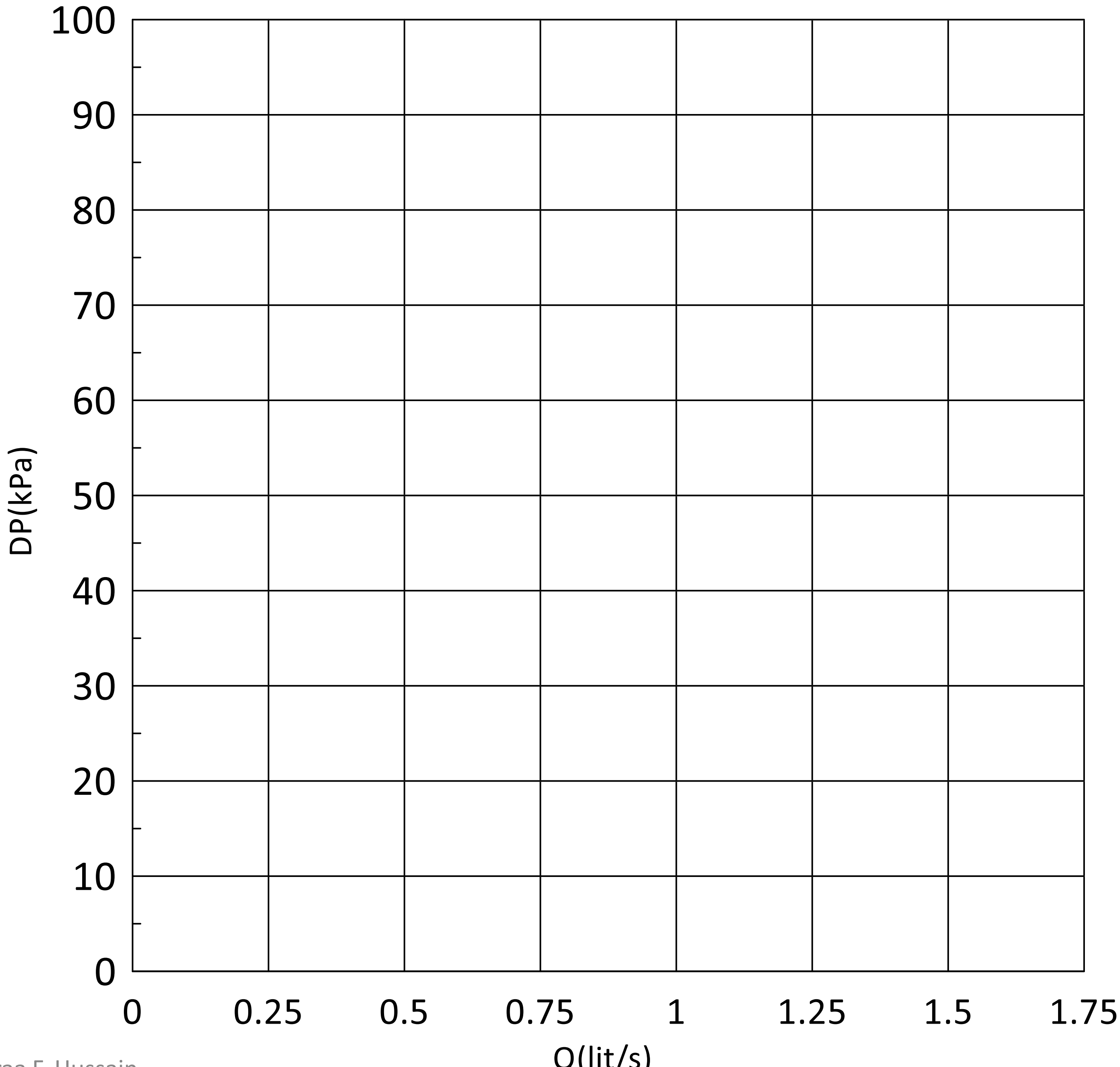
$$\Delta p = 30.\times 1.25^2 = 46.875$$

$$\Delta p = 30.\times 1.5^2 = 67.5$$

$$\Delta p = 30.1.75^2 = 91.875$$

Q	$\Delta p = 30.Q^2$
0.25	1.875
0.5	7.5
0.75	16.875
1	30
1.25	46.875
1.5	67.5
1.75	91.875

Graph 1



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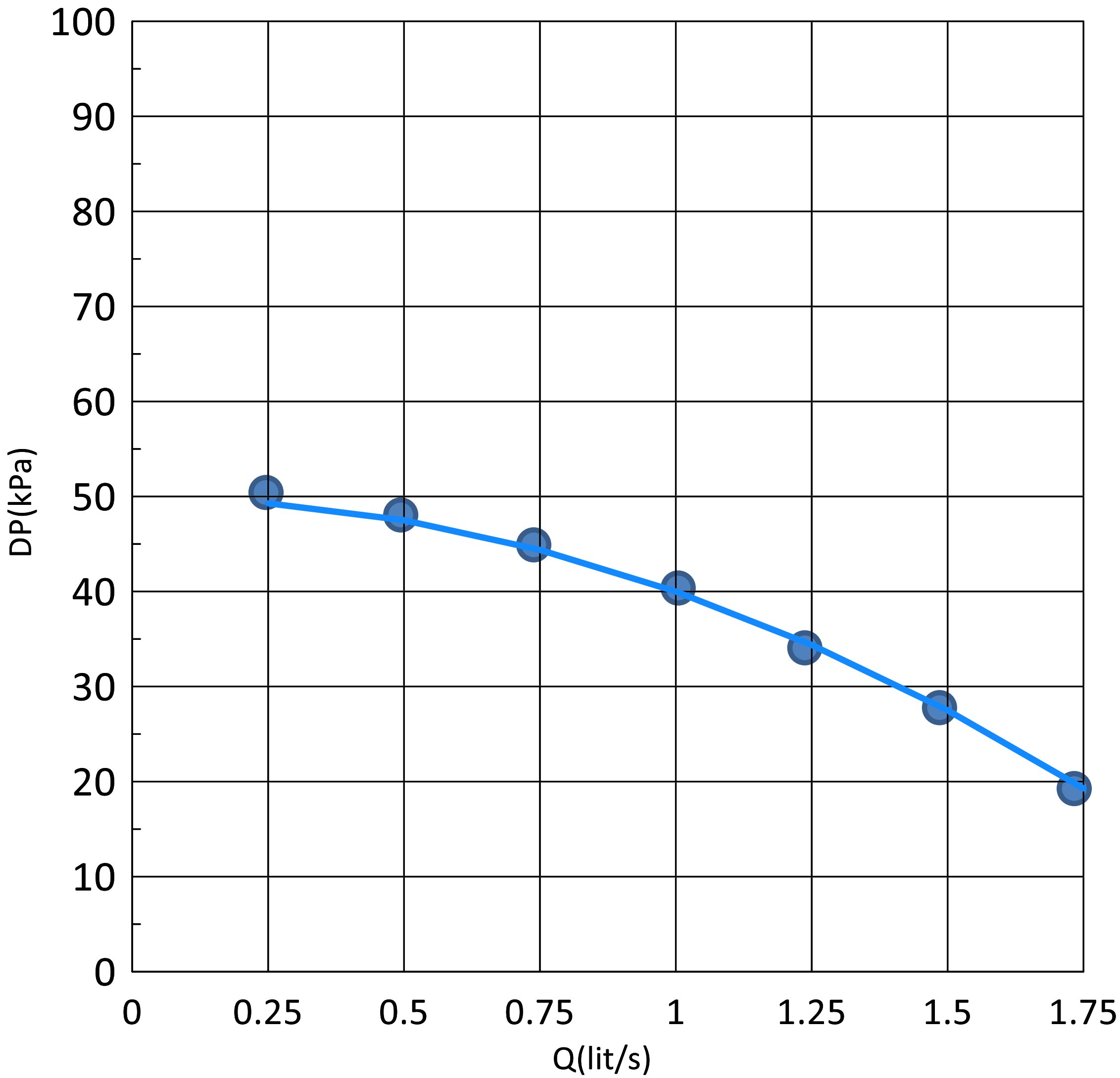
- draw the pump characteristic curve using manufacturer’s catalogue

P	49·38	47·5	44·38	40	34·38	27·5	19·38
Q	0·25	0·5	0·75	1	1·25	1·5	1·75

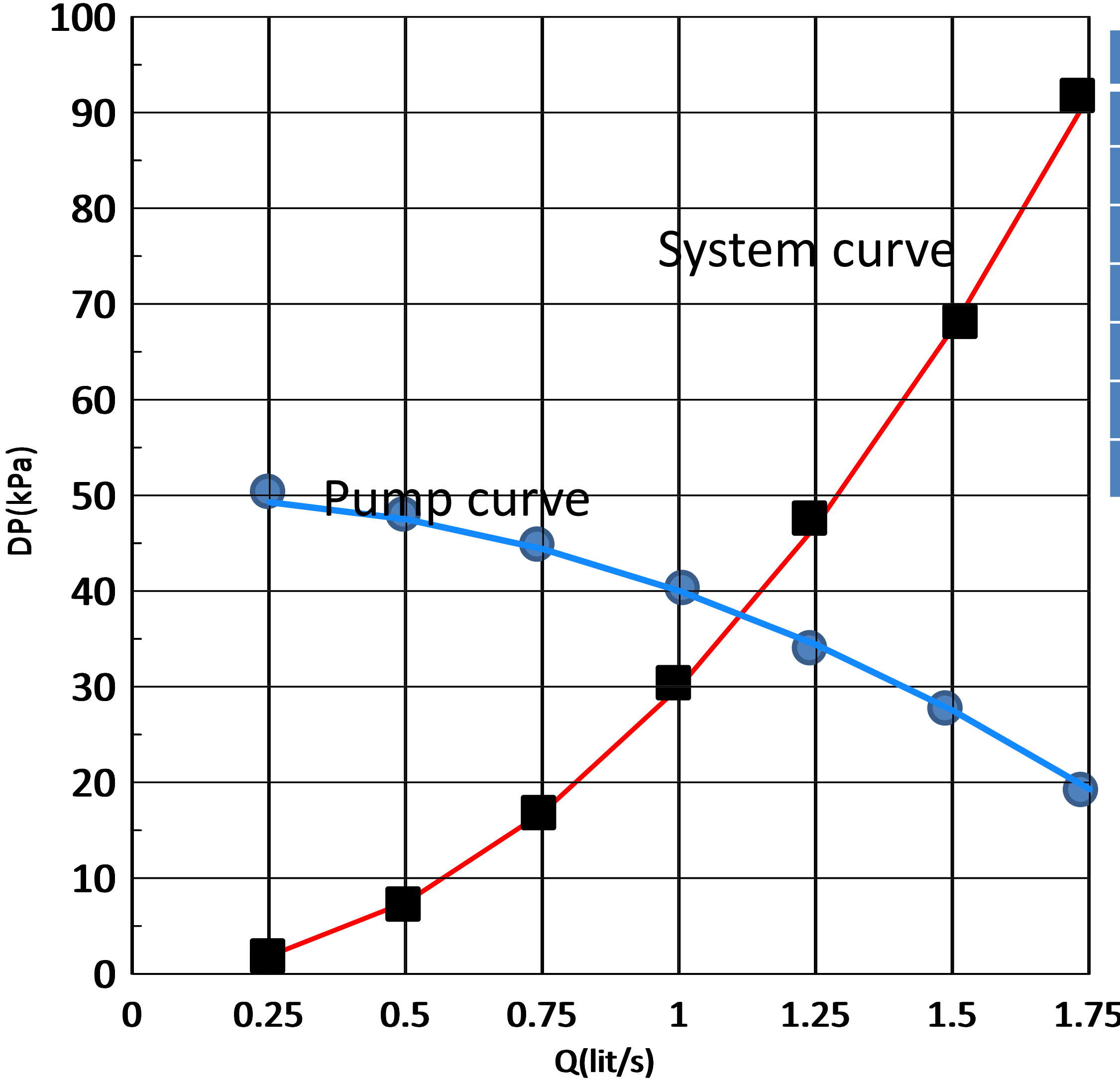
P	49·38	47·5	44·38	40	34·38	27·5	19·38
Q	0·25	0·5	0·75	1	1·25	1·5	1·75

Graph 1



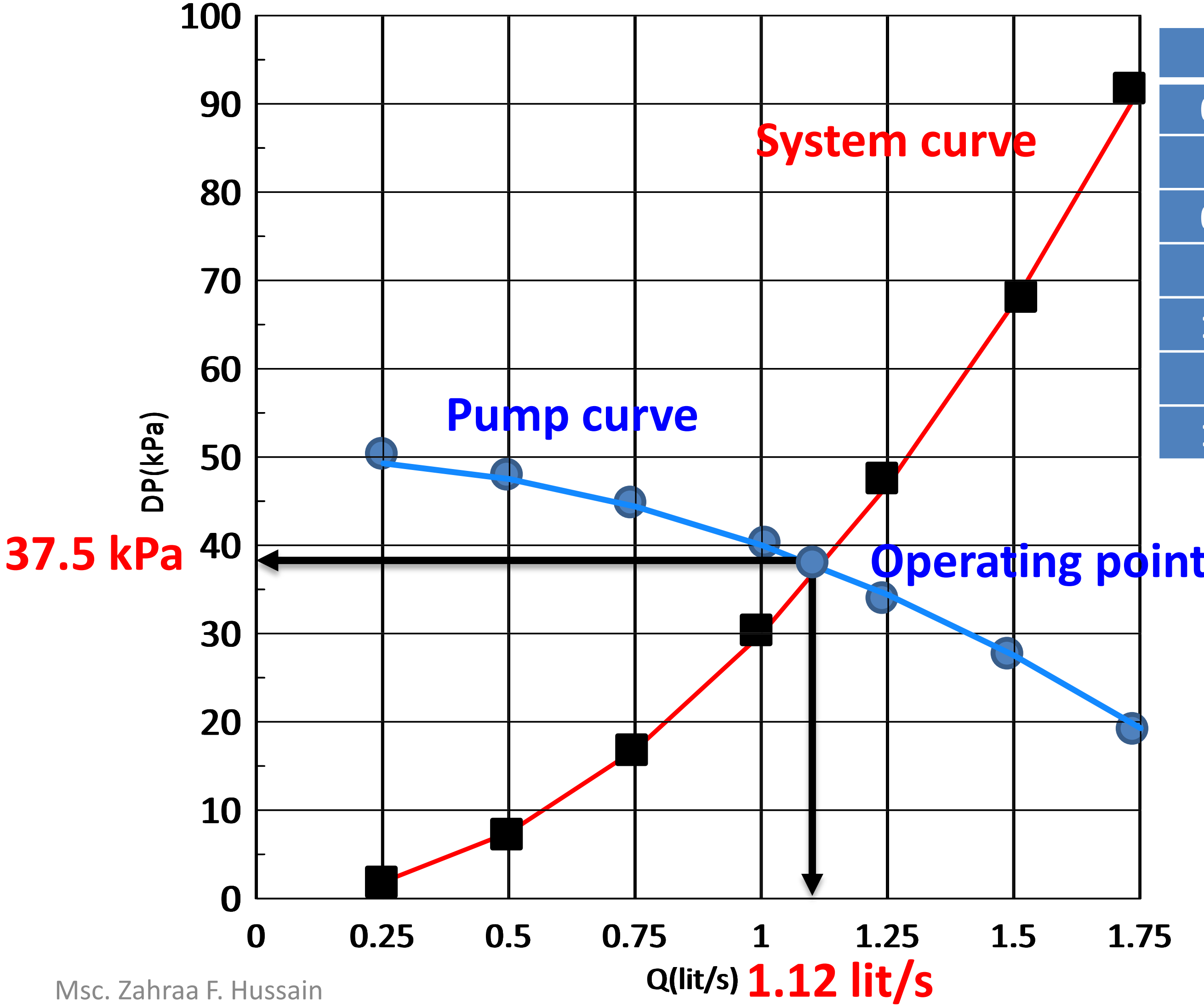
- Then on the same graph, draw the system characteristic curve, as shown bellows:

Graph 1



Q	$\Delta p = 30.Q^2$
0.25	1.875
0.5	7.5
0.75	16.875
1	30
1.25	46.875
1.5	67.5
1.75	91.875

Graph 1



Q	$\Delta p = 30.Q^2$
0.25	1.875
0.5	7.5
0.75	16.875
1	30
1.25	46.875
1.5	67.5
1.75	91.875

- The intersection between the two curves gives the operating points of the system and pump.
- The operating point occurs when the two curves intersect, 1.12 lit/s at 37.5 kPa
- As 1.12 1/s is too high, the pump will need to be slowed down in order to achieve the required flow rate.

- Alternatively, a different pump may give a closer value. This is worth considering when comparing the efficiency of different pumps at different speeds and pressures.

- *Required* Q_2*= 1 lit/s,* $\Delta p_2 = 30$ *kPa*
- *Results* Q_1*=1.12 l/s ,* $\Delta p_1 = 37.5$*,* rpm_1*=12*
- $\frac{Q_2}{Q_1} = \frac{rpm_2}{rpm_1}$
- $rpm_2 = rpm_1 . \frac{Q_2}{Q_1} = 12 \times \frac{1}{1.12} = 10.7\ rps$
- This can also be achieved by using equation (5-8) for example
- $\frac{p_2}{p_1} = \left(\frac{rpm_2}{rpm_1}\right)^2$
- $rpm_2 = rpm_1 . \left(\frac{p_2}{p_1}\right)^{0.5} = 12 \times \left(\frac{30}{37.5}\right)^{0.5} = 10.7\ rps$
- Then to get Q_2*= 1 lit/s,* $\Delta p_2 = 30$ *kPa, the rps should be 10.7 rps*

Design tip

- A functioning pump will have operating losses such belt or drive losses. The pump and system performance curves do not take this into account.

Design tip

- The use of inverters to control the speed of the pump is the most efficient method of controlling and restricting the flow.
- The cost and maintenance requirements of the inverter need to be considered.
- An alternate method is to adjust a globe valve on the pump discharge side to achieve the required flow.
- However the latter method is wasteful of energy and only works if all other parameters remain constant