

Çankaya University
Mechanical Engineering Department
ME 102 Mechanical Engineering Orientation
HW 3-Solution

Q-1 Determine if the following equations is dimensionally consistent:

$$F = \frac{1}{2}m\Delta x^2$$

Where; where F is force, m is mass, x is distance.

<u>Force</u>	F	$\frac{ML}{T^2}$	}	$\frac{ML}{T^2} \stackrel{?}{=} ML^2$
<u>Mass</u>	m	M		
<u>Distance</u>	x	L		
				not equal so dimensionally <u>inconsistent!</u>

Q-2 The equation for the flow of heat during the time interval Δt through an insulated wall is shown by Fourier's Law of heat conduction as:

$$\dot{Q}_{cond} = kA \frac{\Delta T}{L}$$

where k is the thermal conductivity of the material from which the wall is made, A and L are the wall's area and thickness, and ΔT is the difference (in degrees Celsius) between the high- and low-temperature sides of the wall. By using the principle of dimensional consistency, show the correct dimension for thermal conductivity in the SI.

<u>Heat flow</u>	\dot{Q}	$\frac{LM}{T^3}$	(Watt)	}	$\dot{Q} = k \cdot A \cdot \frac{\Delta T}{L}$
<u>Area</u>	A	L^2	(m ²)		
<u>Length</u>	L	L	(m)		
<u>Temperature</u>	T	Θ	(°C)		

$$W = k \cdot \frac{m^2 \cdot ^\circ C}{m} \Rightarrow \underline{k = \frac{W}{m^\circ C}}$$

Q-3 Write the measurement result considering **smallest scale division** of thermometer and the **least count** for the thermometer.



Smallest scale division: 1
least count $1/2 = 0.5$
Reading: 24 ± 0.5

Q-4 A truck accelerates uniformly over a time of 8 seconds starting from rest for a distance of 200 m. Determine the acceleration of the truck.

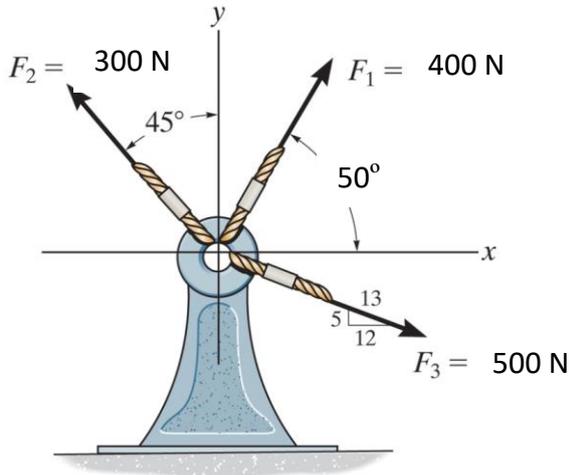
$$a = \frac{dv}{dt} \Rightarrow \int_0^v dv = \int_0^t a dt \Rightarrow v = a \cdot t$$

$$v = \frac{ds}{dt} \Rightarrow \int_0^s ds = \int_0^t v \cdot dt \Rightarrow \int_0^s ds = \int_0^t a \cdot t \cdot dt$$

$$\Rightarrow s = \frac{a \cdot t^2}{2} \Big|_0^t \Rightarrow s = \frac{a \cdot t^2}{2} \Rightarrow 200 = \frac{a}{2} \cdot 8^2$$

$$\Rightarrow \underline{\underline{a = 6,25 \text{ m/s}^2}}$$

Q-5 Find the magnitude and angle of the resultant force acting on the bracket.



$$F_1 = (400 \cdot \cos 50^\circ i + 400 \cdot \sin 50^\circ j) \text{ N} = (257.12 i + 306.42 j) \text{ N}$$

$$F_2 = (-300 \cdot \sin 45^\circ i + 300 \cdot \cos 45^\circ j) \text{ N} = (-212.13 i + 212.13 j) \text{ N}$$

$$F_3 = \left(\left(\frac{12}{13} \right) \cdot 500 i - \left(\frac{5}{13} \right) \cdot 500 j \right) \text{ N} = (461.54 i - 192.31 j) \text{ N}$$

$$F_{\text{net}} = (506.53 i + 326.24 j) \text{ N}$$

• Magnitude of resultant force: $\sqrt{(506.53)^2 + (326.24)^2}$
 $= 602.5$

• $\tan \theta = \frac{326.24}{506.53} = 0.64$

$\arctan(0.64) = 32.62^\circ$

$\theta = 32.62^\circ$

Q-6 A force of 60 kN is acting on a circular copper rod with diameter of 15 mm as shown in the figure. (E modulus of elasticity = 110 GPa for copper)

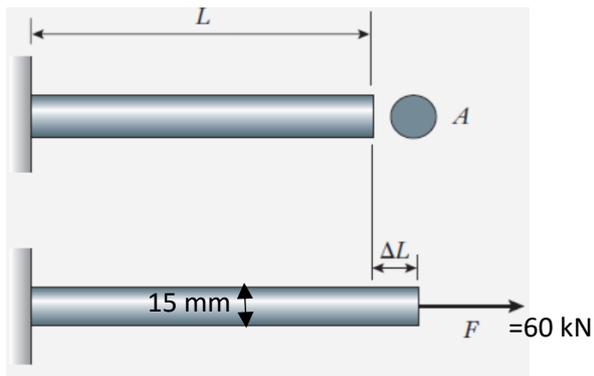
a) Calculate the stress in the rod.

b) If the linear relationship between stress and strain for a bar in simple tension or compression is expressed by the equation:

$$\sigma = E\varepsilon$$

where σ is the axial stress, ε is the axial strain, and E is a constant of proportionality known as the modulus of elasticity for the material, find the axial strain.

c) if the initial length of the rod is 20 cm, find the elongation of the rod ($\Delta L = \delta$).



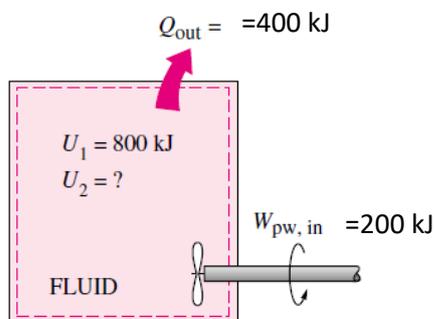
$$a) \sigma = \frac{P}{A} = \frac{60}{(0,015)^2 \cdot \pi / 4} = 338900 \text{ kPa} = \underline{338,9 \text{ MPa}}$$

$$b) \varepsilon = \frac{\sigma}{E} \Rightarrow \varepsilon = \underline{3,08 \cdot 10^{-3}}$$

$$c) \varepsilon = \frac{\Delta L}{L} \Rightarrow \Delta L = \varepsilon \cdot L = 3,08 \cdot 10^{-3} \cdot 0,2$$

$$\Rightarrow \underline{\underline{\Delta L = 6,16 \cdot 10^{-4} \text{ m}}}$$

Q-7 A rigid tank contains hot fluid that is cooled by doing work on the system by a paddle wheel. Initially the internal energy of the fluid is 800 kJ. During the cooling, fluid loses 400 kJ of heat to the surrounding and the paddle wheel does 200 kJ of work on the fluid. Determine the final internal energy on the fluid if kinetic and potential energy change of the fluid is neglected.



$$\Delta E = 1Q_2 - 1W_2 \Rightarrow \Delta \cancel{K}_0 + \Delta \cancel{P}_0 + \Delta U = 1Q_2 - 1W_2$$

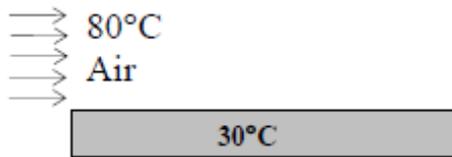
$$U_2 - U_1 = 1Q_2 - 1W_2$$

$$\text{where } 1Q_2 = -400, 1W_2 = -200$$

$$\Rightarrow U_2 - 800 = -400 - (-200) \Rightarrow U_2 = 800 - 200 = 600$$

$$\Rightarrow \underline{U_2 = 600 \text{ kJ}}$$

Q-8 Hot air at 80°C is blown over a 10 m^2 flat surface at 30°C . If the convection heat transfer coefficient is $60 \text{ W/m}^2\cdot^\circ\text{C}$, determine the rate of heat transfer from the air to the plate, in kW.



$$\dot{Q} = h \cdot A \cdot \Delta T = 60 \cdot 10 \cdot (80 - 30) = 30000 \text{ W}$$

$$\underline{\underline{\dot{Q} = 30 \text{ kW}}}$$