How to work on engineering problems ([1]).

1: Make a good drawing/sketch. This helps you to get a clear picture about what the problem is and, at the exam, if that is all you do, there might be some credit for it.

2: Solve as far as possible in symbolic form, stating clearly the relevant fundamental principles and underlying assumptions.

3: Check that your result is dimensionally correct.

4: Check that your result makes sense by considering the limits.

5: Insert numbers if required. *Be meaningful in the number of digits.*

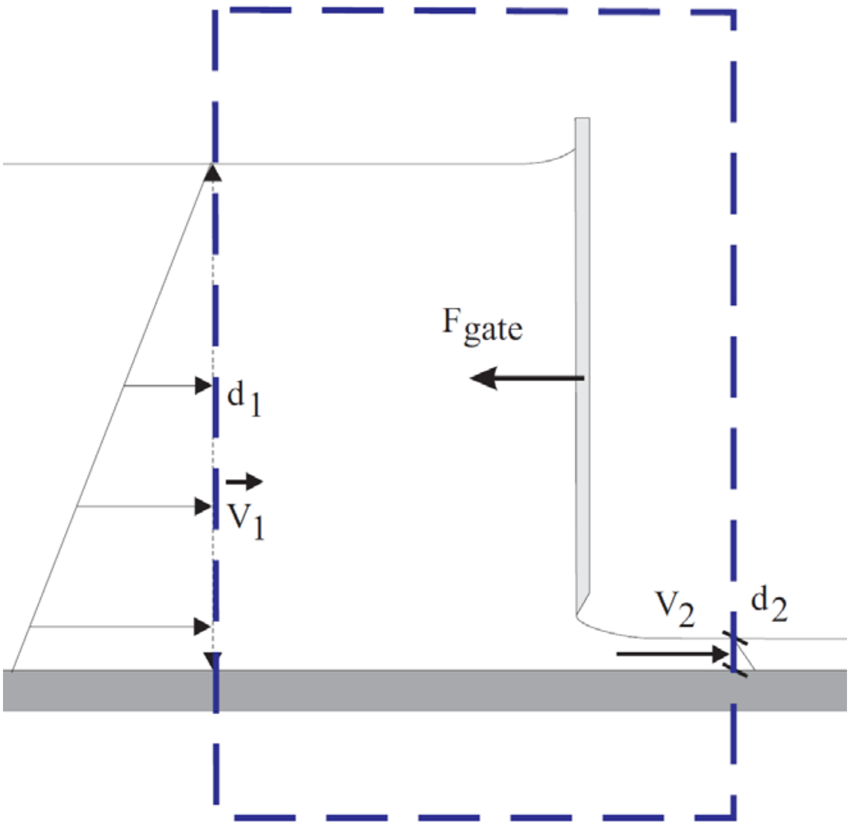
5b: Provide all your results with units - SI units must be utilised.

6: Check that your result is physically reasonable and meaningful, when possible.

[1] Originally developed by Professor P. Nielsen, expanded by Prof. H.. Chanson with relevant CIVL3140 Catchment Hydraulics application from Prof. H.. Chanson.

Example
Water flows beneath a vertical sluice gate in a smooth, rectangular and horizontal channel. The gate is 3.4 m wide. When the flow rate is 5 m^3/s, the upstream water level is 2.5 m and the downstream water level is 0.219 m, calculate the force acting on the gate.

1: Your drawing, where all quantities have been given a symbol.



2: The application of the *continuity principle* gives the flow velocity upstream and downstream of the gate.

The *momentum principle* states the rate of change of momentum flux equals the sum of the forces applied to the control volume. Considering the control volume illustrated in the above sketch, the application of the momentum principle in the horizontal direction gives, for a smooth channel, in a **symbolic form**:

$$F_{gate} = \frac{1}{2} \times \rho \times g \times B \times \left(d_1{}^2 - d_2{}^2\right) - \rho \times Q \times (V_2 - V_1)$$

Based upon the lecture material developed into "The Hydraulics of open channel flow: an introduction" (2004), pp. 15-16 & 51-52.

3: Check the dimensions:

$$M\frac{L}{T^2} = \frac{M}{L^3}\frac{L}{T^2}L^2 = \frac{M}{L^3}\frac{L^3}{T}\frac{L}{T} \qquad \text{OK}$$

4: Make sense of the limits:

The above equation may be rewritten as:

$$F_{gate} = \rho \times \left(\frac{1}{2} \times g \times d_1{}^2 \times \left(1 - \left(\frac{d_2}{d_1} \right)^2 \right) \times B - \frac{Q^2}{B \times d_1} \times \left(\frac{1}{d_2/d_1} - 1 \right) \right)$$

Typical limits include:

$F_{gate} = \rightarrow \infty$ for $B \rightarrow \infty$ OK

$F_{gate} = \rightarrow 0$ for $B \rightarrow 0$ OK

$F_{gate} = \rightarrow \infty$ for $d_1 \rightarrow \infty$ OK

Higher density gives larger force OK

Note that any consideration of the limits must take into account the basic principle of conservation of mass. For example, for a given flow rate, the upstream and downstream flow depths must fulfil continuity.

5: Insert numbers:

$$F_{gate} = 0.5 \times 998.2 \times 9.80 \times 3.4 \times \left(2.5^2 - 0.219^2\right)$$
$$-998.2 \times 5 \times \left(\frac{5}{0.219 \times 3.4} - \frac{5}{2.5 \times 3.4}\right)$$

F_{gate} = **7.26×10^{4} N = 72.6 kN**

In engineering, most results are presented with 2 to 3 digits, although the complete calculations may be performed with a greater accuracy.

5b. Units: the force is expressed in N.

6. Meaningful results

When the flow rate is zero, the gate is closed, the upstream depth is 2.5 m, and the downstream depth 0.219 m, the force acting on the closed sluice gate would the resultant of the hydrostatic pressure forces:

$$(F_{gate})_{Q=0} = \frac{1}{2} \times g \times d_1{}^2 \times B - \frac{1}{2} \times g \times d_2{}^2 \times B$$
$$= 0.5 \times 998.2 \times 9.80 \times (2.5^2 - 0.219^2) \times 3.4$$
$$= 1.03 \times 10^5 \text{ N}$$

Such a force (~ 1×10^{5} N) is of the same order of magnitude as, albeit different from, the obtained result ($F_{gate} \approx 0.7 \times 10^5$ N).

IMPORTANT

In presence of flow motion, there is a change in momentum flux which counterbalances to some extent the difference in pressure forces at both ends of the control volume. Thus the force acting on the gate in presence of flow motion must be smaller than the above limit (resultant of hydrostatic pressure forces).