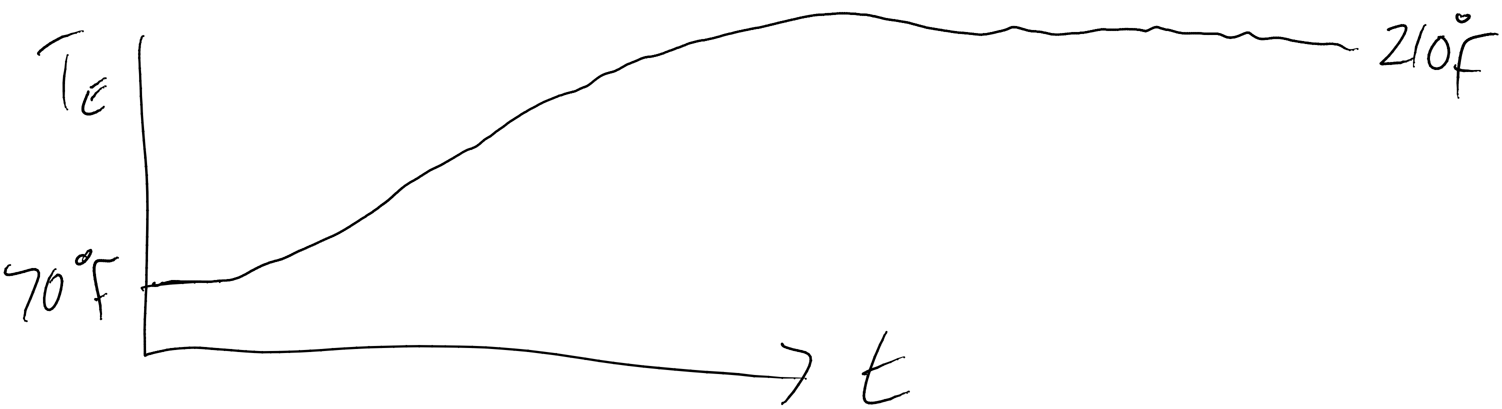
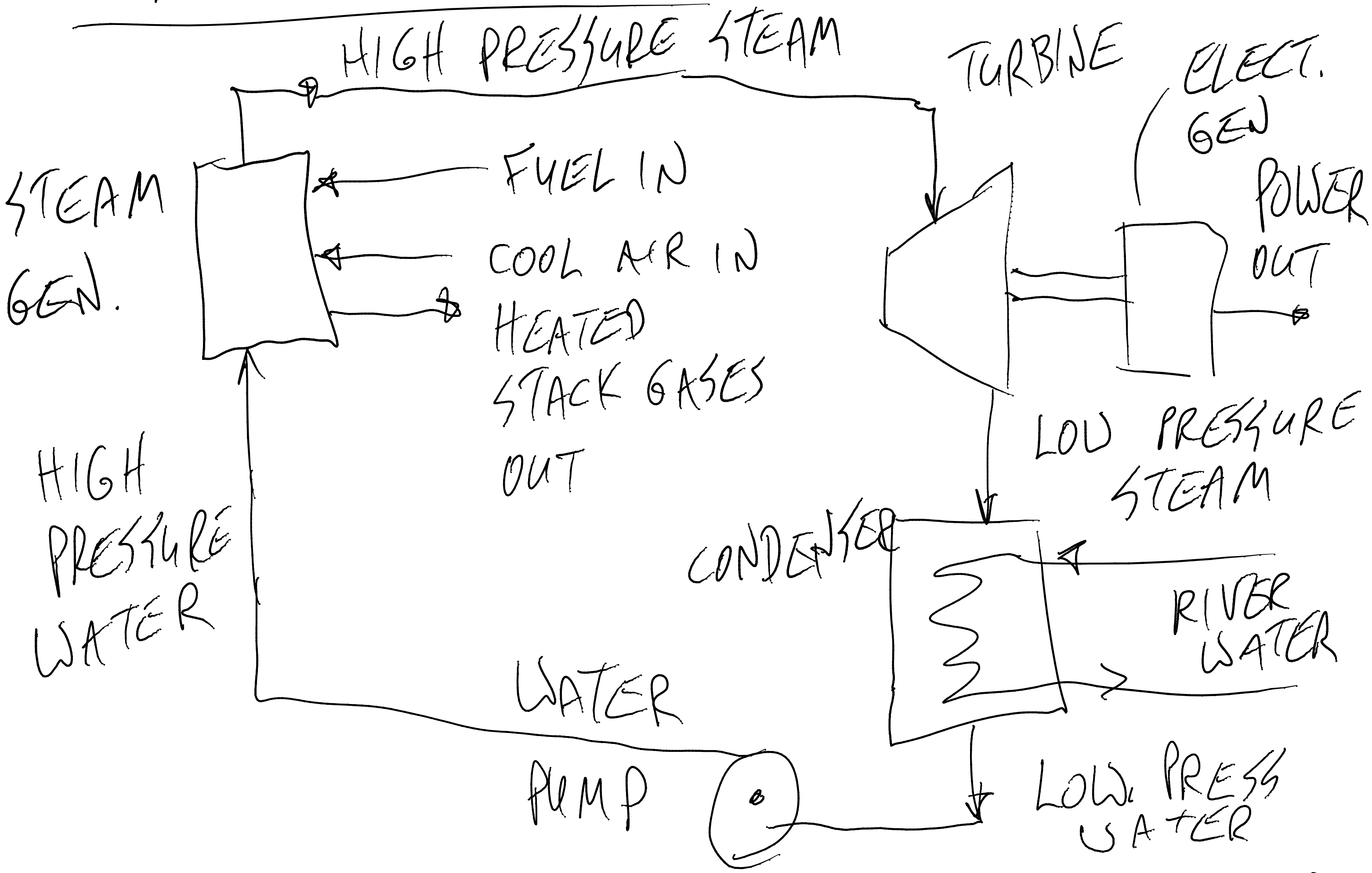


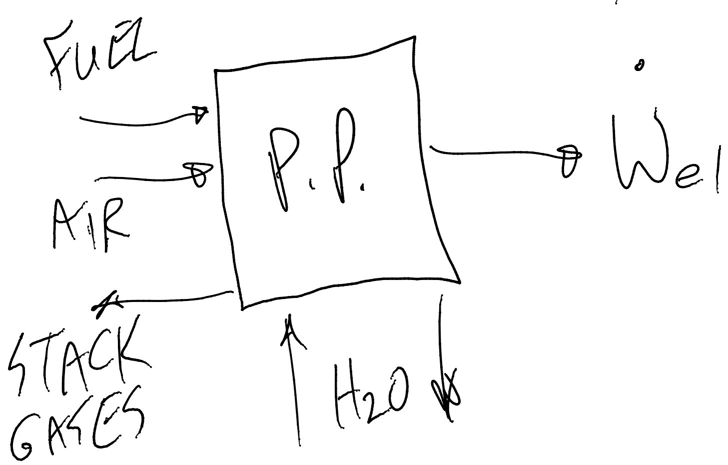
STEAM POWER PLANT

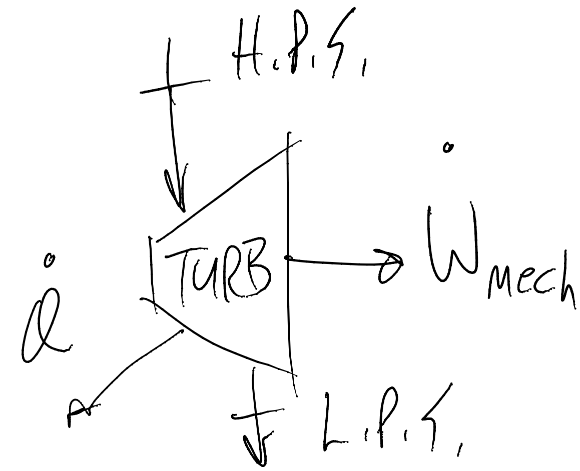


- PHASE CHANGE (LIQUID/VAPOR, VAPOR/LIQUID)
- PRESSURE/TEMPERATURE/DENSITY CHANGES

- COMBUSTION
- HEAT TRANSFER
- FLUID FLOW

ANALYZE: GLOBAL, INDIVIDUAL COMPONENTS





OBJECTIVES: FOR A GIVEN POWER OUTPUT, FIND:

- FUEL RATE
- COMBUSTION AIR
- PUMP POWER
- EFFICIENCY = $\dfrac{\text{POWER OUT}}{\text{POWER IN}} < 1$

— PROBLEM SOLVING:

- DEFINE KNOWNS, UNKNOWNS
- MAKE UNIT CONVERSIONS
- APPLY LAWS

- SOLVE ALGEBRAICALLY (NO NUMBERS HERE)

$$\dot{Q} = \dot{m} \, C_p \, \Delta T$$

$$200\,W = 35 \cdot 27.9 \cdot \Delta T$$

$$\Delta T = \frac{\dot{Q}}{\dot{m} C_p} = \frac{(200\ \cancel{W})\left(\frac{\cancel{J/s}}{\cancel{W}}\right)}{\left(35\ \frac{\cancel{kg}}{\cancel{s}}\right)\left(4.18\ \frac{J}{\cancel{kg} \cdot K}\right)} \quad \frac{1}{1000}$$

- SANITY CHECK ANSWER 0.000000035

3.5

SI VS. ENGLISH

$$F = ma \qquad \boxed{\left(1\ LBF\right) = \left(1\ LBM\right)\left(32.2\ \frac{ft}{s^2}\right)}$$

$$\frac{1\ LBF \cdot s^2}{32.2\ LBM \cdot ft} = \text{CONVERSION FOR ENGLISH}$$

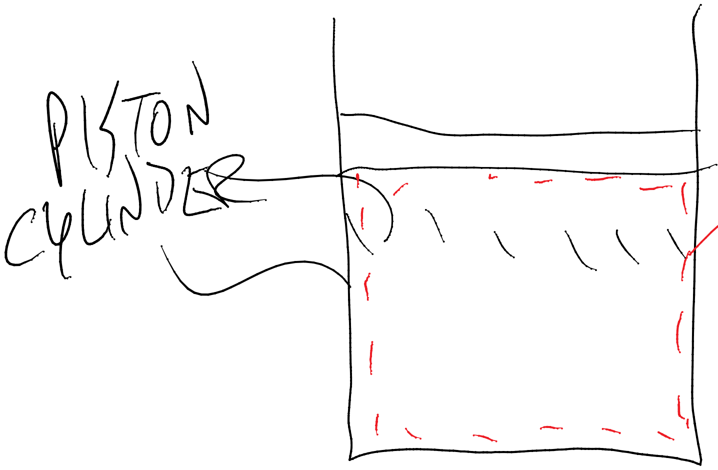
$$32.2\ \frac{LBM}{SLUG}$$

$$1\ N = 1\ kg \cdot 1\ \frac{m}{s^2}$$

$$CF = \frac{1\ N \cdot s^2}{kg \cdot m}$$

DEFINITIONS

- A **THERMODYNAMIC SYSTEM** IS A QUANTITY OF MATTER OF FIXED MASS AND IDENTITY UPON WHICH ATTENTION IS FOCUSED FOR STUDY.
- THE **SURROUNDINGS** IS EVERYTHING EXTERNAL TO THE SYSTEM.
- THE **SYSTEM BOUNDARIES** SEPARATE THE SYSTEM FROM THE SURROUNDINGS, MAY BE FIXED OR MOVABLE.
- **CLOSED SYSTEM**: FIXED QUANTITY OF MASS

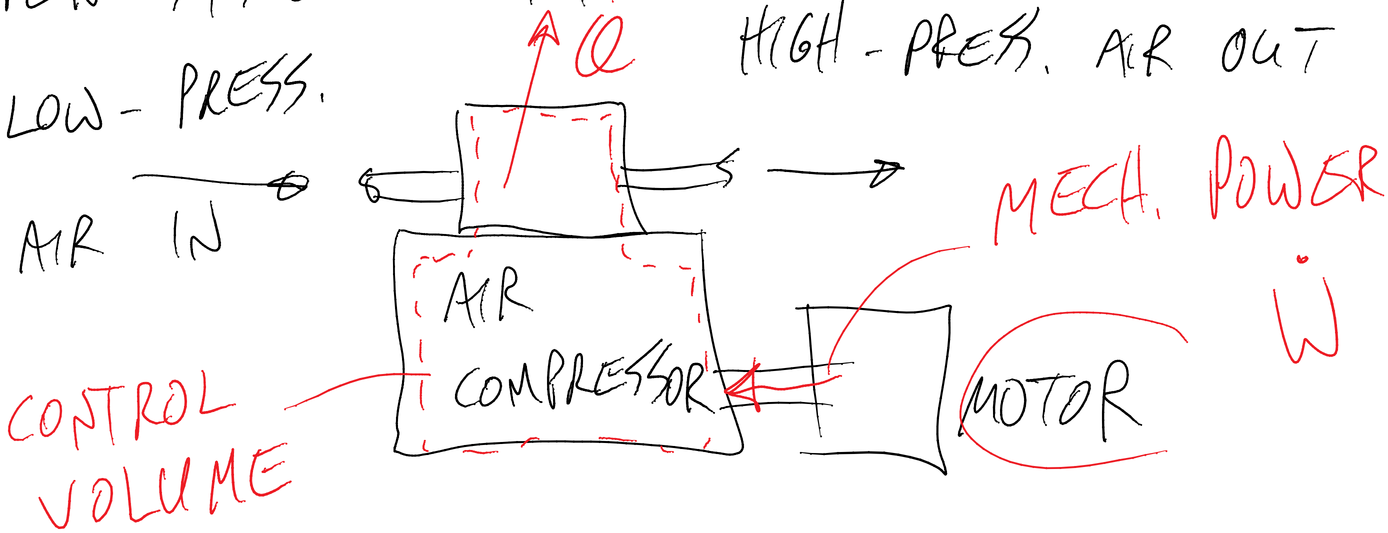


SYSTEM BOUNDARIES

HEAT AND WORK CAN CROSS BOUNDARIES

- OPEN SYSTEM: FIXED VOLUME

• OPEN SYSTEM: FIXED VOLUME



MASS, MOMENTUM, HEAT AND WORK CROSS THE SYSTEM BOUNDARIES.

• A THERMODYNAMIC STATE OF A SUBSTANCE IS DEFINED BY OBSERVABLE PROPERTIES, SUCH AS PRESSURE, TEMPERATURE, DENSITY, ...

• AN EXTENSIVE PROPERTY DEPENDS DIRECTLY ON THE MASS OF THE SYSTEM, SUCH AS VOLUME.

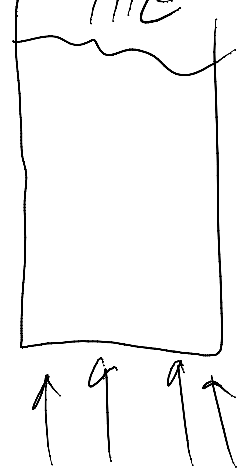
• AN INTENSIVE PROPERTY IS INDEPENDENT

OF MASS, SUCH AS TEMP., PRESS., DENSITY...

AN EXTENSIVE PROPERTY CAN BE CHANGED TO A SPECIFIC PROPERTY BY DIVIDING BY THE SYSTEM MASS.

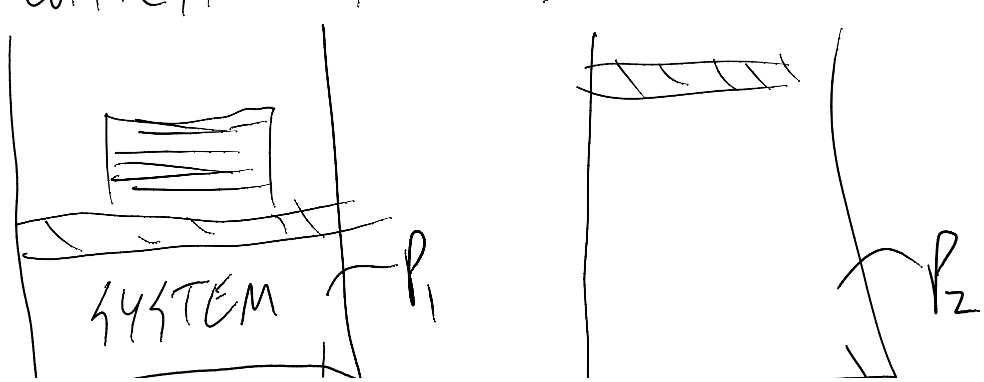
$$\text{SPECIFIC VOLUME} = v = \frac{V}{m} \qquad \frac{m^3}{kg}, \frac{ft^3}{LBM}$$

- EQUILIBRIUM MEANS THAT A PARTICULAR PROPERTY IS UNIFORM THROUGHOUT THE SYSTEM.



- A PROCESS IS THE PATH OF THE SUCCESSION OF STATES THROUGH WHICH THE SYSTEM PASSES.

0.001 IN



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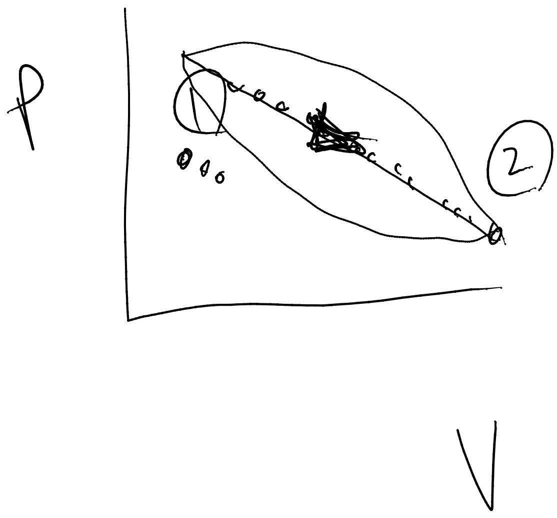


A QUASI-EQUILIBRIUM PROCESS IS ONE IN WHICH THE DEVIATION FROM THERMODYNAMIC EQUILIBRIUM IS INFINITESIMAL.

~~PROB. 31~~

$$\text{MASS} = 3.75 \times 10^{9} \ \frac{\text{kg}}{\text{YR}}$$

- THE CONTINUUM APPROXIMATION ASSUMES THAT THE MEAN FREE PATH OF THE MOLECULES IS SMALL COMPARED TO VOLUME IN

QUESTION.

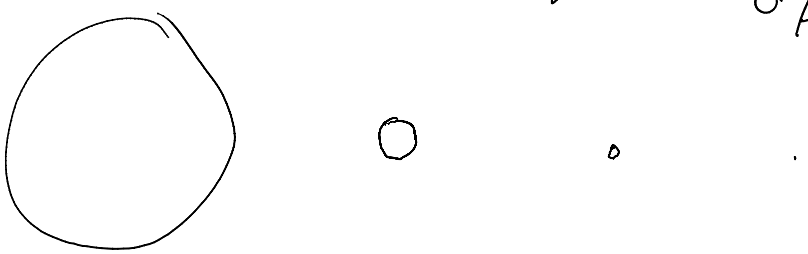
~~DEFINITION OF PRESSURE~~

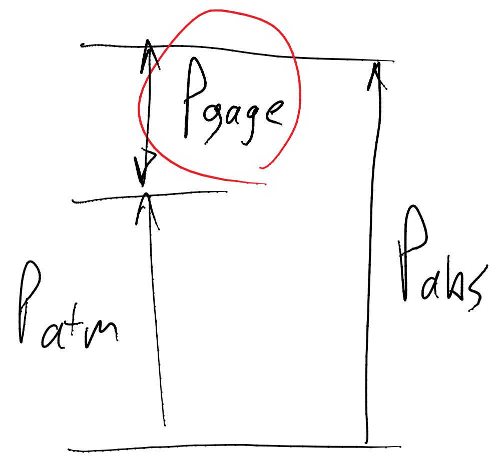
$$P = \lim_{\Delta A \to a} \frac{\Delta F}{\Delta A}$$

$\Delta F \to$ FORCE

$\Delta A \to$ AREA

$a \to$ CONTINUUM APPROXIMATION

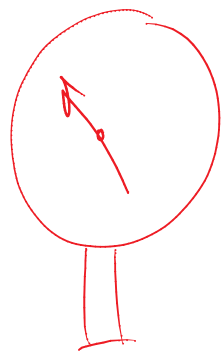




P_{abs} = ABSOLUTE PRESS.

P_{atm} = ATMOSPHERIC PRESS.

P_{gage} = GAGE PRESSURE.



$$P_{gage} = P_{abs} - P_{atm}$$

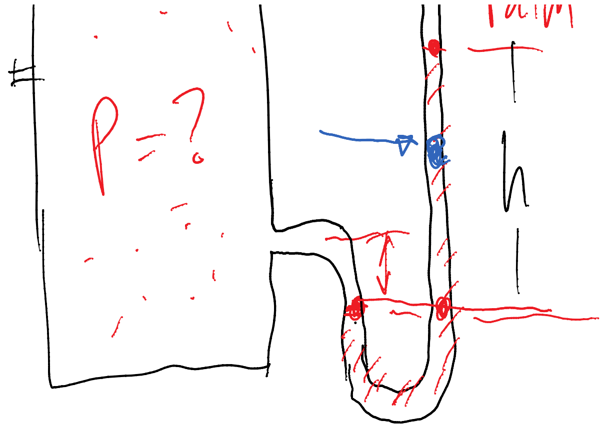
IDEAL GAS RELATION: ABSOLUTE PRESSURE

~~EXAMPLE~~

MERCURY MANOMETER

"RHO"

$$\rho_m = 13,550 \ \frac{kg}{m^3}$$

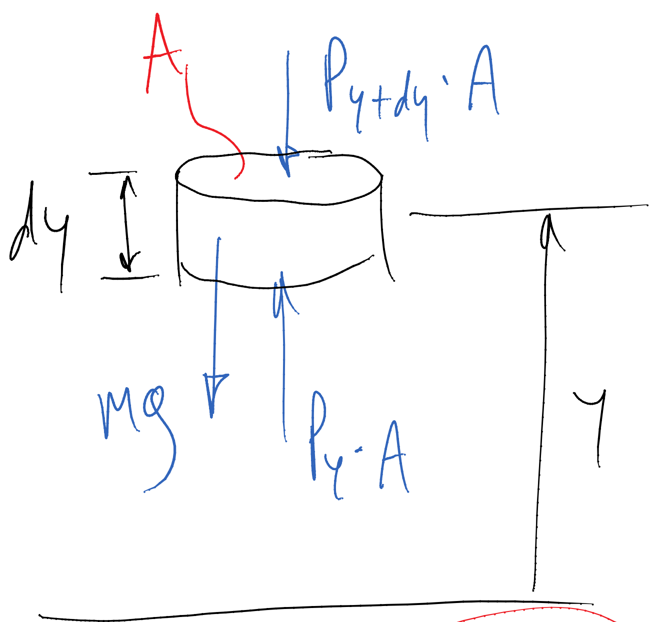


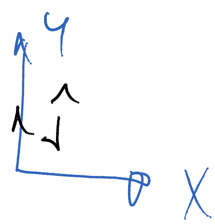
$\rho_m = 13,550 \frac{kg}{m^3}$

$h = 2\,m$, $g = 9.81 \frac{m}{s^2}$

FIND P_{abs}, P_{gage}. WHAT ABOUT WATER?

($\rho_w = 1000 \frac{kg}{m^3}$) FIND h.





FORCE BALANCE:

$$P_y \cdot A - P_{y+dy} \cdot A - mg = 0$$

$$m = \rho \cdot V = \rho \cdot dy \cdot A$$

$$P_y \cdot A - P_{y+dy} \cdot A - \rho g A\, dy = 0$$

$$P_y - P_{y+dy} - \rho g\, dy = 0$$

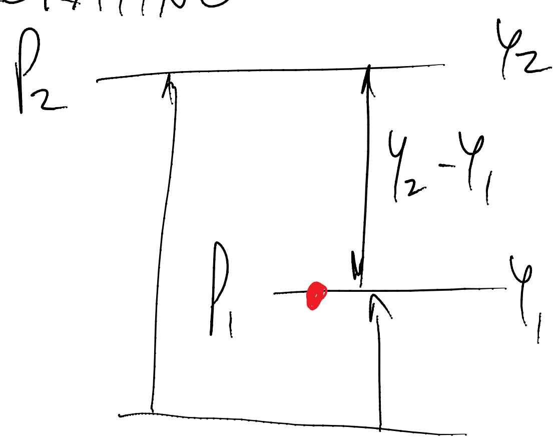
$$\boxed{P_{y+dy} = P_y + \left(\frac{dP_y}{dy}\right)\cdot dy} + \cancel{\left(\frac{d^2P_y}{dy^2}\right)}\cdot\left(\frac{dy^2}{2!}\right) + \cdots \rightarrow 0$$

TAYLOR SERIES: NEGLECT HIGHER-ORDER TERMS

$$P_y - \left[P_y + \left(\frac{dP_y}{dy}\right)\cdot dy\right] - \rho g\, dy = 0$$

$$\frac{dP_y}{dy} = -\rho g$$

SEPARATE VARIABLES & INTEGRATING:



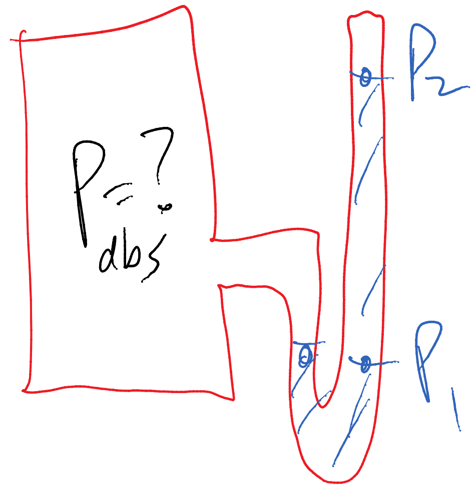
$$dP_y = (-\rho g)\, dy$$

$$\int_1^2 dP_y = (-\rho g)\int_1^2 dy$$

$$P_2 - P_1 = (-\rho g)(y_2 - y_1)$$

LET $y_2 - y_1 = h$

$$\boxed{P_1 = P_2 + \rho g h}$$



$$P_{abs} = P_{atm} + \rho g h$$

FROM BEFORE,

$$\boxed{P_{gage}} = P_{abs} - P_{atm} = \boxed{\rho g h}$$

$$P_{atm} = 1.01 \times 10^5 \frac{N}{m^2}$$

$$\frac{N}{m^2} = Pa$$

$$P_{abs} = \left(1.01 \times 10^5 \frac{N}{m^2}\right) + \left(13{,}550 \frac{\cancel{kg}}{m^{\cancel{3}}}\right)\left(9.81 \frac{\cancel{m}}{s^2}\right)\left(2.0\, \cancel{m}\right)\left(\frac{1\, N \cdot s^2}{\cancel{kg} \cdot \cancel{m}}\right)$$

$$\boxed{P_{atm} = 100\ kPa}$$

$$1\ kPa = 1000\ Pa = 1000 \frac{N}{m^2}$$

$$\boxed{P_{abs} = 3.66 \times 10^5 \frac{N}{m^2}}$$

$$P_{gage} = \left(3.66 \times 10^5 \frac{N}{m^2}\right) - \left(1.01 \times 10^5 \frac{N}{m^2}\right)$$

$$\boxed{P_{gage} = 2.65 \times 10^5 \frac{N}{m^2}}$$

FIND h IF FLUID IS WATER:

$F = ma$

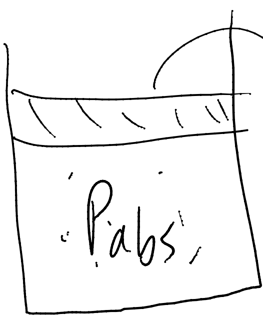
$$P_{gage} = \rho g h$$

$$h = \frac{P_{gage}}{\rho_w g} = \frac{\left(2.65 \times 10^5 \frac{N}{m^2}\right)\left(1.0 \frac{kg \cdot m}{N \cdot s^2}\right)}{\left(1000 \frac{kg}{m^3}\right)\left(9.81 \frac{m}{s^2}\right)}$$

$$\boxed{h = 27.0\ m}$$

EXAMPLE

DREADED PISTON/CYLINDER ARRANGEMENT:



$A = 10\ ft^2 \qquad g = 32.2\ \frac{ft}{s^2}$

$P_{atm} = 14.7\ PSIA, \quad P_{abs} = 30\ PSIA$

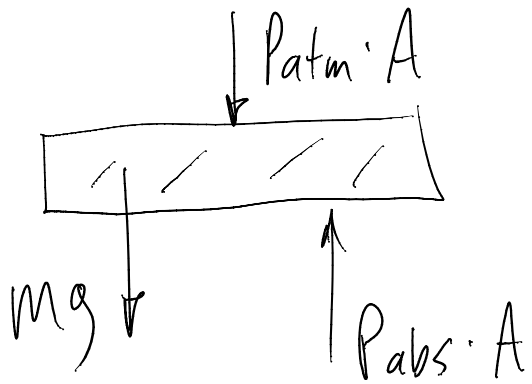
$$PSIA = \left(\frac{LBF}{IN^2}\right)_{ABSOLUTE}$$

FIND THE MASS OF THE PISTON.

$$P_{atm} = \left(14.7\ \frac{LBF}{IN^2}\right)\left(\frac{12\ IN}{ft}\right)^2 = 2117\ \frac{LBF}{ft^2}$$

$P_{abs} = 4320\ \frac{LBF}{}$

$$P_{abs} = 4320 \frac{LBF}{ft^2}$$



$$P = \frac{F}{A}$$

FBD

$$P_{abs} \cdot A = P_{atm} \cdot A + mg$$

$$F = ma$$

$$1\,LBF = (1\,LBM)\left(32.2 \frac{ft}{s^2}\right)$$

$$m = \frac{A}{g}\left(P_{abs} - P_{atm}\right)$$

$$m = \frac{(10\,\cancel{ft^2})}{\left(32.2\,\frac{\cancel{ft}}{\cancel{s^2}}\right)} \cdot \left(4320 - 2117\,\frac{\cancel{LBF}}{\cancel{ft^2}}\right)\left(\frac{32.2\,LBM \cdot \cancel{ft}}{\cancel{LBF} \cdot \cancel{s^2}}\right)$$

$$\boxed{m = 2.2 \times 10^{4}\,LBM}$$

DEFINITION OF SPECIFIC VOLUME:

$$v = \frac{V}{m} = \frac{\text{SYSTEM VOLUME}}{\text{SYSTEM MASS}}$$

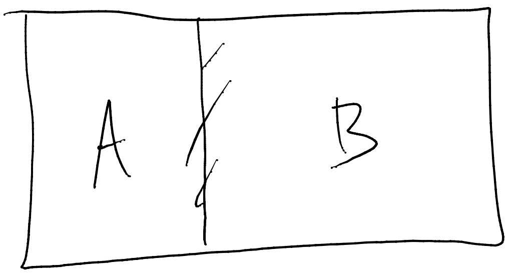
$$v = \frac{1}{\rho}$$

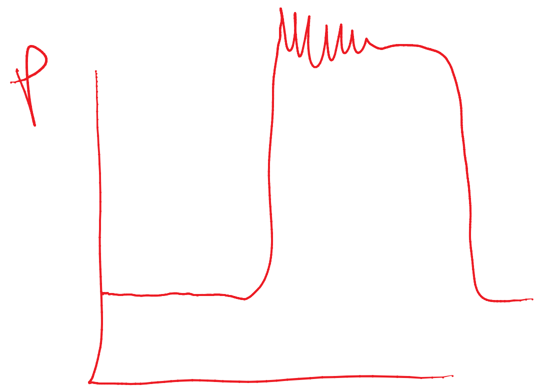
EXAMPLE

$$v_A = 17.196 \frac{m^3}{kg}, \quad V_A = 0.2\ m^3$$

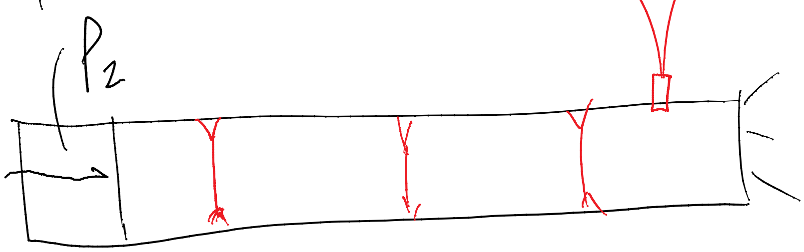
$$v_B = 3.418 \frac{m^3}{kg}, \quad V_B = 0.5\ m^3$$

FIND v_T





SHOCK TUBE



$$v_A = \frac{V_A}{m_A}, \quad v_B = \frac{V_B}{m_B}$$

CONSERVE MASS: $m_T = m_A + m_B$

TOTAL VOLUME: $V_T = V_A + V_B$

TOTAL SPECIFIC VOLUME:

$$v_T = \frac{V_T}{} = \frac{V_A + V_B}{}, \quad m_A = \frac{V_A}{} \quad m_B = \frac{V_B}{}$$

$$v_T = \frac{V_T}{m_T} = \frac{V_A + V_B}{m_A + m_B}, \quad m_A = \frac{V_A}{v_A}, \quad m_B = \frac{V_B}{v_B}$$

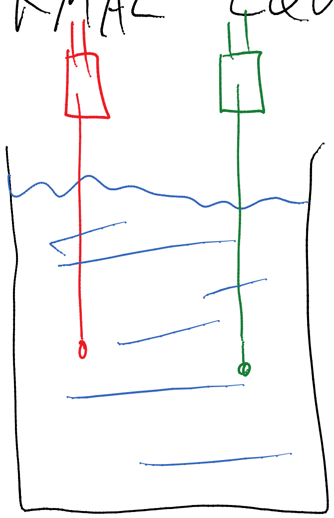
$$v_T = \frac{V_A + V_B}{V_A / v_A + V_B / v_B}$$

$$v_T = \frac{(0.2\ m^3) + (0.5\ m^3)}{(0.2\ m^3)/(17.196\ \frac{m^3}{kg}) + (0.5\ m^3)/(3.418\ \frac{m^3}{kg})}$$

$$\boxed{v_T = 4.43\ \frac{m^3}{kg}}$$

ZEROTH LAW OF THERMO

TWO BODIES WHICH ARE EACH IN THERMAL EQUILIBRIUM WITH A THIRD BODY ARE IN THERMAL EQUILIBRIUM WITH EACH OTHER.



THERMOCOUPLE

RESISTANCE TEMPERATURE DETECTOR

WATER : $\pm 0.015\,^{\circ}C$

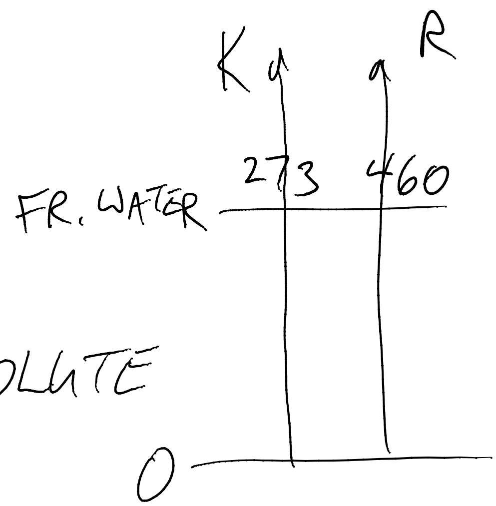
→ CALIBRATE

COST	ACCURACY
\$28.00	$\pm 1.0\,^\circ C$
\$7000.00	$\pm 0.0043\,^\circ C$

CALIBRATE

$\pm 0.023\,^\circ C$

$$\dot{Q} = \dot{m}\, C_p (T_o - T_i)$$



TEMPERATURE

KELVIN, RANKINE ARE ABSOLUTE TEMPERATURE SCALES:

$$1.8\,^\circ R = 1\,K$$

CELSIUS, FAHRENHEIT:

$$T(^\circ C) = T(K) - 273\,, \quad T(^\circ F) = T(^\circ R) - 460$$

$$T(^\circ F) = 1.8 \cdot T(^\circ C) + 32$$

Pvt diagram

Thursday, May 09, 2013
12:53 PM