Question 1

a) Define a fluid. [5 marks]

b) Define Newton’s Law of viscosity. [6 marks]

c) Water, whose coefficient of viscosity is $1.0 \times 10^{-3}$ Ns/m$^2$, flows over a horizontal plate 5.0m long and 3.0m wide. The velocity of the water increases, through a boundary layer, from zero at the plate surface to 0.8m/s at a distance of 12mm above the plate. Calculate the total friction force acting on the plate. [14 marks]

Question 2

a) State the principle of Archimedes. [4 marks]

b) A body of mass 100g and of specific gravity 2.0 is suspended by a thread so as to be completely immersed in a liquid of specific gravity 0.92.

i) Calculate the tension in the thread. [9 marks]

ii) If the thread is cut, calculate the initial acceleration of the body. [8 marks]

iii) Why will the acceleration not be maintained as the body falls in the liquid? [4 marks]
Question 3

a) Write down Bernoulli’s equation, describing each term and stating all assumptions.

[11 marks]

b) Figure Q3 shows a pitot-static tube connected to a U-tube manometer for the measurement of air flow speed. Show that the air speed, $v_a$, is given by:

$$v_a = \sqrt{\frac{2h \rho_l g}{\rho_a}}$$

[10 marks]

c) Such a tube is being used as an air speed indicator for an aircraft, and an observer records $h=0.12\text{m}$, using a manometer liquid of density, $\rho_l=8.0\times10^2 \text{ kg/m}^3$. The density of air is $1.3 \text{ kg/m}^3$. Calculate the speed of the aircraft.

[4 marks]

![Figure Q3](image)
Question 4

a) Write down the linear momentum equation, linking the net force, $F$, acting on a flowing fluid element bounded by planes 1 and 2, and the mass flow rate $\dot{m}$, flow velocity $v$, and static pressure $p$, at the planes 1 and 2.  

[7 marks]

b) A rocket engine combustion chamber of cross-sectional area, $A_1$, contains a virtually incompressible gas of density $\rho$, at pressure $p$. The gas escapes through a small orifice of area $A_2$ to the atmosphere, where the pressure is $p_a$. Derive equations for:

i) The speed of efflux of the gas.  

[9 marks]

ii) The thrust (net force) exerted on the rocket.  

[9 marks]

Question 5

The drag force acting to decelerate a space capsule during atmospheric entry is being investigated in a sub-scale experiment. The drag force $F$, is theoretically expected to depend upon the atmospheric density $\rho$, the capsule velocity $V$, the capsule diameter $D$, the viscosity of air $\mu$, the atmospheric pressure $p$, and the speed of sound in the outside air $a$.

a) Employ Buckingham’s $\pi$ theory to identify the non-dimensional groups which must be equated to ensure dynamic similarity between full scale and the sub-scale experiment.  

[19 marks]

b) What are the names of these non-dimensional groups?  

[3 marks]

c) Comment on the physical meaning of these non-dimensional groups?  

[3 marks]