Unravelling the mystery surrounding Bernoulli's

Daniel Bernoulli was a Dutch born Swiss Scientist, who discovered basic principles of fluids. The Bernoulli principle is that a fluid (liquid or gas) in motion can have three types of energy

- Potential energy
- Kinetic energy
- Pressure energy

These can be interchanged but unless energy is taken out (e.g. turbulence or friction) or energy is put in (e.g. pump) then the total energy must be constant.

The frictional loss is neglected in calculations due to being small compared to the total energy, however, you must consider frictional loss in certain circumstances e.g. sprinkler calculations

To use Bernoulli's theorem in calculations it is important to have all three forms of energy in the same units. The Systems International (SI) unit for energy is the Joule ($kg.m^2/s^2$) however; when using Bernoulli the energy is expressed per unit mass or per unit volume.

Therefore, there are different forms of the Bernoulli Equation depending on whether we are working with either joules per kilogram (j/kg) or joules per meter cubed (j/m^3). In order to simplify the matter, I am only going to use the Bernoulli Equation that expresses the energy in the form of joules per metre^3 (j/m^3) which I believe is easier to apply to IFE examination questions.

Potential energy

This is the energy due to the potential above the datum line from which all the energies are measured. The potential energy per m^3 of fluid can be considered as

$$\rho g o \quad (Joules/m^3)$$

Where

p = density (kg/m^3)
g = acceleration due to gravity (9.81 m/sec^2)
H = height (m)

Kinetic energy

The kinetic energy is due to the fluid being in motion. The Kinetic energy can be considered as

$$\tfrac{1}{2}\,\rho v^2 \qquad (Joules/m^3)$$

Where   p = density (kg/m³)
         V = Velocity (m/sec)

Pressure energy

The pressure energy is due to being under pressure. The SI unit of pressure is Pascal but in the Fire Service, the Bar and metres head are still used. Therefore, you must remember to use the correct formula

To convert from Bar to Pascal's you use the following

$$P \times 100{,}000 \qquad (Joules/m^3)$$

Where   P = Pressure (Bar)

To convert metres head pressure to Pascal's, you use the following

$$\rho g z \qquad (Metres\ head)\ (Joules/m^3)$$

Where ρ = Density (kg/m³)
            g = acceleration due to gravity 9.81 m/sec²
            z = height (m)

Bernoulli – Pascal's

Where the pressure energy is Pascal's

$$P_A + \rho g H_A + \tfrac{1}{2}\rho v_A^2 = P_B + \rho g H_B + \tfrac{1}{2}\rho v_B^2$$

Where P_A is pressure energy at point A (joules)
            $\rho g H_A$ is the potential energy at point A (joules)
            ρ = Density of fluid (kg/m3)
            g = Acceleration due to gravity 9.81 m/sec
            H = height of column of water
            $\tfrac{1}{2}\rho v_A^2$ is the kinetic energy at point A (joules)
            V = velocity m/sec

Where the pressure energy is Bar

$$P_A \times 100{,}000 + \rho g H_A + \tfrac{1}{2} \rho v_A^2 = P_B \times 100{,}000 + \rho g H_B + \tfrac{1}{2} \rho v_B^2$$

Where the pressure energy is metres head

$$\rho g z_A + \rho g H_A + \tfrac{1}{2} \rho v_A^2 = \rho g z_B + \rho g H_B + \tfrac{1}{2} \rho v_B^2$$

Continuity equation

When considering Bernoulli it is also very important to understand the continuity equation. This is due to the fact that in a closed system the rate of flow Q (m^3 /sec) can be considered as constant.
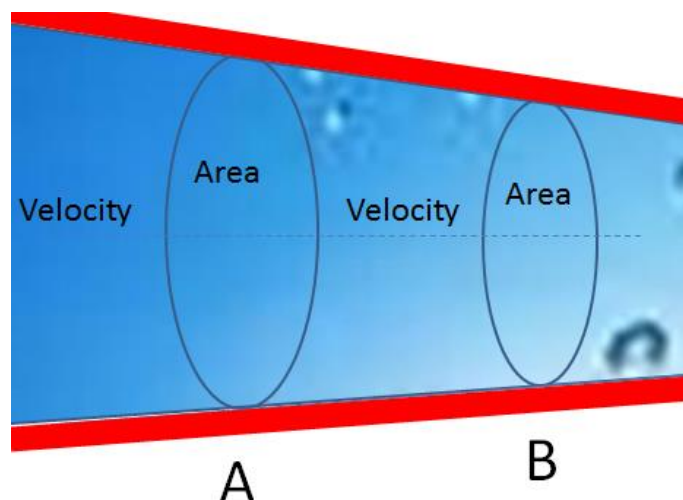
$$Q = VA$$

Where
Q = Rate of flow (m^3/sec)
V = Velocity (m/sec)
A = Area (m^2)

If the flow is constant then

$$Q = V_A A_A = V_B A_B$$

This is shown here in this diagram showing a pipe

As the water flows down the pipe and it tapers out what you will find is that the waters velocity will reduce. In other words as the area increases the velocity falls. This is a very important relationship when attempting Bernoulli calculations as will be shown later. Before we attempt questions involving the use of these equations, I would like to give you a few tips to ensure mistakes are not made.

Tip one

Produce a sketch and enter all the details given in the question first. This will make understanding the problem much clearer.

Diameter of hose =

23m

Datum

Water power= 4000 watts

Rate of flow Q = 500
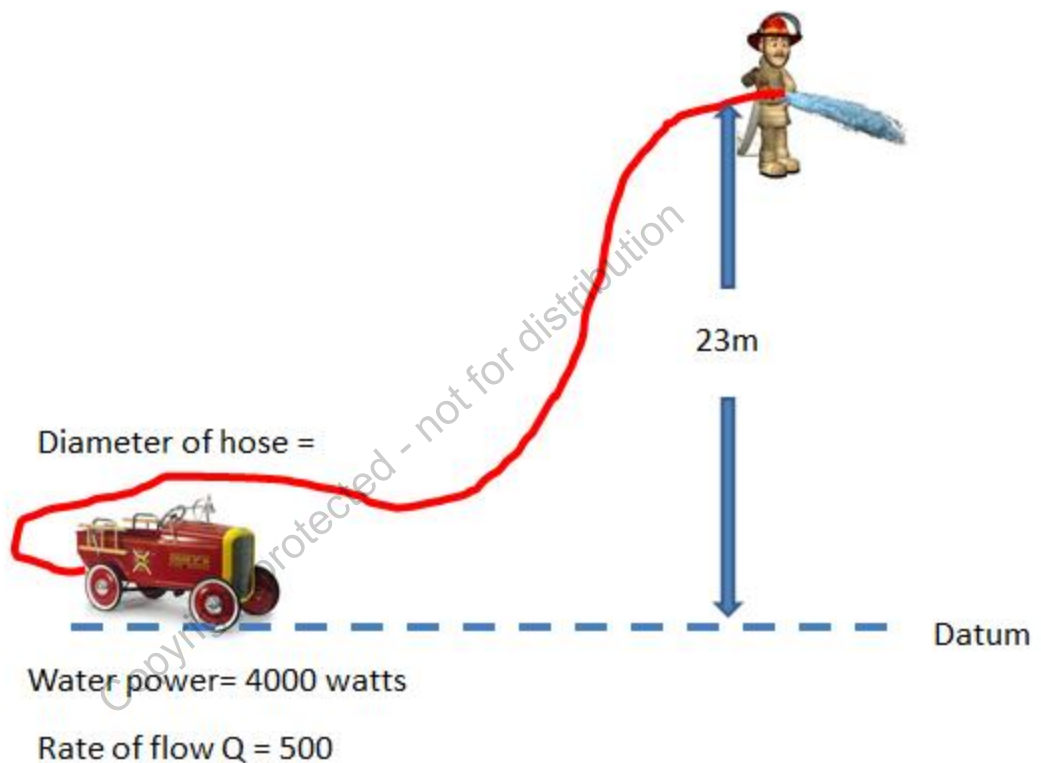
Tip two

Always convert ALL units to SI units before attempting to answer the question. Many candidates make mistakes because they don't convert the units and simply place the number in the formula.

Here is a list of the most common units.

	SI unit
Length (L)	m
Area (A)	m^2
Velocity (V)	m/sec
Acceleration due to gravity (g)	9.81 m/sec^2
Height (h)	m
Metres head (z)	m
Energy (joule)	kg.m^2/s^2
Pressure (Pascal)	n/m^2
Volumetric flow (Q)	m^3/sec

Tip three

You have to place a datum line which is where you are measuring the energies from. Now if this is a horizontal pipe you always put the datum in the centre of the pipe because in this way you have zero potential at both points. This is because the potential energy above and below the datum cancels out. Now if the situation is not in a horizontal pipe for example like this example.

What you do is always place your datum line at the lowest point in the system. In this way only one of the points will have potential energy and it makes it easier to answer the question.

Module 22

This module covers the following topics;

- Bernoullis theorem (principles)

Question 1

A pump is pumping 2m³/min of water the surface of which is 5m below the pump inlet. At the outlet the pump has a diameter of 100mm and at this point the pressure is 8 Bar. From the nozzle (which is at the same level as the pump outlet) the jet rises 35m.

    A) Calculate the energy/kg of the water

        (1) At the outlet of the pump
        (2) At the top of the throw of the jet

    B) Explain why (1) and (2) are not equal
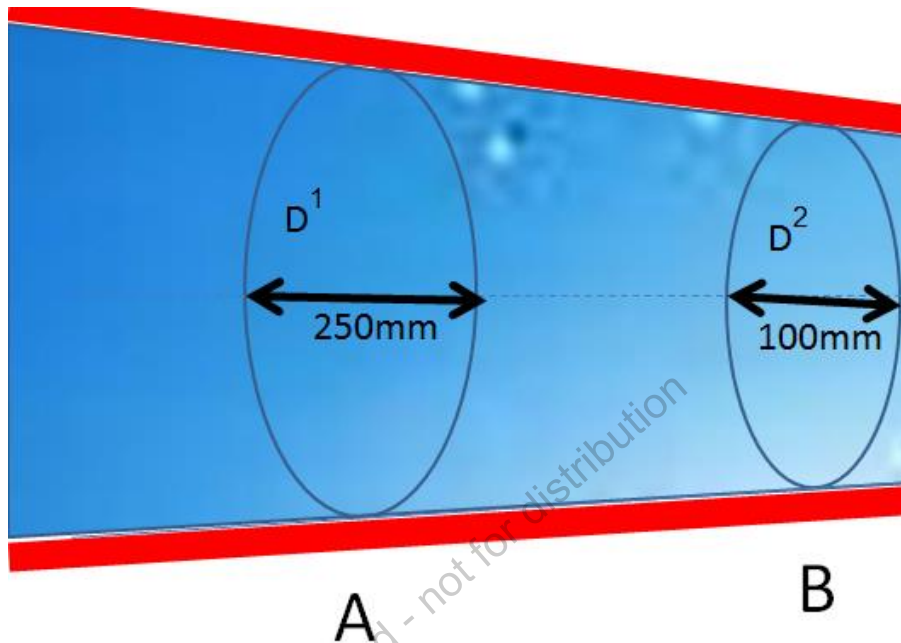   (acceleration due to gravity is 9.81m/sec2)

Question 2

Water is flowing horizontally through a 250mm diameter pipe and into a constriction of 100mm diameter. The pressure difference is measured as 23.5mm of mercury.   Using Bernoulli's theorem, calculate the rate of flow.

(Density of mercury = 13,600 kg/m^3)
(Density of water = 1000 kg/m^3)
(g = 9.81)

Pressure difference = 23.5mm mercury
Density of mercury = 13,600 kg/m^3)

Question 3

A foam generator consists of a horizontal tube of circular cross section which tapers from an input of 80mm internal diameter to 20mm diameter. 750 lts/min of concentrate (Density 1200 kg/m) is flowing through the generator and the pressure inlet is 12 Bar.

What is the pressure at the point where the diameter is 20mm?

Pressure = 12 Bar

Pressure = ?

D^1

80mm

D^2

20mm

A

B
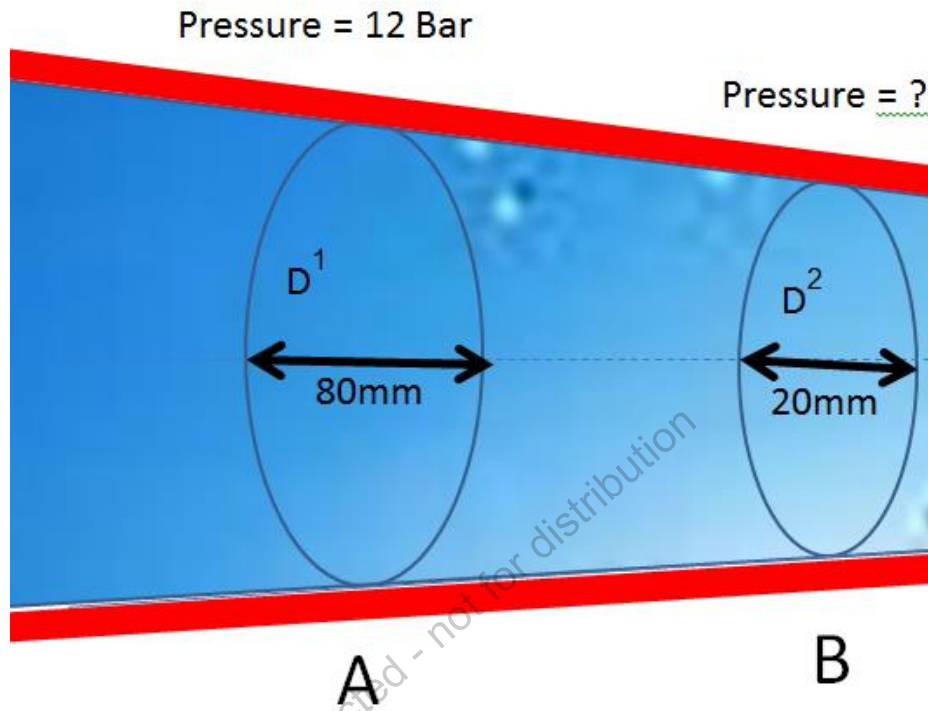
Question 4

Water is flowing in a vertical tapering pipe 2 metres in length. The top of the pipe is 100mm diameter and the bottom is 50mm diameter. The quantity of water flowing is 1300 litres/minute.

Calculate the pressure difference between the top and the bottom of the pipe?
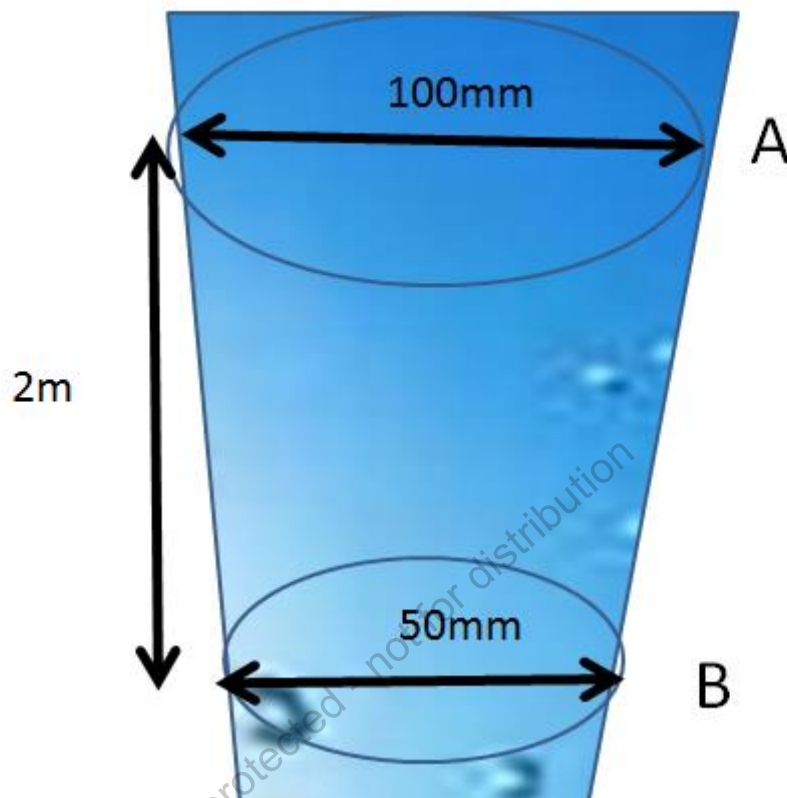
Question 5

A pump supplies 4kw of energy to the water flowing through a 45mm hose. The water flows 15m vertically and through a 25mm branch at a rate of 500 litres/minute. Use Bernoulli's theorem and find the pressure at the branch.

Make a sketch and fill all details as shown here

Q = 500 litres/min
Water power = 4000 watts
d = 45mm

d = 25mm

15m

Datum

A

B
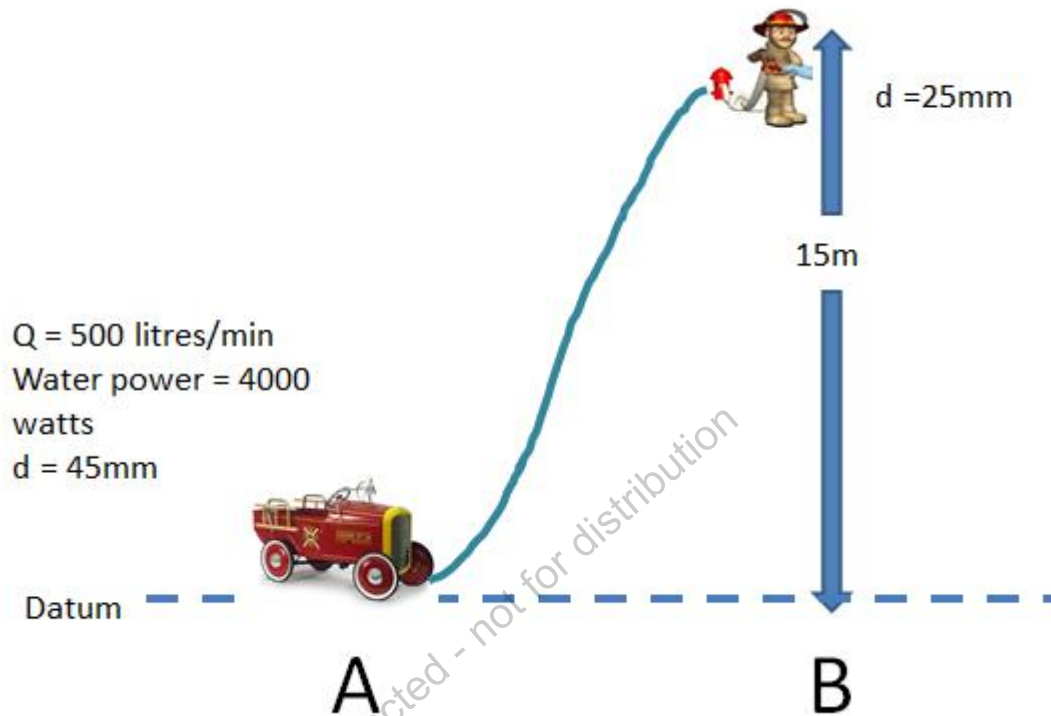
Question 6

If the manometer readings are 800mm and 200mm, what is the flow?
(Density of water = 1000kg/m³)

HA = 800mm Water

HB = 200mm Water

Cross section

Datum 2000mm²

Cross section

A

B