SHOW THE PATH

MECH-322 Fluid Mechanics
ASSESSMENT 1--SOLUTION

NAME____

WRITE ALL ANSWERS IN BLUE EXAM BOOKLET
WRITE NAME ON EXAM AND ON BLUE EXAM BOOKLET RETURN BOTH

1. DEFINITIONS

A. What is the field of Mechanical Engineering?
   - *Mechanical Engineering is the applied science focused on the design and analysis of components and systems that move and have motion, and the design and analysis of components and systems that converts energy from one form to another to do work.*
   - *Engineering in general is applied sciences for the benefit of mankind to ensure survivability for future generations.*

B. What is Fluid Mechanics?
C. What is Fluid Viscosity?
D. What is the mathematical relation for SHEAR STRESS and DRAG/SHEAR FORCE and describe each term and provide units of each term?
E. What is the NO-SLIP boundary condition?
F. What is the difference between an incompressible and a compressible fluid?
G. What is the difference between a Newtonian and a Non-Newtonian fluid?
H. What is the definition of Specific Gravity AND Specific Weight? What are the correct units?
I. What is the definition of Torque and what are the correct units?
   - *Torque is the measure of the resisting energy [N-m;ft-lbf] to a force acting over a distance and causing a rotation about an axis.*

J. What is the definition of a standard coordinate system on a Galactic RED STAR in the DELTA Quadrant of 3D space?
K. What is the value of a number without units?
L. Convert 45 RPM to radians/sec.
   - $\omega_0\left[\frac{rad}{s}\right]=\omega\left[\frac{\cancel{rev}}{\cancel{min}}\right]\bullet\frac{2\pi\ rad}{\cancel{rev}}\bullet\frac{60\ \cancel{min}}{\sec}$

M. How do I compute POWER, if Shear Force and Velocity are KNOWN, and, what are the proper SI and BKS units?

2. The temperature distribution in a fluid is given below along with its velocity vector field:

$$T[C](x,y,t)=\left(10[]x+5[]t\,y^{2/3}+24[]e^{-\alpha[]t}\right)[C]$$

"10"

$$[C]=[][m]\rightarrow[]=\frac{[C]}{[m]}\rightarrow\left[C/m\right]$$

"5"

$$[C]=[][s][m^{2/3}]\rightarrow[]=\frac{[C]}{[s-m^{2/3}]}$$

"24"

$$[C]=[][unitless]\rightarrow[C]$$

"α"

$$[unitless]=[][s]\rightarrow[]=1/s$$

$$\vec{V}\left[\frac{m}{s}\right](x,y,t)=\left(u\hat{i}+v\hat{j}\right)\left[\frac{m}{s}\right]$$

$$=\left((\overbrace{20[]xt+45[]y}^{u})\hat{i}-(\overbrace{23[]x^{-2/9}+50[]xyt}^{v})\hat{j}\right)\left[\frac{m}{s}\right]$$

"20"

$$[m/s]=[][m][s]\rightarrow[]=\frac{[m/s]}{[m][s]}=\left[\frac{1}{s^2}\right]$$

"45"

$$[m/s]=[][m]\rightarrow[]=\frac{[m/s]}{[m]}=\left[\frac{1}{s}\right]$$

"23"

$$[m/s]=[][m^{-2/9}]\rightarrow[]=\frac{[m/s]}{[m^{-2/9}]}=\left[\frac{m^{\frac{11}{9}}}{s}\right]$$

"50"

$$[m/s]=[][m][m][s]\rightarrow[]=\frac{[m/s]}{m^2-s}=\frac{1}{m-s^2}$$

where t is in seconds, x and y are in meters, and T is in degrees C.

a. Determine the correct units for the brackets [] for both T and V?

b. The TOTAL DERIVATIVE is defined as: $\frac{DT}{Dt}\left[\frac{C}{s}\right]=\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)\left[\frac{C}{s}\right]$

i. Determine the form of the TOTAL DERIVATIVE and show that units are correct.

$$T[C](x,y,t)=\left(10[]x+5[]t\,y^{2/3}+24[]e^{-\alpha[]t}\right)[C]$$

$$u[\frac{m}{s}]=(\overbrace{20[]xt+45[]y}^{u})$$

$$\frac{\partial T}{\partial t}\left[\frac{C}{s}\right]=5\left[\frac{C}{s-m^{2/3}}\right]y^{2/3}[m^{2/3}]-24[C]\alpha[\frac{1}{s}]e^{-\alpha[\frac{1}{s}]t}$$

$$\frac{\partial T}{\partial x}\left[\frac{C}{m}\right]=10\left[C/m\right]$$

$$\left\{u\left[\frac{m}{s}\right]\frac{\partial T}{\partial x}\left[\frac{C}{m}\right]\right\}\left[\frac{C}{s}\right]=\underbrace{\left\{\overbrace{(20\left[\frac{1}{s^2}\right]x[m]t[s]+45[\frac{1}{s}]y[m])}^{u}\right\}\left[\frac{\cancel{m}}{s}\right]\overbrace{10\left[C/\cancel{m}\right]}^{\frac{\partial T}{\partial x}}}_{\left[\frac{C}{s}\right]}$$

3. A 12” Dia plate is placed over a fixed bottom plate with a $\Delta = 0.1$ in gap. The fluid between the plates is glycerin $\mu = 3.13E-2 \dfrac{lbf-s}{ft^2}$ and the plate rotates with an angular velocity of $\omega = 2$ rpm. Assume the velocity in the gap is linear (straight line) and neglect shear stress on the edge of the rotating plate. An electric motor rotates the plate with TORQUE T_q.

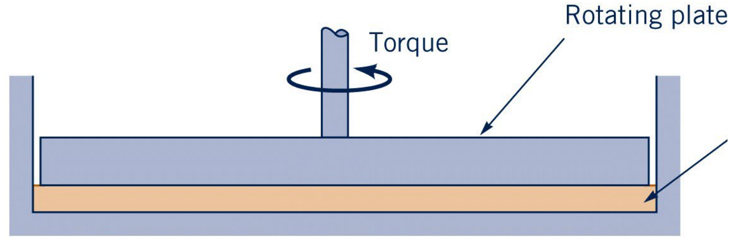
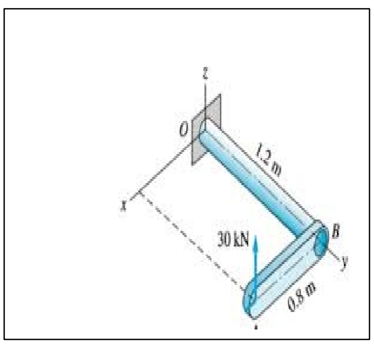
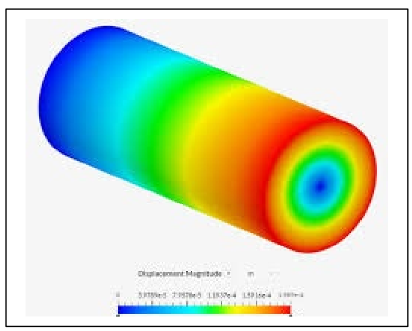


Figure P1.89

a. In words, explain what fluid principle governs the magnitude of the Torque?
    i. *The shear stress between the rotating disk and the stationary surface results in a SHEAR or DRAG FORCE. The shaft TORQUE (N-m) or energy must oppose the DRAG FORCE acting at a distance. This TORQUE also creates an internal material shear stress within the solid rotating shaft which is a function of the shaft diameter and material type.*
    ii. *Torque (N-m) must be greater than the opposing shear drag force x moment arm (N-m).*





b. What is the parametric expression of the linear velocity profile in the gap, i.e.,

$$V(y,\Delta,D,\omega_0)\left[\frac{ft}{s}\right] = \frac{\frac{D[ft]}{2}\omega_0\left[\frac{rad}{s}\right]}{\Delta[ft]}y[ft]; \quad 0 \le y \le \Delta$$

c. What is parametric expression for SHEAR FORCE [lbf], $F_D(\Delta, D, \omega_0\left[\frac{rad}{s}\right], \mu)[lbf]$, (also known as drag force) and verify units?

$$F_D \equiv \text{ Shear Force or Shear Drag}$$

$$=\text{Shear Stress x } A_{contact}$$

$$= \mu \frac{\partial V}{\partial y} \bullet A_{contact}$$

$$= \mu[] \overbrace{\frac{\frac{D[]}{2}\omega_0[rad/s]}{\Delta[]}}^{\frac{\partial V}{\partial y}} \left(\frac{\pi D^2[]}{4}\right) \to f(D^3)$$

$$= \left[\frac{lbf - s}{ft^2}\right]\left[ft^3\right]\left[\frac{1}{s}\right]\left[\frac{1}{ft}\right]$$

$$= lbf$$

$$F_D[lbf] = \mu[\frac{lbf - s}{ft^2}] \frac{\frac{D[ft]}{2}\omega_0[rad/s]}{\Delta[ft]} \left(\frac{\pi D^2[ft^2]}{4}\right)$$

$$T_q[lbf - ft] = F_D[lbf] \bullet \text{Moment Arm} \to \text{TORQUE}$$

$$= \mu[\frac{lbf - s}{ft^2}] \frac{\frac{D[ft]}{2}\omega_0[rad/s]}{\Delta[ft]} \left(\frac{\pi D^2[ft^2]}{4}\right) \bullet \frac{D}{2}$$

$$= \frac{\mu D^4 \omega_0 \pi}{16\Delta} \to f(D^4)$$

$$P[\frac{lbf - ft}{s}] = F_D[lbf] \bullet \text{Velocity}\left[\frac{ft}{s}\right] \to \text{POWER}$$

$$= \mu[\frac{lbf - s}{ft^2}] \frac{\frac{D[ft]}{2}\omega_0[rad/s]}{\Delta[ft]} \left(\frac{\pi D^2[ft^2]}{4}\right) \bullet \overbrace{\frac{D[ft]}{2}\omega_0\left[\frac{rad}{s}\right]}^{\text{Velocity}}$$

$$= \frac{\mu D^4 \pi \omega_0^2}{16\Delta}[\frac{lbf - ft}{s}]$$

$$= \underbrace{T_q[lbf - ft] \bullet \omega_0\left[\frac{rad}{s}\right]}_{\frac{ft-lbs}{s}} \to \text{POWER}$$

d. What is parametric expression for TORQUE [ft-lbf] and verify units.

e. What is parametric expression for POWER [ft-lbs/sec] and verify units.