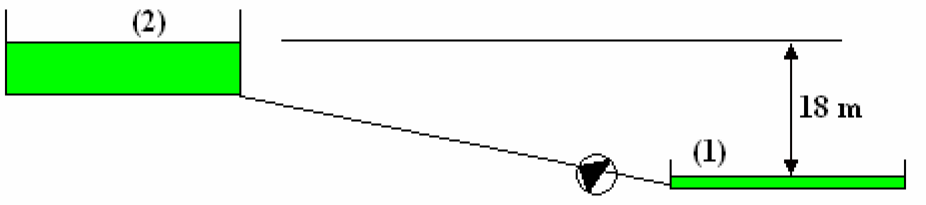
The water surface in a reservoir is 18 m above the water surface level of a river. The reservoir is to be supplied with a steady flow rate of 1100 1itres/min of water from the river using a centrifugal pump. The suction and delivery pipes will have a diameter of 100 mm and total equivalent length of 120 m. The friction factor f for the pipes may be assumed to be 0.020. Three geometrically similar pumps with impeller diameters of 165 mm, 182 mm and 214 mm respectively are available and test results for the 182 mm diameter impeller pump running at 3000 rev/min are given in the table.

(a) Determine which pump is the most appropriate to use for this application and give reasons for your choice.

(b) Calculate the pump speed which will match the supply requirements and determine the power required to drive the pump under these conditions. The water density is 1000 kg/m^3.

Table for 182 mm at 3000 rev/min

discharge q (litres/min)	0	500	1000	1500	2000	2500
head H (m)	43.8	42.5	38.8	33.0	25.2	16.3
overall efficiency η(%)	0	38	61	71	71	54



Bernoulli ΔH is the head added by the pump

$h_1 + z_1 + u_1^2/2g + \Delta H = h_2 + z_2 + u_2^2/2g + h_f + \text{exit loss}$ velocity = 0 at free surface

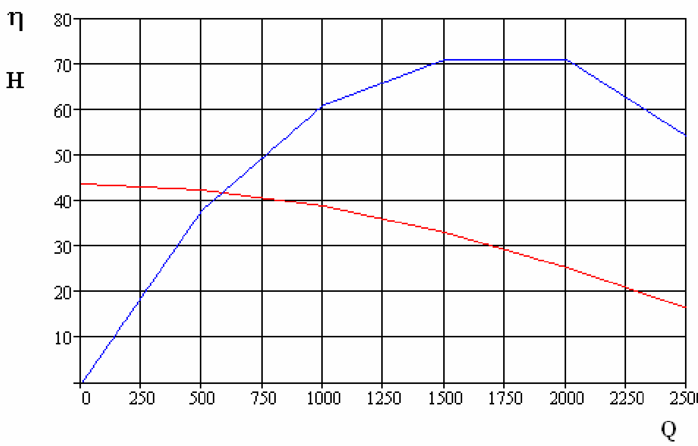
$0 + 0 + 0 + \Delta H = 0 + 18 + 0 + h_f + \text{exit loss}$

$\Delta H = 18 + h_f + \text{exit loss}$

$$\Delta H = 18 + \frac{0.02 \times 120 \times u^2}{2g \times 0.1} + \frac{u^2}{2g} \qquad u = \frac{Q}{\pi \times 0.05^2} = 127.32Q$$

$\Delta H = 18 + 20656.7Q^2$ Given Q = 1.1/60 = 0.01833 m^3/s $\Delta H = 18 + 20656.7(0.01833)^2 = 24.94$ m

Plot the pump characteristic for 182 mm and 3000 rev/min



The optimal point is at 1750 litres/min (0.0292 m^3/s) with H = 30 m and η = 72% approx

The required Ns is

$$Ns = \frac{NQ^{1/2}}{H^{3/4}} = \frac{3000 \times 0.0292^{1/2}}{30^{3/4}} = 40$$

To achieve this, the speed must be changed to produce the required head and flow.

$$Ns = 40 = \frac{NQ^{1/2}}{H^{3/4}} = \frac{N \times 0.01833^{1/2}}{24.94^{3/4}}$$

N = 3296.6 rev/min

A higher speed means a smaller pump is required. Choose the 165 mm pump. We need to determine the operating characteristics of this pump when running at the same speed (3000 rev/min).

$$\frac{\Delta H_1}{N_1^2 D_1^2} = \frac{\Delta H_2}{N_2^2 D_2^2} \qquad \Delta H_2 = \frac{D_2^2}{D_1^2}\Delta H_1 = \left(\frac{165}{182}\right)^2 \Delta H_1 = 0.822\Delta H_1$$

$$\frac{Q_1}{N_1 D_1^3} = \frac{Q_2}{N_2 D_2^3} \qquad Q_2 = \frac{D_2^3}{D_1^3} Q_1 = \left(\frac{165}{182}\right)^3 Q_1 = 0.745 Q_1$$

Table for 165 mm at 3000 rev/min Efficiency assumed unchanged.

discharge q (litres/min)	0	372.5	745	1117.5	1490	1862.5
head H (m)	36	34.9	31.9	27.1	20.7	13.4
overall efficiency η(%)	0	38	61	71	71	54

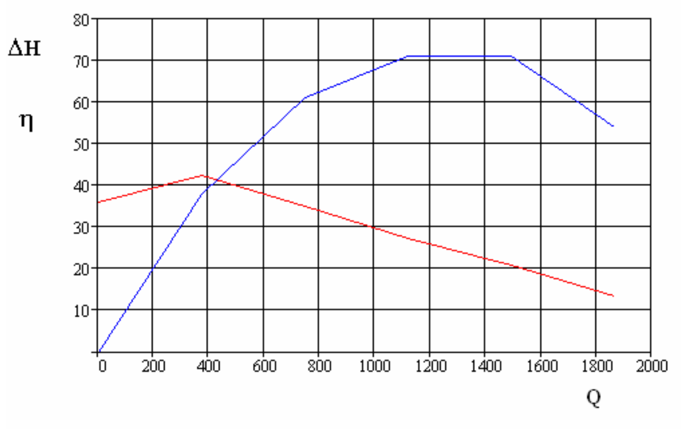
The optimal point is at 1300 l/min (0.0217 m^3/s) and 24 m head. The required Ns is

$$Ns = \frac{NQ^{1/2}}{H^{3/4}} = \frac{3000 \text{ x } 0.0217^{1/2}}{24^{3/4}} = 40.7$$

To achieve this, the speed must be changed to produce the required head and flow.

$$Ns = 40.7 = \frac{NQ^{1/2}}{H^{3/4}} = \frac{N \text{ x } 0.01833^{1/2}}{24.94^{3/4}}$$

N = 3357 rev/min



NB This work was not needed since for a geometrically similar pump we should have the same Ns (40) and hence the speed should be 3298 rev/min as calculated earlier.

The water power = mgΔH = 183.3 x 9.81 x 24.94 = 44846 W (The mass of 183 litres is 183 kg)

The power input = WP/η = 44846/0.72 = 62287 W