	HYDRAULICS - Rev 2015 TED 4011 ANSWER KEY		
Q no	**Scoring Indicators**	**split score**	**Total score**
I	**PART A**		
a	It states that pressure or intensity of pressure at a point in a static fluid is equal in all directions.	2	2
b	Bottom edge of the notch or top of a weir over which the water flows is known as the crest or sill of notch or weir.	2	2
c	Coefficient of contraction = $\frac{\text{area of jet at venacontracta}}{\text{area of orifice}}$ Coefficient of discharge, $C_d = \frac{\text{actual discharge}}{\text{theoretical discharge}}$	2	2
d	It is the velocity with which water reaches weir or notch before it passes over it. It creates an additional head $h_a = V_a^2/2g$	2	2
e	HGL – Line which gives sum of pressure head and datum head of a flowing fluid TEL – Line which give sum of pressure head, kinetic head and datum head of a flowing fluid	2	2
II	**PART B**		
a	Absolute pressure – pressure which is measured with reference to absolute vacuum pressure Gauge pressure – pressure which is measured with the help of a pressure measuring instrument with atmospheric pressure as datum. Atmospheric pressure – pressure exerted by the envelop of air on earth surface. It decrease with increase in altitude.	2 2 2	6
b	Given, $d_1 = 0.2\ m \Rightarrow a_1 = 0.0314\ m^2$ $d_2 = 0.1\ m \Rightarrow a_2 = 0.00785\ m^2$ $Q = a_1 V_1 = 0.0314 \times 4.5 = 0.1413\ m^3/s$ $V_2 = \frac{a_1 V_1}{a_2} = 18\ m/s$	1 1	

	Rate of discharge = 0.1413 m^3/s Velocity at smaller end = 18 m/s	2 2	6
c	<u>Orifice</u> is a small opening of any cross section on the side or at bottom of a tank through which a fluid is flowing <u>Mouthpiece</u> is a short tube fitted to a circular orifice provided in a tank such that it projects towards outside or inside. <u>Types of mouthpieces</u>: i) External and internal (based on position) 2) Running free and running full (based on discharge)	2 2 2	6
d	Sketch <u>Principle</u>: From reservoir water is conveyed to turbine through penstock. Nozzle at end of penstock increase kinetic energy of water. Jet from nozzle strikes buckets fixed on runner. The impact of water on the surface of the bucket produces a force causes the runner to rotate, thus supplying a torque or mechanical power to shaft.	2 4	6
e	For unsuppressed weirs for which crest length is less than the width of channel, effect of end contraction is to be considered. End contraction decreases the effective length of crest of weir and decreases discharge. Each end contraction reduces crest length by 0.1 × H, where H is the head over the weir		6

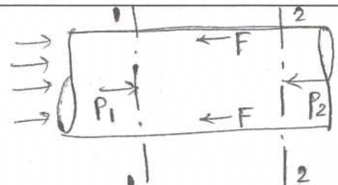
f	When a valve fitted to the end of a pipe carrying water from a tank is suddenly closed, momentum of flowing water is suddenly destroyed. This causes a high pressure wave to be transmitted along the pipe creating noise called knocking. Also this wave has effect of hammering on walls of pipe and hence it is known as water hammer.		6
g	1. Loss due to sudden enlargement, $h_e = \frac{(V_1 - V_2)^2}{2g}$ 2. Loss due to sudden contraction, $h_c = \frac{0.5 V_2^2}{2g}$ 3. Loss at entrance of pipe, $h_i = \frac{0.5 V^2}{2g}$ 4. Loss at exit of pipe, $h_o = \frac{V^2}{2g}$ 5. Loss due to bend in pipe, $h_b = \frac{kV^2}{2g}$ k – coefficient of bend		6
	PART C		
III (a)	1. Potential energy – energy possessed by virtue of its position. Potential head / datum head = z	2	
	2. Pressure energy – energy possessed by fluid by virtue of the pressure at which it is maitained Pressure head = $P/\rho g$	2	
	3. Kinetic energy – energy possessed by fluid by virtue of its motion Kinetic head = $V^2/2g$	2	6
(b)	Pressure at A, $P_A = 1\ kgf/cm^2$ $= 9.81 \times 10^4\ N/m^2$	1	
	Pressure at B, $P_B = 1.8\ kgf/cm^2$ $= 17.658 \times 10^4\ N/m^2$	1	

	Pressure above X − X in left limb $= 171675 + 133416\,h$ Pressure above X − X in right limb $= 17.65 \times 10^4 + 8829\,(2+h)$ Equating both and solving we get Difference in mercury level in manometer, $h = \underline{\underline{0.181\ m}}$	2 2 (3)	9
IV (a)	Figure External forces tending to accelerate fluid element $= p \cdot da - (p + dp)\,da = -dp \cdot da$ —— ① Component of weight in the direction of motion $= -\rho g \cdot da \cdot ds \cos\theta = -\rho g \cdot da \cdot ds \cdot \frac{dz}{ds}$ $= -\rho g \cdot da \cdot dz$ —— ② Mass of fluid element $= \rho \cdot da \cdot ds$ —— ③ Acceleration of fluid element in direction of motion $= v \cdot \frac{dv}{ds}$ —— ④ Using ①, ②, ③ and ④, by Newton's second law, Force = mass × acceleration $-dp \cdot da - \rho g\, da \cdot dz = \rho\, da \cdot ds \cdot v \cdot \frac{dv}{ds}$ $\frac{dp}{\rho} + v \cdot dv + g \cdot dz = 0$ ← Euler's eqn Integrating to get $\frac{p}{\rho g} + \frac{v^2}{2g} + z = \text{constant}$ ← Bernoulli's equation	1 1 1 1 1 1 1	

	Limitations: 1. Velocity is assumed to be uniform at any cross section 2. Assumed that no external force is acting 3. Assumed that there is no loss of energy while flowing 4. Energy due to centrifugal force (if path is curved) not considered.	3	10
(b)	$Q = 2500\ l/min = 0.04167\ m^3/s$ $d = 0.2 m \Rightarrow a = 0.0314\ m^2$ $Q = aV \Rightarrow V = \frac{Q}{a} = 1.327\ m/s$ $\frac{V^2}{2g} = 0.08976\ m$ $P/\rho g = 2.0387\ m$ Total head $= \frac{P}{\rho g} + \frac{V^2}{2g} + Z$ $= 7.128\ m$	1 1 1 2	5
V (a)	$d = 0.4\ m \Rightarrow a = 0.001256\ m^2$ Theoretical velocity, $V_{th} = \sqrt{2gH}$ $= \sqrt{2 \times 9.81 \times 10} = 14\ m/s$ Actual discharge, $Q_{act} = C_d \times Q_{th}$ $= 0.6 \times a \times V_{th}$ $= 0.0105\ m^3/s$ Actual velocity, $V_{act} = C_v \times V_{th}$ $= 13.72\ m/s$	1 2 3 3	9
(b)	**Impulse Turbine** - Jet of water strikes the buckets with kinetic energy - Pressure of water is atmospheric from inlet to outlet **Reaction Turbine** - Water pass over moving vanes with pressure energy - Pressure varies from max to min as it pass through vanes.		

	- Air tight casing not needed - Work done is entirely due to change in K.E - Comparatively small in size & run at high speed - Suitable for high heads	- Casing is essential - Work done is due to change in pressure and velocity - Large in size and run at relatively low speed - Suitable for low heads	1X6	6
VI (a)	Sketch **Working :** - Liquid is acting on one side of piston - It has one suction pipe and one delivery pipe - Pump operates in 2 strokes (i) Suction stroke Piston moves to right as crank rotate. Vacuum is created on left side of piston. Vacuum causes suction valve to open and liquid is drawn from sump. (ii) Delivery stroke Piston moves inward to left and high pressure is built up in cylinder. Delivery valve is now opened and liquid is forced into delivery pipe.		2 2 2	6
(b)	$D = 4\ m \Rightarrow A = 12.566\ m^2$ $d = 0.5\ m \Rightarrow a = 0.196\ m^2$ (i) $H_1 = 5\ m$, $H_2 = 2\ m$ $T = \frac{2A}{C_d \cdot a\sqrt{2g}}\left[\sqrt{H_1} - \sqrt{H_2}\right] = 39.58$ sec ii) $H_1 = 5m$, $H_2 = 0$		3 3	

	$T = \frac{2A}{C_d \cdot a \cdot \sqrt{2g}} \sqrt{H_1} = 107.7$ sec	3	9
VII (a)	(i) Expression for discharge of V notch (rightangled) is very simple (ii) For measuring low discharge, V notch is more accurate (iii) For V notch only one reading (H) is required to compute discharge (iv) Ventilation of V-notch is not necessary	3x2	6
(b)	Without considering velocity of approach, $Q = \frac{2}{3} C_d \cdot L\sqrt{2g}\ H_1^{3/2}$ $\{H_1 = 0.2$ $= 0.0982\ m^3/s$ $V_a = Q/A = 0.1309\ m/s$ $h_a = \frac{V_a^2}{2g} = 0.000873\ m$ Considering velocity of approach, $Q = \frac{2}{3} C_d \cdot L\sqrt{2g}\left[(H_1 + h_a)^{3/2} - h_a^{3/2}\right]$ $= 0.0988\ m^3/s$	1 2 1 1 2 2	9
VIII (a)	Length of weir = 36 m, No. of posts = 12 − 1 = 11 Effective length of weir, $L = 36 - 11 \times 0.6$ $= 29.4\ m$ $h_a = \frac{V_a^2}{2g} = 0.2038\ m$ No. of end contractions = 2x12 = 24 $Q = 1.84\left[L - 0.1n(H + h_a)\right]\left[(H+h_a)^{3/2} - h_a^{3/2}\right]$ $= 75.246\ m^3/s$	2 2 2 3	9
(b)	(i) Francis' formula $Q = 1.84\ L H^{3/2}$		

	$Q = 1.84 \times 1.5 \times 0.4 = 0.6982 \ m^3/s$	3	
	(ii) Bazin's formula $Q = m L \sqrt{2g} \ H^{3/2}$ where, $m = 0.405 + \frac{0.003}{H} = 0.4125$ $\therefore Q = 0.6932 \ m^3/s$	3	6
IX (a)	Figure 	1	
	Applying Bernoulli's equation between 1-1 & 2-2 $\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z + h_f$ $h_f = \frac{P_1 - P_2}{\rho g}$ —— (1) By Froude's experiments, $F = f' \cdot P \cdot l v^2$ Propelling force on fluid between 1-1 & 2-2 = $(P_1 - P_2)a$ Propelling force = frictional resistance force $\Rightarrow \frac{P_1 - P_2}{\rho g} = \frac{f'}{\rho g} \cdot \frac{P}{a} \cdot l v^2$ —— (2) P- perimeter From (1), $h_f = \frac{f'}{\rho g} \cdot \frac{P}{a} \cdot l v^2 \cdot \frac{2g}{2g}$ $= \frac{f l v^2}{2g} \cdot \frac{P}{a}$, where, $f = \frac{2g f'}{\rho g}$ For circular pipe, $P = \pi d$, $a = \frac{\pi}{4} d^2$ $P/a = 4/d$ $\Rightarrow h_f = \frac{4 f l v^2}{2 g d}$ ← Darcy - Weisbach equation		

	where, f – Darcy's coefficient.		10
(b)	Width of channel, $b = 6$ m Depth of channel, $d = 3$ m Area $= 6 \times 3 = 18\ m^2$, $i = \frac{1}{2000}$ Perimeter $= b + 2d = 12$ m Hydraulic mean depth, $m = \frac{A}{P} = 1.5$ m Velocity of flow, $V = C\sqrt{mi} = 1.506$ m/s	2 3	5
Xa	For most economical trapezoidal channel, $\frac{b + 2nd}{2} = d\sqrt{n^2+1}$ Substituting values, $b = 1.236\,d$ —— ① Area of trapezoidal section $= (b + nd)\,d$ $\Rightarrow 40 = 1.736\,d^2 \Longrightarrow d = 4.8$ m ① $\Rightarrow b = 1.236 \times 4.8 = 5.933$ m Also, $m = d/2 = 2.4$ m Discharge $Q = AC\sqrt{mi} = 80\ m^3/s$	1 1 2 2 3	9
Xb	$A = b \times d = 2 \times 1.5 = 3\ m^2$ $P = b + 2d = 2 + (2 \times 1.5) = 5$ m $m = \frac{A}{P} = 0.6$ Using Manning's formula, $C = \frac{1}{N} \cdot m^{1/6} = 76.54$ Discharge, $Q = AC\sqrt{mi}$ $= 3 \times 76.54\sqrt{0.6 \times \frac{1}{2000}}$ $= 3.977\ m^3/s$	1 2 1 2	6