The University of Jordan
Faculty of Engineering & Technology
Chemical Engineering Department

(0905241) Fluid Mechanics	Summer Semester – 2016/2017
Midterm Exam	
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Dear students:
Answer all questions to the best of your ability and knowledge.
Start with the easiest question to you. Use only the available space.
Don't waste your time on the questions that you are not confident about.
You know that cheating is not accepted and you would not need it anyway!
Good Luck!

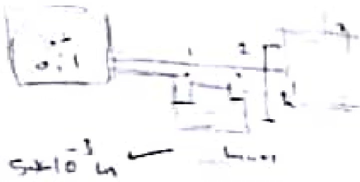
Question #	Gained points	Full points
1	1	4
2	7	8
3	4	5
4	4	8
5	4	5
Total	20 +2 → 22	30

Q1 [4 points]
A capillary tube viscometer is being used to measure the viscosity of an oil having a specific gravity of 0.90. The following data apply:

Tube inside diameter = 2.5 mm = D
Manometer fluid = mercury
Manometer deflection = 177 mm = h
Length between manometer taps = 300 mm = L
$\gamma_{Mercury} = 132.8\ kN/m^3$
Velocity of flow = 1.58 m/s = v

(a) Find the pressure difference ($p_1 - p_2$) in Pa.
(b) Determine the viscosity of the oil.

$SG_{oil} = .9$



a) $P_1 + \gamma_{oil}(h) - \gamma_m(h) = P_2$

$P_1 - P_2 = h(\gamma_m - \gamma_{oil}) = 307.9275\ \frac{N}{m^2}$

→ 5×10^{-3} m

b) $\mu_1 = \frac{(P_1 - P_2) D^2}{32 u L} = \frac{(307.9275 * (2.5*10^{-3})^2}{32 * 1.58 * 300\times10^{-3}}$

$= 1.277$ N.s

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7

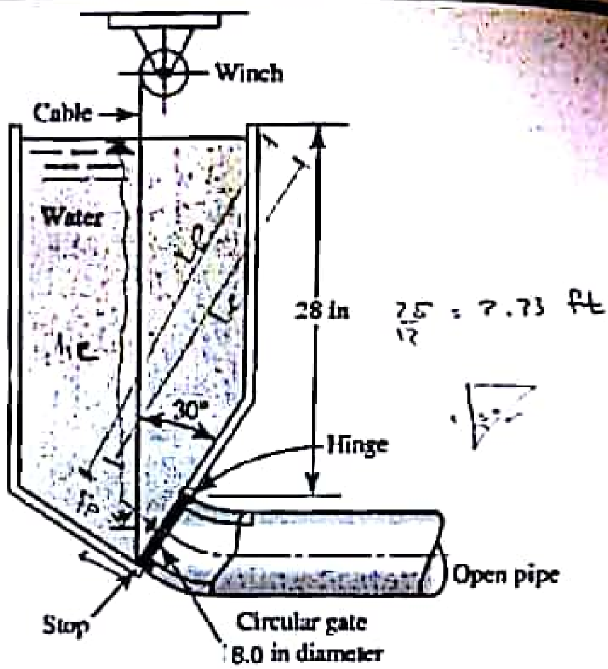
Q2 [8 points]

The figure below shows a tank of water with a circular pipe connected to its bottom. A circular gate seals the pipe opening to prohibit flow. To drain the tank, a winch is used to pull the gate open.

3 (a) Compute the resultant force on the circular gate.

2.5 (b) Compute the location of the center of pressure on the gate, L_p.

1.5 (c) Compute the amount of force that the winch cable must exert to open the gate.



$\frac{28}{12} = 2.33$ ft

$\frac{8\text{ in}}{12\text{ in}}\frac{1\text{ ft}}{} = .667$ ft

a) $F_R = \gamma h_c A$ $\qquad \cos\theta = \frac{1}{2}$

$A = \frac{\pi d^2}{4} = .349\ ft^2$

$\gamma = 62.4\ lb/ft^3$

$h_c = \left[\frac{D}{2} \cdot \cos(30)\right] + \frac{28}{12}$

$= .2889 + 2.333 = 2.6217\ ft$

$.7225 \cdot \cos ...$

$F_R = 57.097\ lb$

b) $L_p = L_c + \frac{I_c}{L_c A}$ $\qquad L_c = h_c,\ I_c = \frac{\pi d^4}{64} = 9.7157 \times 10^{-3}$

$= 2.6218 + \frac{9.7157 \times 10^{-3}}{2.6218 \times .349} = 2.632\ ft$

L_c not h_c

c) $\Sigma M_{Hinge} = 0$

$F_R L - F_c L = 0$

$F_R((L_p - L_c) + \frac{D}{2}) - F_c(\frac{8}{12} \cdot \cos 60) = 0$ $\qquad F_c = \frac{F_R\ ((L_p - L_c) + \frac{D}{2})}{.667}$

$F_{cable} = \cancel{59.97}$ 29.923 lb

$\cancel{35.66}$

$\cancel{18.379} / \cancel{.667}$

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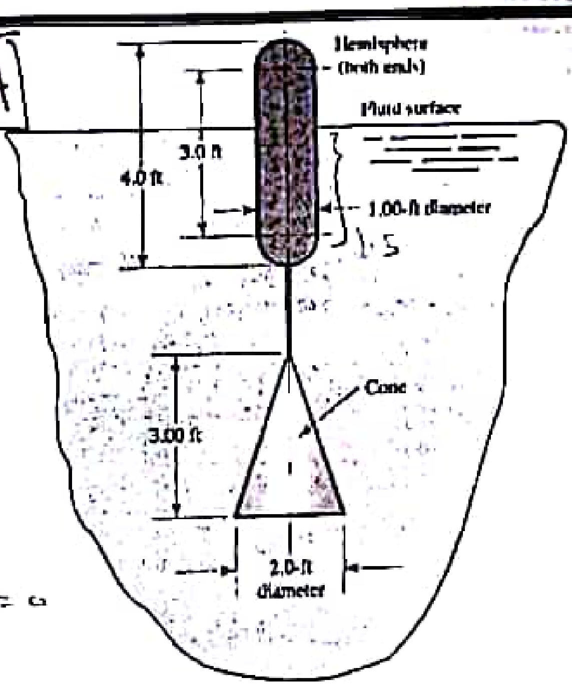
Q3 [5 points]

A buoy is to support a cone-shaped instrument package immersed in seawater ($\gamma = 64\ lb_f/ft^3$), as shown in the figure. The buoy is made from a uniform material having a specific weight of 8.00 lb_f/ft^3. At least 1.50 ft of the buoy must be above the surface of the seawater for safety and visibility. Calculate the maximum allowable weight of the instrument package.

4



$\Sigma F = 0$

$W_{Buoy} + W_{cone} - F_{B,Buoy} - F_{B,cone} = 0$

$\gamma_{Buoy} V_{Buoy} + \gamma_{con} V_{cone} + \gamma_w V_{Buoy} - \gamma_w V_{cone}$

submerged

$\gamma_{Buoy} = 8$

$\gamma_w = 64.2$

$V_{con} = \frac{\pi d^2 H}{12}$

$V_{cone} = 3.14\ ft^3$

$V_{Buoy} = .5\ \frac{\pi d^3}{6} + \pi \left(\frac{1}{4}\right) \cdot 1.5$

2

$= 1.44\ ft^3$ ok

$W_{cone} = F_{B\,Buoy} + F_{B\,cone} - W_{Buoy}$ (total buoy volume * γ)

$= 281.5\ lb$

α

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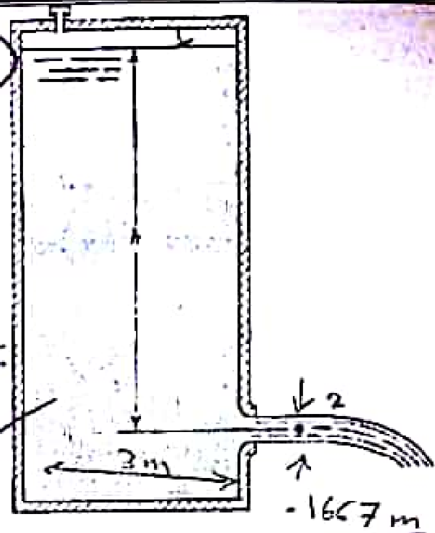
Q4 [8 points] The next figure shows a tank with a diameter of 3.00 m and a 2-in diameter nozzle.

4

3 **(a)** What depth of fluid above the outlet nozzle is required to deliver 200 gal/min of water from the tank shown in?

(b) Compute the time required to empty the tank starting from the depth computed in part (a).



$Q = 200 \frac{gal}{min} \left| \frac{1 m^3}{264.17 gal} \right| \frac{1 min}{60 s} = .0126 \; m^3/s$

.1667 m

a) $Q = uA$

$u = \frac{Q}{A} = .578 \; m/s$

$A = \frac{\pi d^2}{4}$

Tank = $7.07 \; m^2$

nozzle = $.0218 \; m^2$

Apply MEB

contraction

no shaft work

$\frac{1}{2}(u_2^2 - \cancel{u_1^2}) + g\underbrace{(z_2 - z_1)}_{-H?} + \frac{P_2 - P_1}{\rho} = \cancel{W_f} - \cancel{W_s}$

assume frictionless

$Q\,in = Q\,out$

$u_1 A = u_2 A$

$\frac{1}{2} u_2^2 = gH$

$u_1 = \frac{u_2 A_2}{A_1}$

$A_1 >> A_2$

$H = \frac{1}{2}\frac{u_2^2}{g} = .0170 \; m$

o.k

$u_1 \approx 0$

$u_1 = 1.78 \times 10^{-3} \; m/s$

b) $\frac{dV}{dt} = Q_{in} - Q_{out}$

$\frac{dHA}{dt} = u_{in} A - u_{out} A \qquad A = \frac{\pi d^2}{4}$

$\frac{dH}{dt} = \frac{u_{in} d_{in}^2 - u_{out} d_{out}^2}{d_{tank}^2}$

$\int_H^0 dH \frac{d_{tank}^2}{u_{in} d_{in}^2 - u_{out} d_{out}^2} = \int_0^t dt$

$u_{in} = 0$

$u_{out} = \sqrt{2gh}$

$t]_0^t = t - 0 = t$

$-214395 . H]_H^0 = t$

$H]_H^0$

$\boxed{t = 3644.7 \; sec}$

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8.59

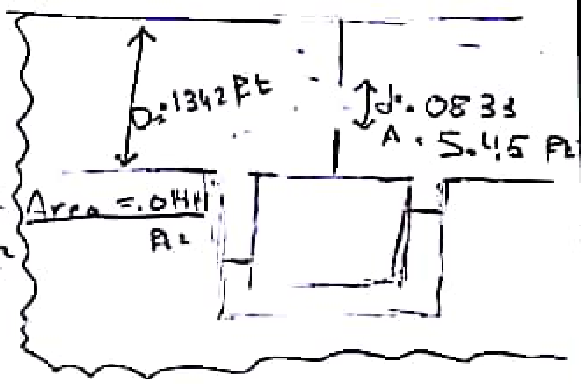
$Q = k A_o \sqrt{2(P_1-P_2)/\rho}$

Q5 [5 points] The flow of kerosene ($\gamma = 51.2\frac{lb_f}{ft^3}, \mu = 3.43 \times 10^{-5}\ lb_f.s/ft^2$) is being measured with an orifice meter. The pipe is a 1.5-in Schedule 40 pipe and the orifice diameter is 1.00 in.. For a pressure difference of 0.53 psi across the orifice, calculate the volume flow rate of kerosene.

4

$\gamma_F = 51.2$ orifice

$\mu = 3.43 \times 10^{-5}$



$P_1 - P_2 = .53 \frac{lbf}{in^2}\left(\frac{12\ in}{1\ ft}\right)^2 = 76.32\ lbf/ft^2$

$Q = kA\sqrt{2(P_1-P_2)/\rho}$

$A_o = \frac{\pi d^2}{4} = 5.45 \times 10^{-3}\ ft^2$

$\rho = \frac{\gamma}{g} = \frac{51.2}{32.174} = 1.5913\ \frac{kg}{ft^3}$?

k $\begin{cases} Re = \frac{\rho u d}{\mu} \rightarrow u \text{ is missing} \rightarrow \text{Try and error} \\ \frac{d}{D} = .6 \end{cases}$

— assume $\boxed{k = .65}$

$Q = .65 \times 5.45 \times 10^{-3} \times \sqrt{2(76.32)/1.5913}$

$= 34.695\ ft^3$

$Q = uA \Rightarrow u = \frac{Q}{A} = 6.366\ ft/s$

$\boxed{k = .6}$ $\begin{cases} Re = \frac{1.5913 \times 6.366 \times .0833}{3.43 \times 10^{-5}} = 2.46 \times 10^4 \\ \frac{d}{D} = .6 \end{cases}$

same value for k — stop

$Q = 32.03\ ft^3$

Re-calculate Q

$Q = 32.03\ ft^3$

Re-calculate u

$u = 5.88\ ft/s$

$Re = 2.2723 \times 10^4$

$\boxed{k = .6}$ $\begin{cases} \\ \frac{d}{D} = .6 \end{cases}$

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Useful Information:

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å) = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	$\boxed{1\ m^3}$ = 1000 L = 10^6 cm^3 = 10^6 mL = 35.3145 ft^3 = 220.83 imperial gallons = $\boxed{264.17\ gal}$ = 1056.68 qt 1 ft^3 = 1728 $in.^3$ = 7.4805 gal = 0.028317 m^3 = 28.317 L = 28,317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N = 4.4482×10^5 dynes
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bar = 1.01325×10^6 dynes/cm^2 = 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/$in.^2$ (psi) = 33.9 ft H_2O at 4°C = 29.921 in. Hg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h = 0.23901 cal = 0.7376 ft·lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486×10^{-4} Btu/s = 1.341×10^{-3} hp

g = 9.8066 m/s² = 980.66 cm/s² = 32.174 ft/s²

In rotating drum viscometer: $\mu = \frac{\tau . \Delta r}{v_1}$

In capillary-tube viscometer: $\mu = \frac{(p_1 - p_2) D^2}{32 v L}$

In falling-ball viscometer: $\mu = \frac{(\gamma_s - \gamma_f) D^2}{18 v}$

$$V_{cone} = \frac{\pi D^2 H}{12}$$

$$V_{sphere} = \frac{\pi D^3}{6}$$

$$I_c(rectangle) = \frac{B H^3}{12}$$

$$I_c(circle) = \frac{\pi D^4}{64}$$

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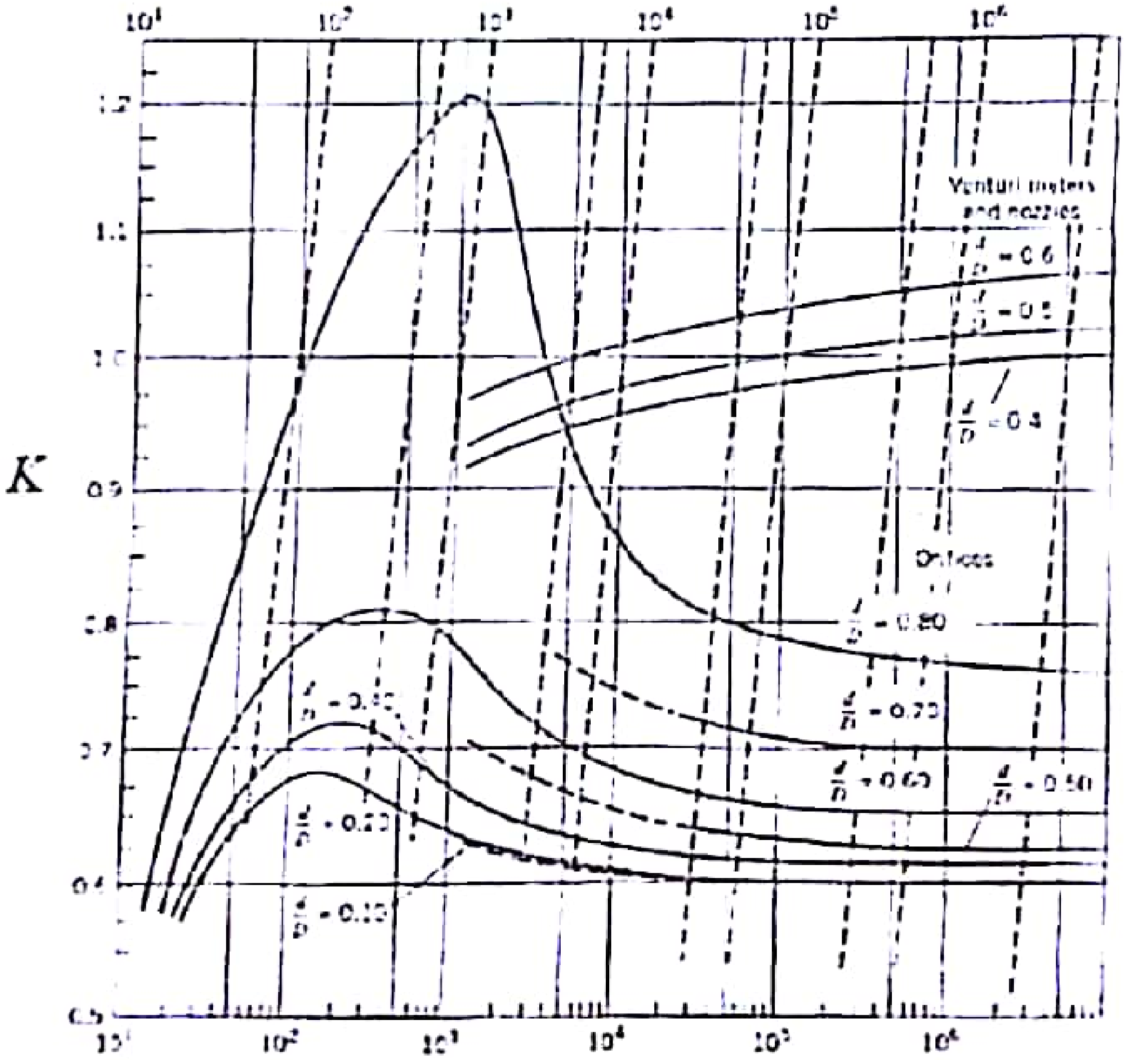
TABLE F.1 Schedule 40

Nominal Pipe Size		Outside Diameter		Wall Thickness		Inside Diameter			Flow Area	
NPS (in)	DN (mm)	(in)	(mm)	(in)	(mm)	(in)	(ft)	(mm)	(ft^2)	(m^2)
1/8	6	0.405	10.3	0.068	1.73	0.269	0.0224	6.8	0.000 394	3.660×10^{-5}
1/4	8	0.540	13.7	0.088	2.24	0.364	0.0303	9.2	0.000 723	6.717×10^{-5}
3/8	10	0.675	17.1	0.091	2.31	0.493	0.0411	12.5	0.001 33	1.236×10^{-4}
1/2	15	0.840	21.3	0.109	2.77	0.622	0.0518	15.8	0.002 11	1.960×10^{-4}
3/4	20	1.050	26.7	0.113	2.87	0.824	0.0687	20.9	0.003 70	3.437×10^{-4}
1	25	1.315	33.4	0.133	3.38	1.049	0.0874	26.6	0.006 00	5.574×10^{-4}
1¼	32	1.660	42.2	0.140	3.56	1.380	0.1150	35.1	0.010 39	9.653×10^{-4}
1½	40	1.900	48.3	0.145	3.68	1.610	$\boxed{0.1342}$	40.9	$\boxed{0.014\ 14}$	1.314×10^{-3}
2	50	2.375	60.3	0.154	3.91	2.067	0.1723	52.5	0.023 33	2.168×10^{-3}



$$Re_d = \rho \bar{u}_d d / \mu$$

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