City&Guilds

9210-134
Level 6 Graduate Diploma in Engineering
Hydraulics and hydraulic machines

Sample Paper

You should have the following for this examination
- one answer book
- drawing instruments
- non programmable calculator

No additional data is attached

General instructions
- This examination paper is of **three hours** duration.
- This examination paper contains **eight** questions.
- Answer **any five** questions.
- All questions carry equal marks. The maximum marks for each section within a question are given against that section.
- An electronic non programmable calculator may be used, but the candidate **must** show clearly the steps prior to obtaining final numerical values.
- Drawings should be clear, in good proportion and in pencil. Do not use red ink.
- **Consider the density of water as 1000 kg/m^3 and acceleration due to gravity 9.81 m/s^2.**

1 a) Show that the fluid thrust, acting on a rectangular plate fully immersed in a fluid is equal to the product of the area of the plate and the fluid pressure at the centre of area of the plate. (5 marks)

b) A water tank has a gate in the form of a quadrant of a circle of radius 1 m as shown in Figure Q1. The gate OA is hinged at O and it supports water on one side as shown. Width of the gate (in the direction perpendicular to the vertical plane containing OA) is 3 m. Calculate the external force required to hold the gate in its given position. (10 marks)

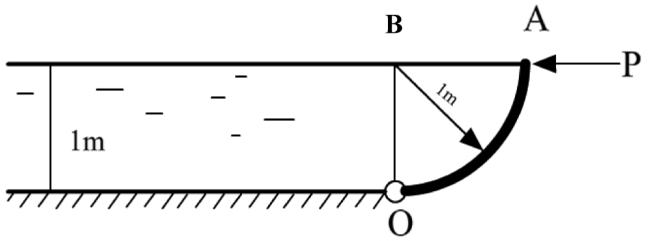

Figure Q1

c) If the curved gate OA is replaced with a vertical gate OB and all other conditions remain the same, explain how the fluid forces and the magnitude of external force P change.
You may use the following information.
The centre of pressure of a plate immersed in a fluid is located **1/3 of immersed height** measured from the bottom edge.
The centre of gravity of a quadrant of radius *r* is located $4r/3\pi$ distance from each edge. (5 marks)

2 a) Show that momentum of flow (I) of fluid can be expressed as follows.
$I = \rho A u^2$
Where ρ = density of fluid,
A = cross sectional area normal to flow velocity.
u = flow velocity. (8 marks)

b) Water flows through an expander as shown in Figure Q2. The pressures at inlet and exit are 7 bar and 2 bar respectively. The flow cross sectional areas at inlet and exit are 0.07 m^2 and 0.16 m^2 respectively. The velocity at the inlet is 20 m/s. The expander is held in a vertical plane, and has a volume of 0.5 m^3 and a mass of 20 kg. (12 marks)

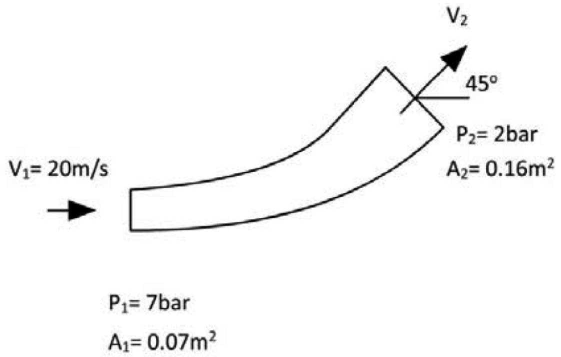

Figure Q2

Assuming steady state conditions, determine the external force required to hold the expander in stable position.

3 a) Write down the Bernoulli equation for incompressible fluid flow and define each term. (6 marks)

b) Two water tanks with a height difference of 10 m between free surfaces are connected by two parallel pipes. The diameters of pipes A and B are 50 mm and 100 mm respectively. Both pipes are 100 m in length. The entry and exit losses are equivalent to 0.5 and 0.8 times the velocity head respectively applicable to both pipes. The Darcy friction coefficient is 0.008.

Find the following.

i) Rate of flow in each pipe. (8 marks)

ii) Diameter of a single pipe that will replace the two pipes giving the same total flow. (6 marks)

You may use the **Darcy-Welsbach** equation with usual notation given below for estimating the head loss due to friction.

$$h_f = \frac{fL}{d}\left(\frac{u^2}{2g}\right)$$

4 a) Explain the terms stagnation properties and critical properties referred to in compressible flow. (6 marks)

b) Air at 8.6 bar and 190 °C expands at the rate of 4.5 kg/s through a convergent-divergent nozzle into a space as shown in Figure Q4 below. Assuming that the inlet velocity is negligible, calculate the following.

i) Temperature, pressure and the density at the throat. (9 marks)

ii) Velocity and cross sectional area at the throat. (5 marks)

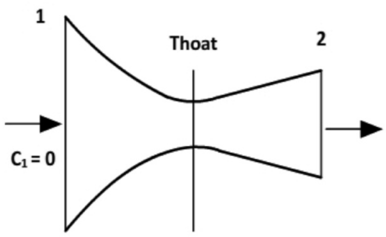

Figure Q4

Use the following equations with usual notations for the calculations, in addition to steady flow energy equation.

$$\frac{T^*}{T_0} = \frac{2}{\gamma + 1} \qquad \frac{P^*}{P_0} = \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}} \qquad \frac{P^*}{P_0} = \left(\frac{2}{\gamma + 1}\right)^{\frac{1}{\gamma - 1}}$$

For air, specific gas constant, R = 287 J/kgK and ratio of specific heat capacities, $\gamma = 1.4$

5 a) Starting from first principles show that the power developed by a rot dynamic machine is given by the following equation. (4 marks)

$W = m(V_{wi}V_{bi} - V_{we}V_{be})$

Where,

W = *Power (W)*

m = *mass flow rate* (kgs^{-1})

V_w = *Whirl Component of fluid velocity* (ms^{-1})

V_b = Blade velocity (ms^{-1})

Suffixes *i* and *e* refer to blade inlet and exit positions.

b) Figure Q5 shows the velocity diagram at inlet of a moving blade of an inward radial flow water turbine. Water leaves the guide vane at an angle α_i to the tangent to the wheel as shown. The inlet angle of the moving blade is 90°. Axial flow velocity at inlet is 20 m/s. The radii of rotating wheel at inlet and exit are 0.6 m and 0.3 m respectively. The rotational speed of the turbine is 200 rpm. The relative velocity at exit is 0.8 times that of inlet.

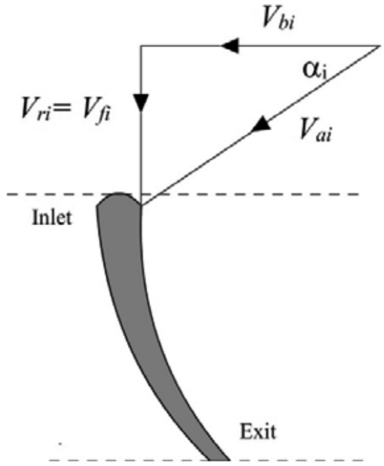

Figure Q5

The following suffixes are used to indicate different velocity components in the diagram.

i – inlet of the blade, ***e*** – exit of the blade, ***r*** – relative to the blade,
a – absolute, ***b*** – blade, ***f*** – flow or axial direction

i) Sketch the velocity diagram for the moving blade exit when the efficiency is maximum (Hint: Whirl velocity component at exit is zero) (6 marks)

Find the following.

ii) Work delivered to the turbine wheel per unit mass flow rate of water. (3 marks)

iii) Moving blade angle at exit. (3 marks)

iv) Diagram efficiency. (2 marks)

v) Mass flow rate for 20 kW power. (2 marks)

6 a) Sketch the theoretical pressure-volume diagram for the cylinder of a reciprocating pump clearly showing the effects of acceleration and friction in both suction and delivery pipes. (10 marks)

b) A reciprocating water pump has the following information:
Stroke = 0.3 m
Piston diameter = 125 mm
Diameter of the suction pipe = 75 mm
Length of the suction pipe = 6 m
Suction head = 3 m

Calculate the maximum speed of the pump that prevents separation if the atmospheric pressure is equivalent to 10.2 m of water and the separation occurs when the pressure head in the cylinder falls below 2.4 m of water. (10 marks)

Suction head for acceleration at the beginning of the stroke is given by the following formula.

$$H_{as} = \frac{L_s}{g}\left(\frac{A}{a_s}\right)\omega^2 R$$

Where,
H_{as} = Additional suction head for acceleration
L_s = Length of suction pipe
A = Cross sectional area of the piston
a_s = Cross sectional area of the suction pipe
ω = Rotational speed of the crank in rad/s
R = Radius of the crank

7 a) Explain with a neat sketch or circuit diagram how the double acting hydraulic cylinder functions and is controlled. Use standard symbols for components in the sketch. (6 marks)

b) A double acting cylinder is used for a reciprocating motion in a machine. The relief valve setting is 70 bar. The cross sectional areas of the piston area and the rod are 0.02 m^2 and 0.005 m^2 respectively. The pump flow rate is 0.0012 m^3/s. Find the cylinder speed and the load capacity for extending stroke and retracting stroke. (8 marks)

c) What is the purpose of using a regenerative circuit in controlling a double acting cylinder? Explain your answer with a sketch of a hydraulic circuit diagram. (6 marks)

8 a) Explain with a sketch the working of a torque converter. (8 marks)

b) Explain the phenomenon of cavitation in hydraulic machines. (6 marks)

c) Explain the phenomenon of water hammer and how the effect of it could be minimized. (6 marks)