FLUID MECHANICS I

SEMM 2313

Question 1

a) The pressure rise, ΔP, generated by a pump depends on the impeller diameter, D, its rotational speed, N, the fluid density, ρ and viscosity, μ and the rate of discharge, Q. Show that the relationship between these variables may be expressed as :

$$\Delta P = \rho N^2 D^2 \phi\left[\frac{Q}{ND^3}, \frac{\rho N D^2}{\mu}\right]$$

b) A given pump rotates at a speed of 1000rev/min, and its duty point it generates a head of 12m when pumping water at a rate of 15 liter per second. Calculate the head generated by a similar pump, twice the size, when operating under dynamically similar conditions and discharging 45 liter per second. The influence of Reynolds number is negligible.

Answer 1

$$N_2 = 375 \ \ rpm \ , \qquad \Delta P_2 = 6.75 \ m$$

Question 2

Kenaikan kapilari, h, untuk suatu cecair dalam tiub berubah menurut diameter tiub, d, pecutan gravity, g, ketumpatan bendalir, ρ, ketegangan permukaan, σ dan sudut sentuh, θ.

a) Dengan menggunakan kaedah *Teorem Buckingham Pi*, tentukan kumpulan tanpa dimensi *Pi* yang menghubungkan kesemua parameter yang disebutkan.

b) Dalam ujikaji pertama, kenaikan kapilari ialah $h=3cm$. Dalam ujikaji yang lain, diameter tiub dan ketegangan permukaan bendalir adalah separuh daripada ujikaji pertama sementara ketumpatan bendalir pula adalah dua kali ganda. Sudut sentuh untuk kedua-dua ujikaji ini adalah sama. Tentukan nilai h untuk ujikaji kedua.

Answer 2

$$h_2 = 1.5 \quad cm$$

Question 3

a) Kesusutan tekanan, ΔP, untuk aliran likat mantap dan tidak boleh mampat dalam paip lurus mengufuk dipengaruhi oleh panjang paip, l, halaju purata, U, kelikatan, μ, diameter paip, D, ketumpatan bendalir, ρ dan kekasaran dalaman, ε. Dengan menggunakan kaedah Buckingham Pi, tentukan kumpulan-kumpulan tidak berdimensi yang menghubungkan parameter-parameter ini.

b) Sebatang paip berdiameter 40cm mengalirkan minyak (s=0.86, μ=10^{-1}Pa.s). Jika keadaan ini diulang dalam makmal dengan menggunakan air (μ=10^{-3}Pa.s) dan paip berdiameter 50mm dari jenis yang serupa, tentukan halaju air yang setara jika minyak mengalir pada halaju 10m/s.

Answer 3

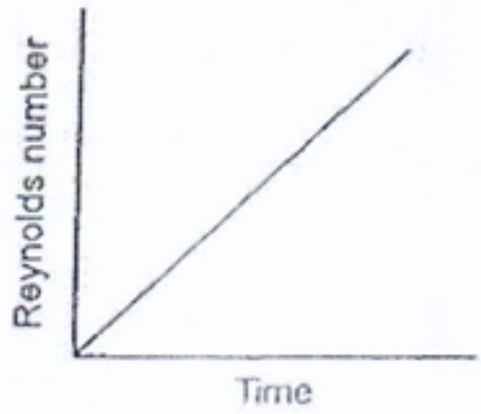
$$u_2 = 0.688 \quad m/s$$

Question 4

The energy losses per unit weight of fluid flowing through a nozzle connected to a hose can be estimated by ; $h = M \cdot \left(\frac{D}{d}\right)^4 \cdot \frac{V^2}{2g}$. Check the homogeneity of the equation.

where ;

h	=	Energy loss per unit weight
M	=	Constant (gradient of graph 1)
D	=	Hose diameter
d	=	Nozzle tip diameter
V	=	Fluid velocity in the hose
g	=	Gravity acceleration



Graph 1

Question 5

A model of incompressible fluid oscillates harmonically with a certain frequency in a pipe. The pressure difference per unit length, Δp_ℓ , at any instant along the pipe can be assume as ;

$$\Delta p_\ell = f\left(D, V_0, \omega, t, \mu, \rho\right)$$

Where;

Δp_ℓ	=	Pressure difference per unit length
D	=	Pipe diameter
V_0	=	Velocity
ω	=	Frequency
t	=	Time
μ	=	Fluid viscosity
ρ	=	Fluid density

Determine the dimensionless group.

If the size of above mention model is ¼ from the actual size and the pressure difference per unit length for actual condition is 5 kPa/m, calculate the Δp_ℓ for model. Assume that the model is used the same incompressible fluid as actual condition.

Question 6

(a) Assuming the drag force, F, exerted on a body is a function of the following:

Fluid density	ρ
Fluid viscosity	μ
Diameter	d
Velocity	v

Show that the drag force can be expressed as

$$F = d^2 v^2 \rho \phi(\text{Re})$$

where ϕ is an unknown function and Re is the Reynolds number.

(b) It is necessary to predict the force on a stationary sphere of diameter 0.1 m in a flow of water travelling at 5 m/s. In the laboratory a 1.0 m diameter sphere is placed in a wind tunnel blowing air. To obtain the dynamically similar conditions at what velocity should this flow of air operate? (*Note*: $\mu_{water} = 1.0 \times 10^6$ kg/ms; $\mu_{air} = 1.7 \times 10^5$ kg/ms; $\rho_{water} =$ 1000 kg/m^3; $\rho_{air} = 12.5$ kg/m^3)

Question 7

(a) The drag force, F_D on a ball moving through a fluid at velocity u, can be reasonably assumed to depend on the radius of the ball R, the viscosity of the fluid μ, the mass density of the fluid ρ, and the roughness ε, of the balls surface. Using the method of repeated variables demonstrate that

$$\frac{F_D}{\rho u^2 R^2} = H\left(\frac{\varepsilon}{R}, \frac{\rho u R}{\mu}\right)$$

(b) Experiment for a 0.60 cm radius smooth marble falling through fresh water ($\mu = 1.12 \times 10^{-3}$ Ns/m^2) reveal that the drag force is 1.80×10^{-6} N at $u = 0.020$ m/s. At what speed would the marble have to travel through air at standard atmospheric conditions ($\rho = 1.24$ kg/m^3; $\mu = 1.8 \times 10^{-5}$ Ns/m^2) to be retarded by the same drag force?

Question 8

The rise of liquid in a capillary tube is to be studied. It is anticipated that the rise, h, will depend on surface tension, σ, tube diameter d, liquid specific weight γ , and angle β of attachment between the liquid and tube. Write the functional form of the dimensionless variables.

Use diameter and surface tension as repeating parameter.