# Refrigeration and Air conditioning Engineering.

# 3rd year – refrigeration and Air conditioning Course

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# Pumps selection part 2

## Lecture -18 -

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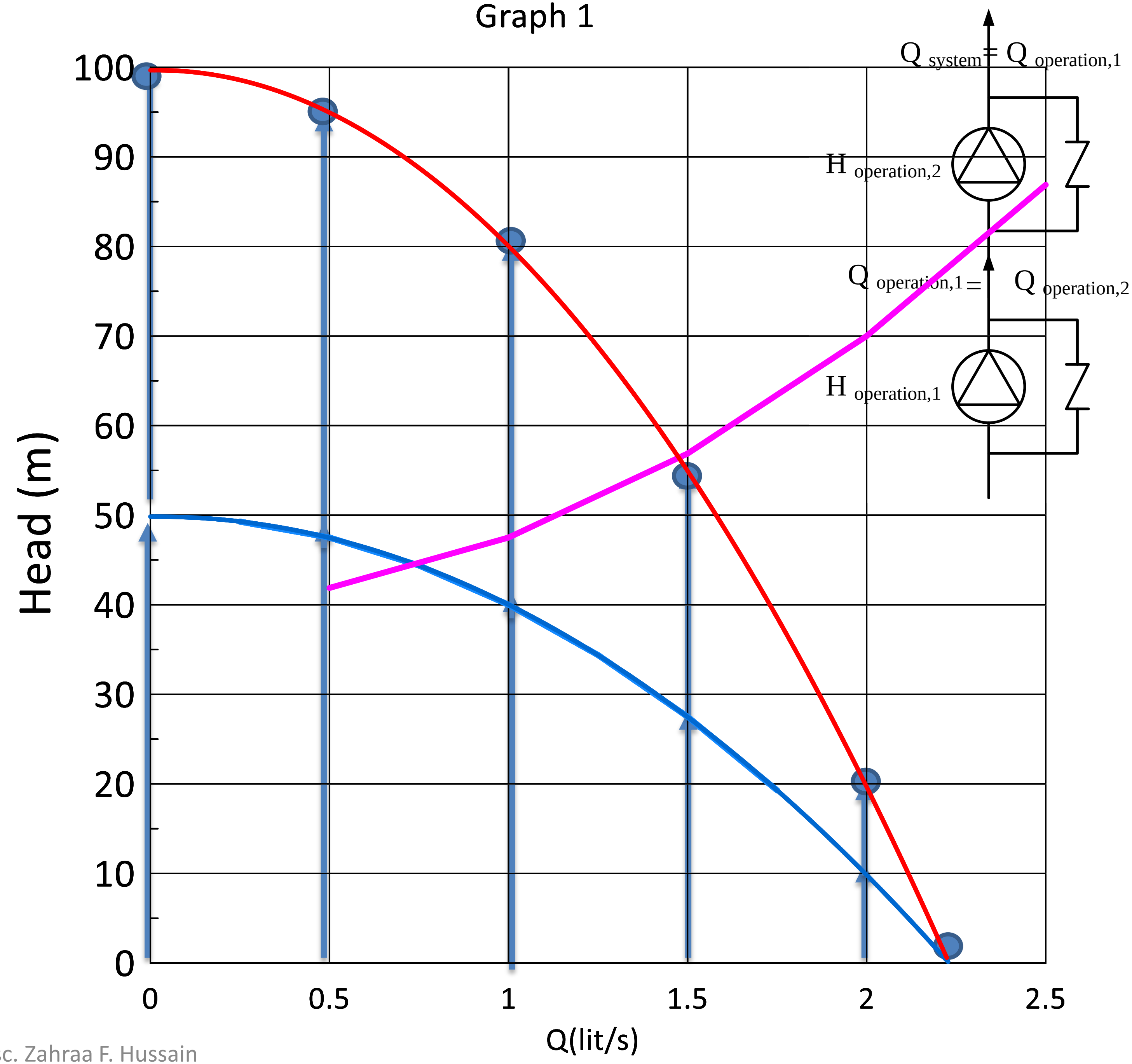
# Pumps operated in series:

- 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.

# Graph 1

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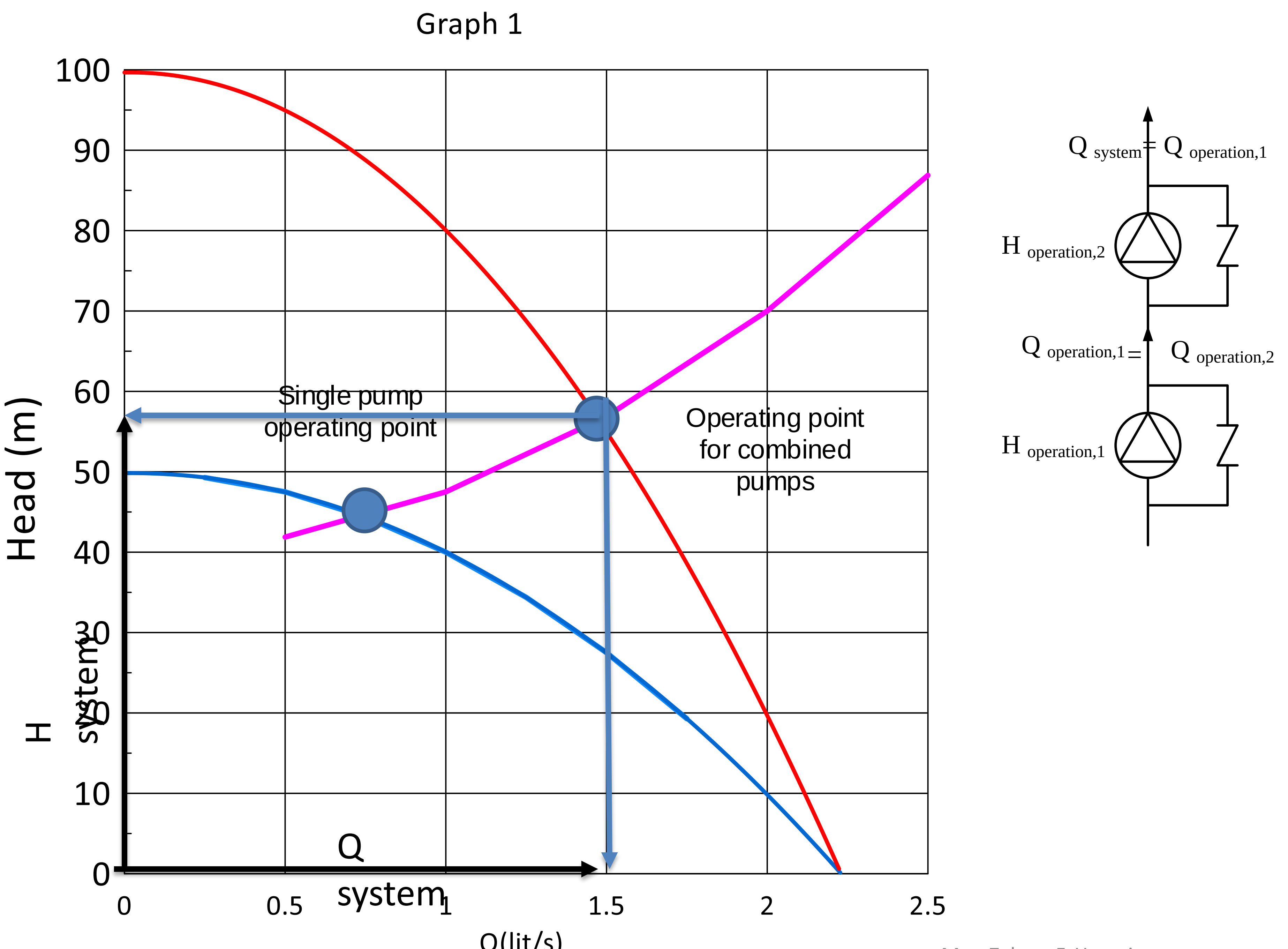


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# Pump laws

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

| | |
|---|---|
| $$\frac{Q_2}{Q_1} = \frac{rpm_2}{rpm_1}$$ | **(5-7)** |
| $$\frac{p_2}{p_1} = \left(\frac{rpm_2}{rpm_1}\right)^2$$ | (5-8) |
| $$\frac{P_2}{P_1} = \left(\frac{rpm_2}{rpm_1}\right)^3$$ | (5-9) |
| $$\frac{p_2}{p_1} = \frac{\rho_2}{\rho_1}$$ | (5-10) |
| $$\frac{Q_2}{Q_1} = \left(\frac{D_2}{D_1}\right)^3$$ | (5-11) |
| $$\frac{p_2}{p_1} = \left(\frac{D_2}{D_1}\right)^2$$ | (5-12) |
| $$\frac{P_2}{P_1} = \left(\frac{D_2}{D_1}\right)^5$$ | (5-13) |

- 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 |
|---|---|---|---|---|---|---|---|

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

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

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

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

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

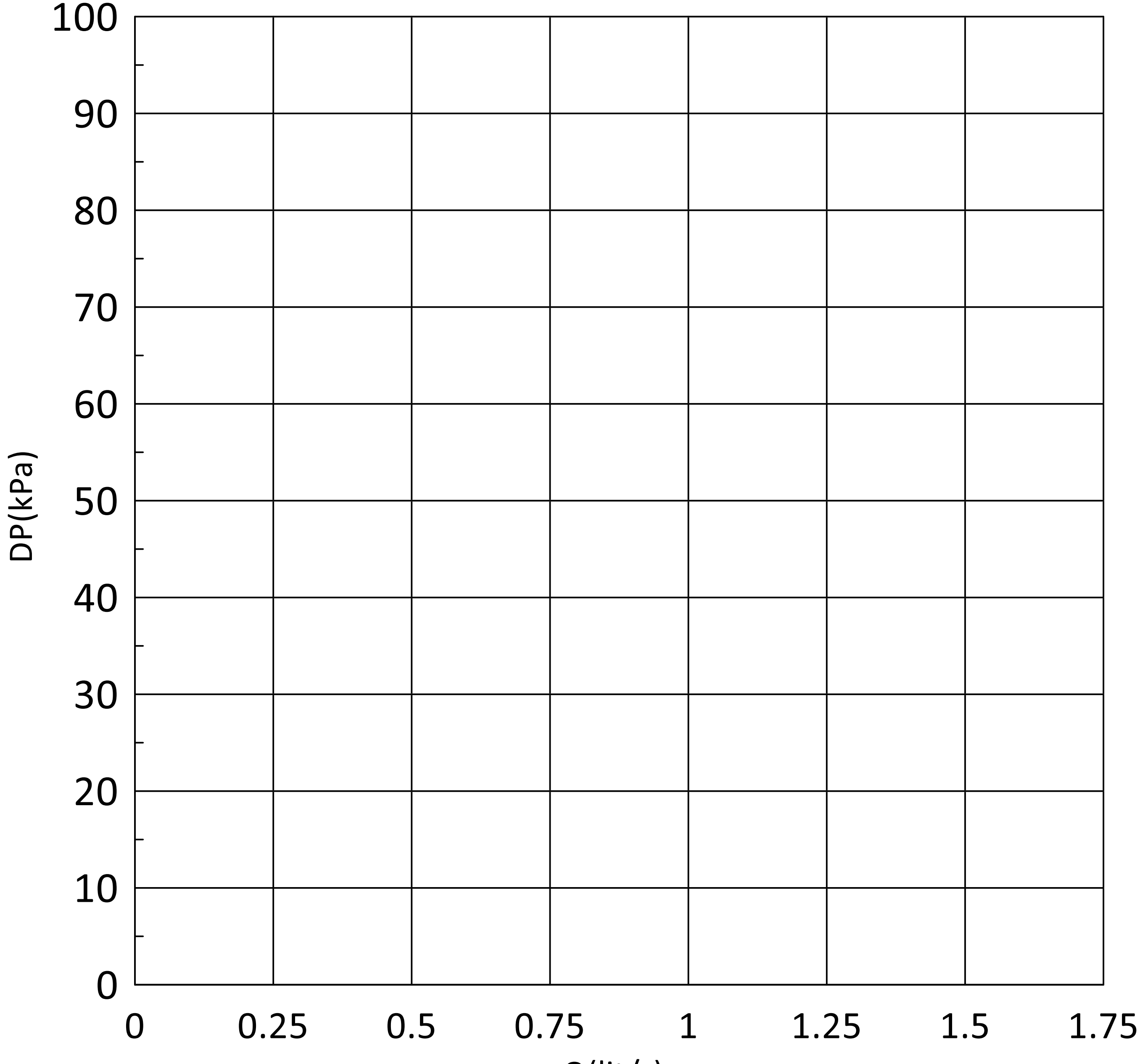
$$\Delta p = 30.\times 1.25^2 = 46.875$$

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

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

| 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 |
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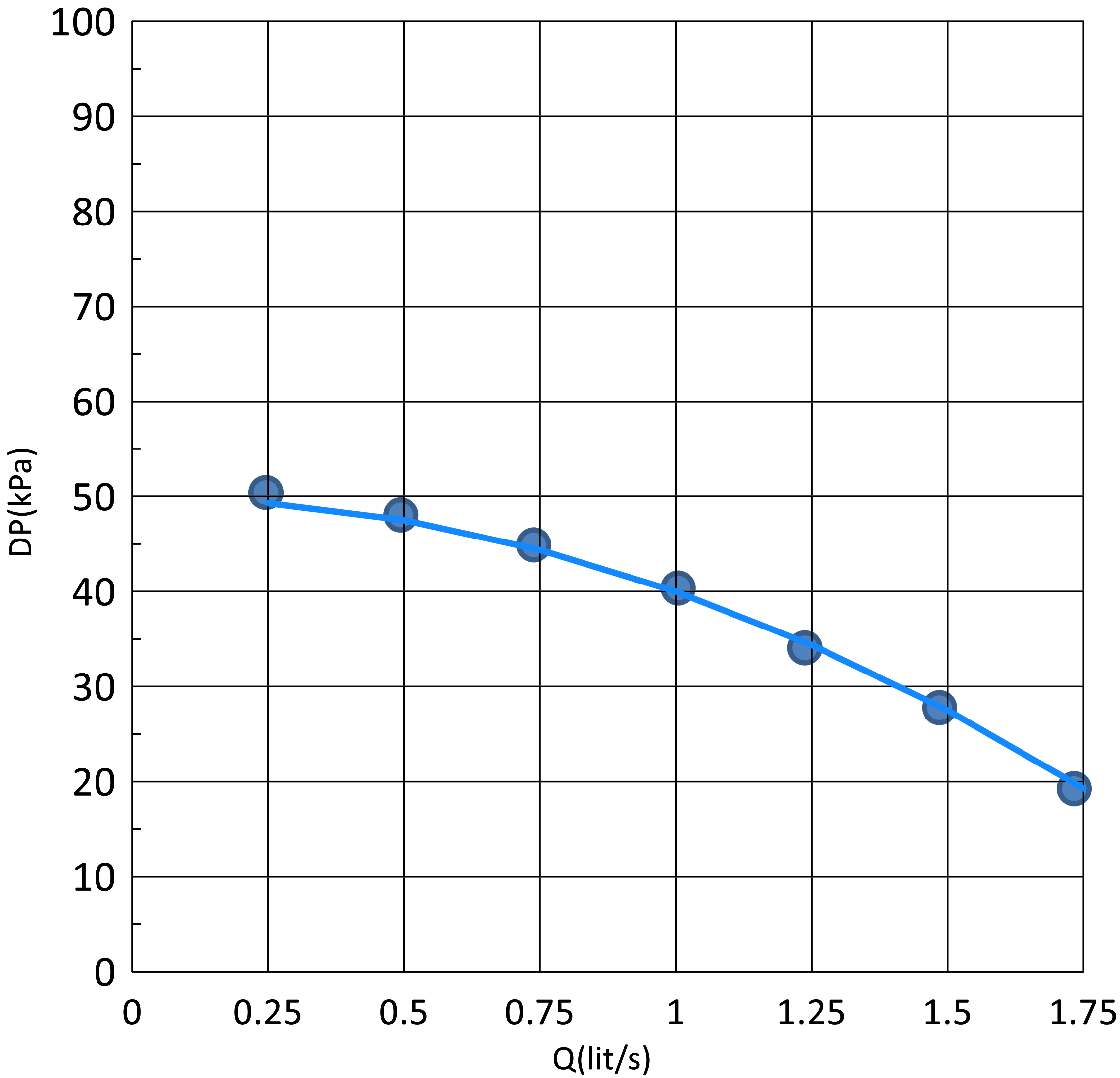
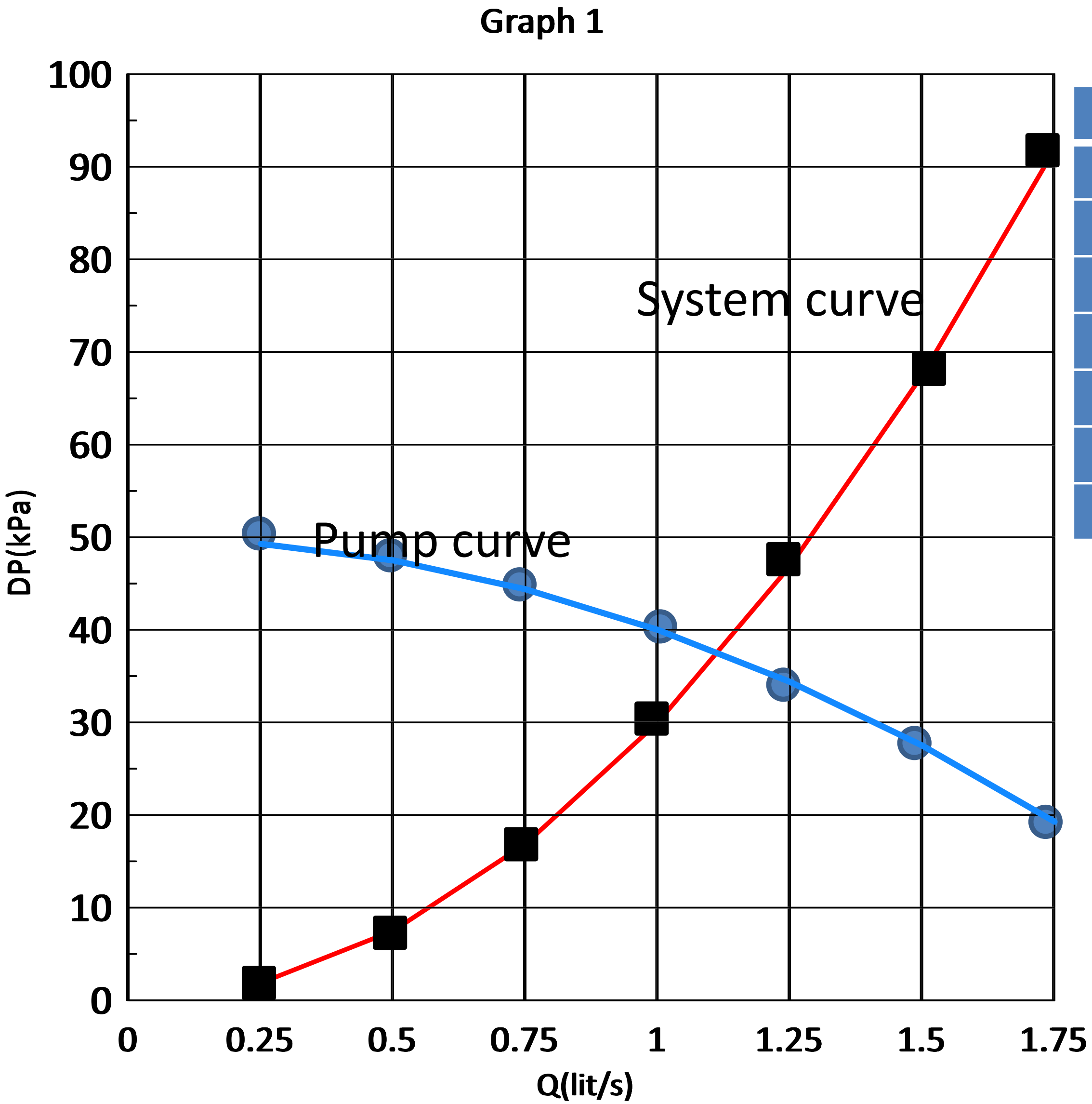
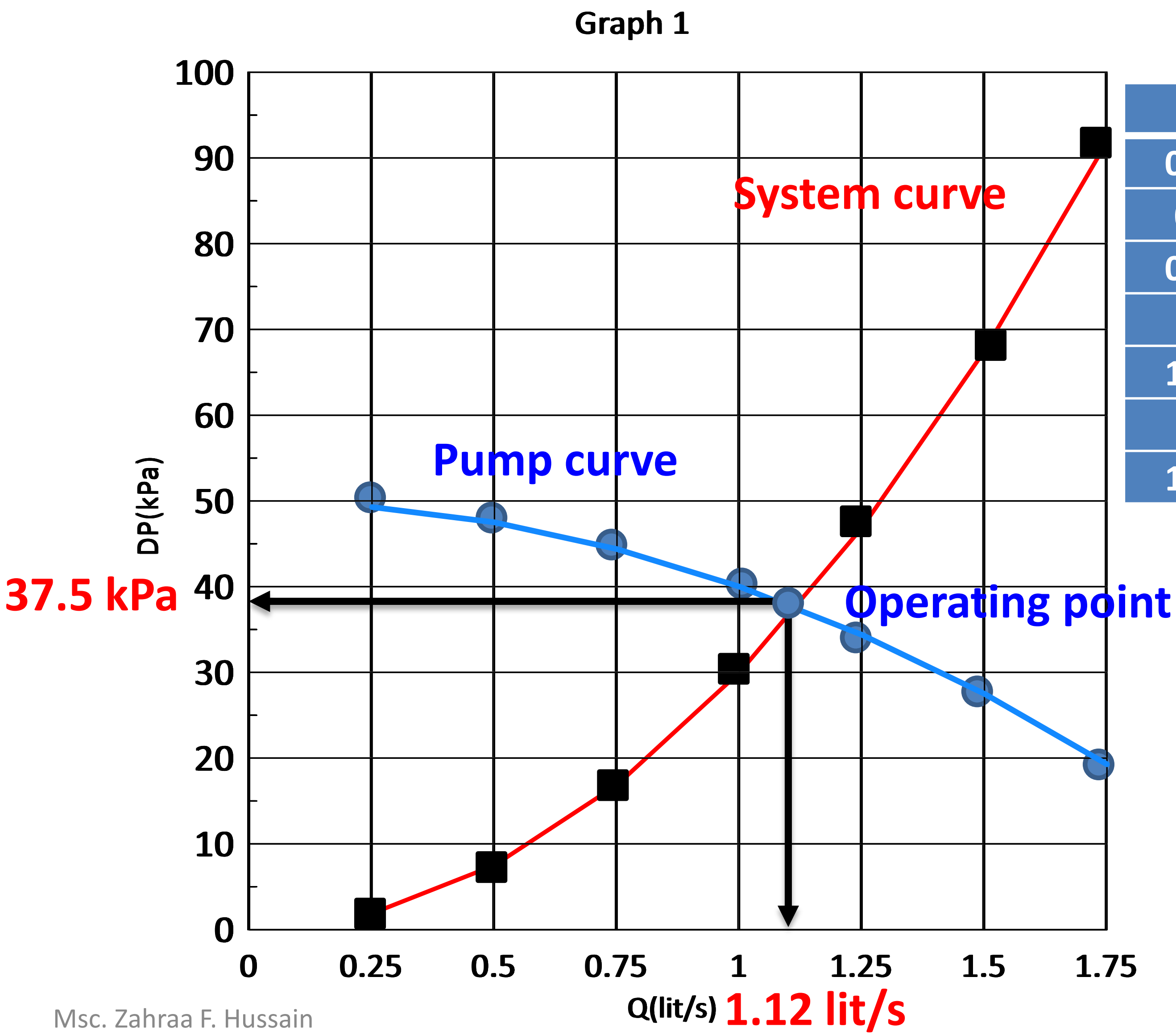
Graph 1



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




| 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 |




| Q | $\Delta p = 30.Q^2$ |
|---|---|
| 0.25 | 1.875 |
| 0.5 | 7.5 |
| 0.75 | 16.875 |
| 1 | 30 |
| 1.25 | 46.875 |
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- 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