



Madarju.com



Fluid Mechanics

Dr. Khaled Rawajfeh



* Fluid → قابلية للجريان والاحتواء في وعاء

① liquid
② ~~solid~~ gas

* يمكن أن تكون في وعاء مفتوح.

تكون في
مفتوح
مغلق

١٢ - كيف وزن أو طول عمود السائل - hydrostatic
تأثير على الأرضية.



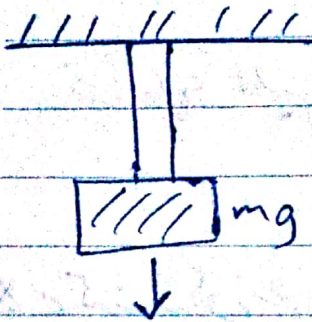
الاجابة

stress → Area مع Force

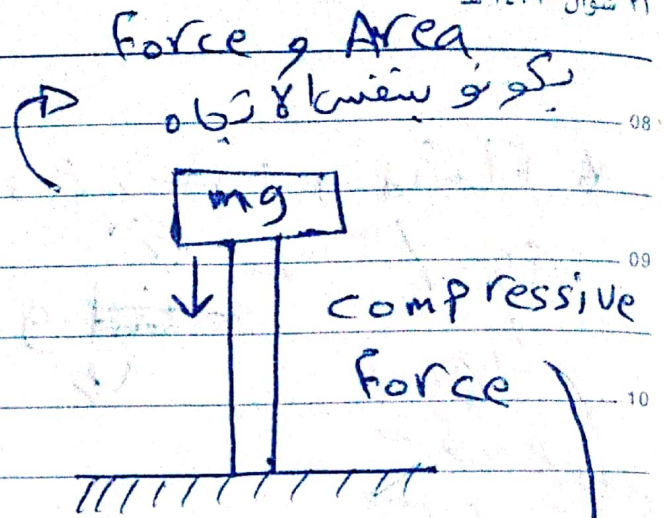
↳ $\vec{F}$

Area $\propto A$

ask, believe & receive



Tensile
Force



Force و Area
يكون بنفسه الاتجاه
الاتجاه ال Area وال Force يكون بنفسه الاتجاه

1 October
FRIDAY

تشرين الأول
الجمعة

Force و Area عكس اتجاه بعض

حركة تماس

- Shear Force → shear stress
اصطكاك القساوي استنزاف المقصود

system Homogenous →

ask ; believe & recieve

الاستعداد عليه

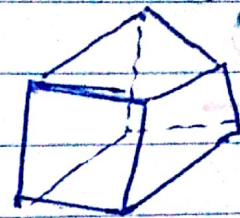
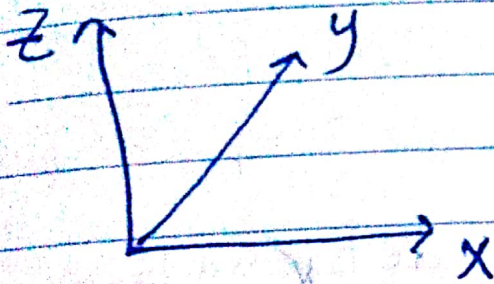
ملاحظات

S	2	9	16	23	30
S	3	10	17	24	31
M	4	11	18	25	
T	5	12	19	26	
W	6	13	20	27	

- open system: in and out are defined.

- control ~~system~~ volume:-

يسمى للحدود التي يتحكم بها المدخل والمخرج
in and out From entire surface.



- 3 normal stresses.
- 6 shear " " "

} 9 ~~components~~
components
(shear stress
Tensor).

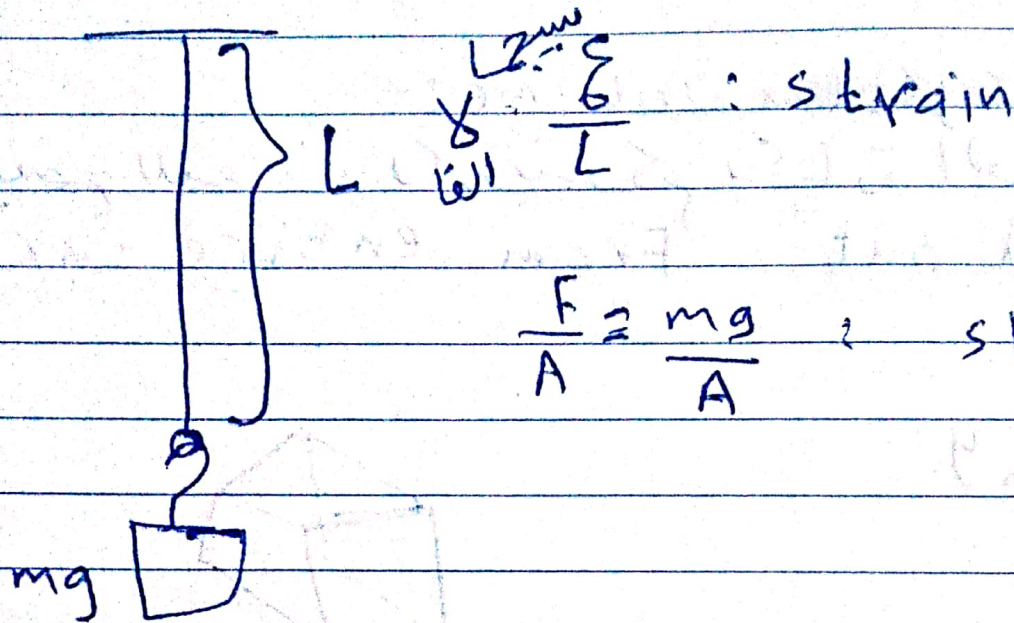
1 magnitude and 2 direction

كل محورين

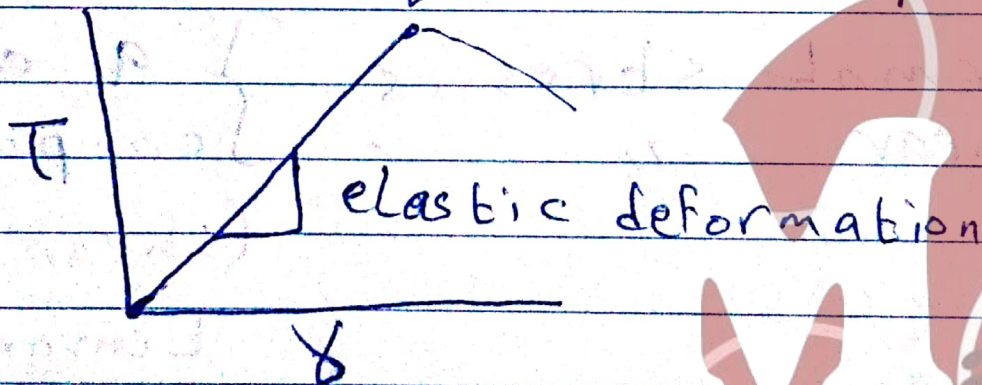
قوة الشد البطني ال solid قوة ضغط
على شكل ثابت.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	8	15	22	29
T	9	16	23	30

solid → elastic deformation



↓ Plastic deformation



Liquid → Free surface Δ

Δ Δ Δ

- Newton's Law of thermodynamics

$$\Sigma F = ma = m \frac{dv}{dt} = \frac{dm}{dt} ?$$

لازم تكون الأبعاد أكبر من المسافة بين
الجزئيات

$$\rho = \frac{M}{V} : \text{Dimensions } [=]$$

الاشياء الأساسية Length, mass, Temp, Time

الوحدات المستقة من الـ dimension
ويتخذ على النظام الذي يتعامل معه.
density.

$$\text{SI unit } D \rightarrow \text{kg/m}^3$$

$$\text{specific weight } (\gamma) = \frac{\text{weight}}{\text{volume}}$$

$$SG_{\text{gas}} = \frac{\rho_{\text{gas}}}{\rho_{H_2} \text{ or } \rho_{\text{air}}}$$

Both at the same temperature and pressure.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

WEEK 40

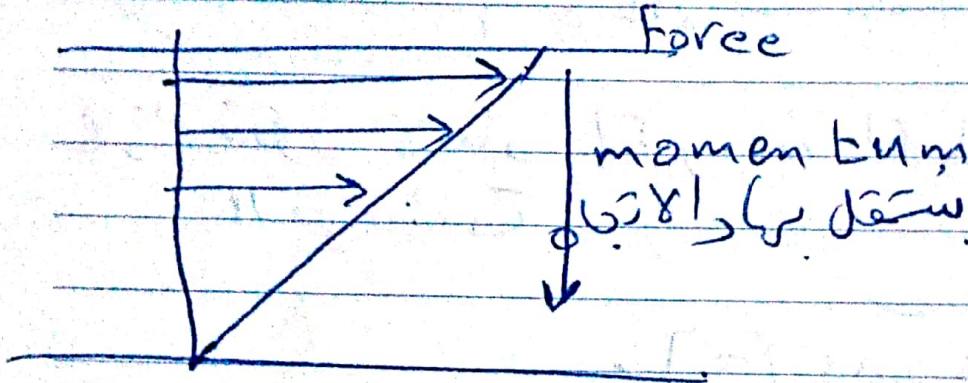
270-95

اللزوجة

* Viscosity : resistance to flow

~~Newton's Law of V~~

مقاومة المادة للجريان



(force)

$$\frac{F}{A} \rightarrow \text{FLUX}$$

تدفق

(Area)

pascal $\rightarrow \frac{F}{A}$

centi poise.

$cP = 10^{-2} \text{ Poise}$

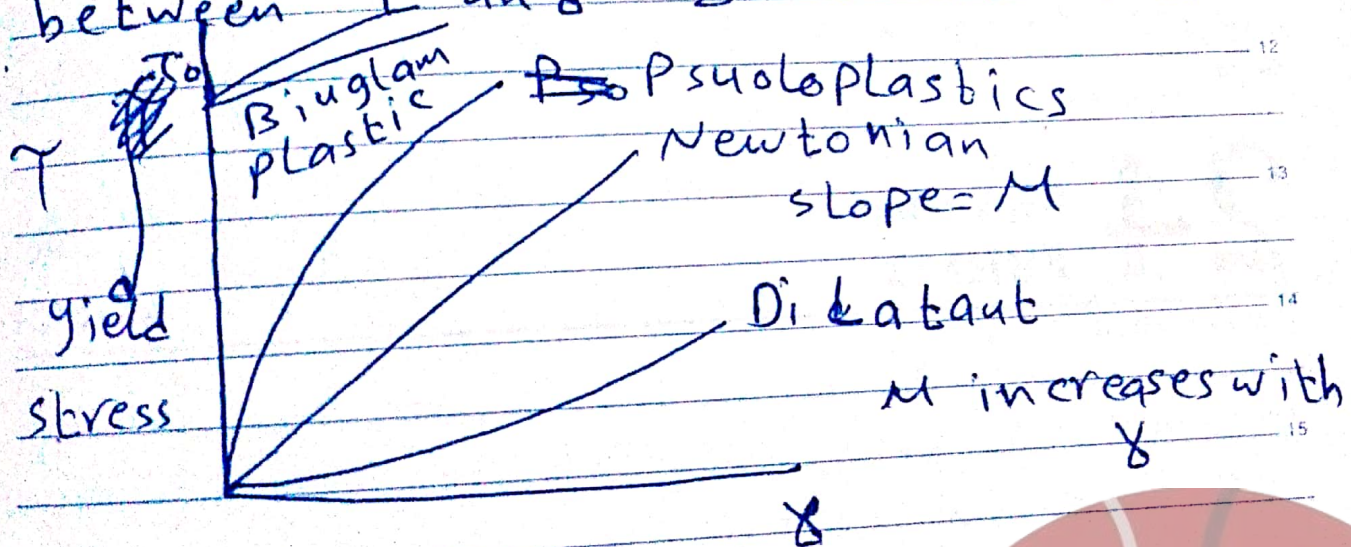
$\mu_{H_2O} = 1 \text{ cP}$ at 68°F
or 20°C

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

* Types of Fluids :- حسب النوع

1 - Newtonian fluids: They Follow newton's Law of viscosity.
most liquids and all gases.

2 - Non Newtonian fluids: Relation between τ and γ is not linear.



3 - Time independent:

* Thixotropics: M decreases with Time
ملاحظات

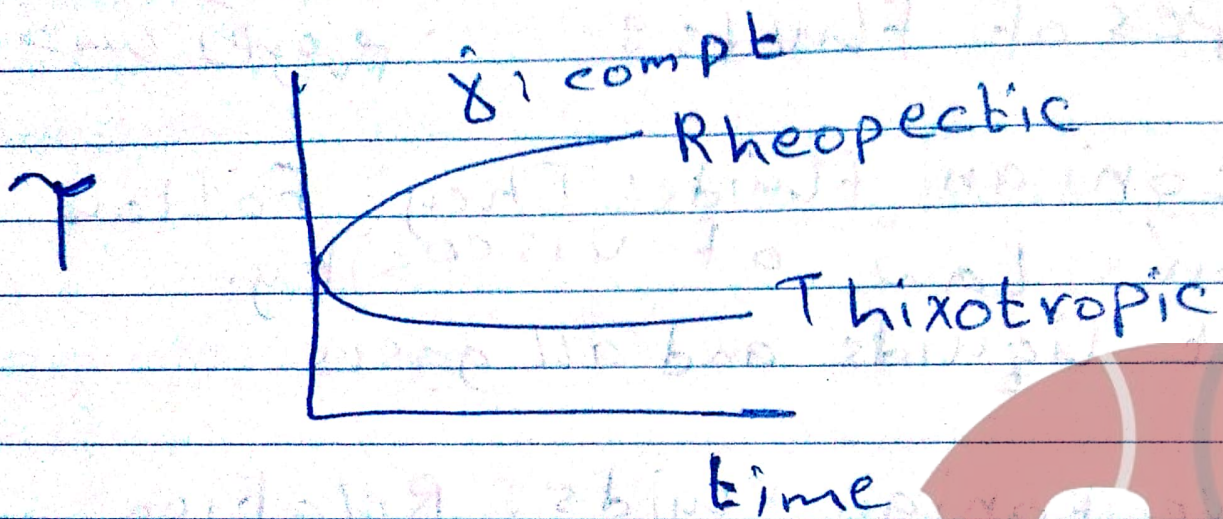
* Rheopectics: M increase with Time.
ask ; believe & recieve

Viscoelastic Fluid: They show elastic behavior.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

14 Shawwal 1431 H

14 شوال 1431 هـ



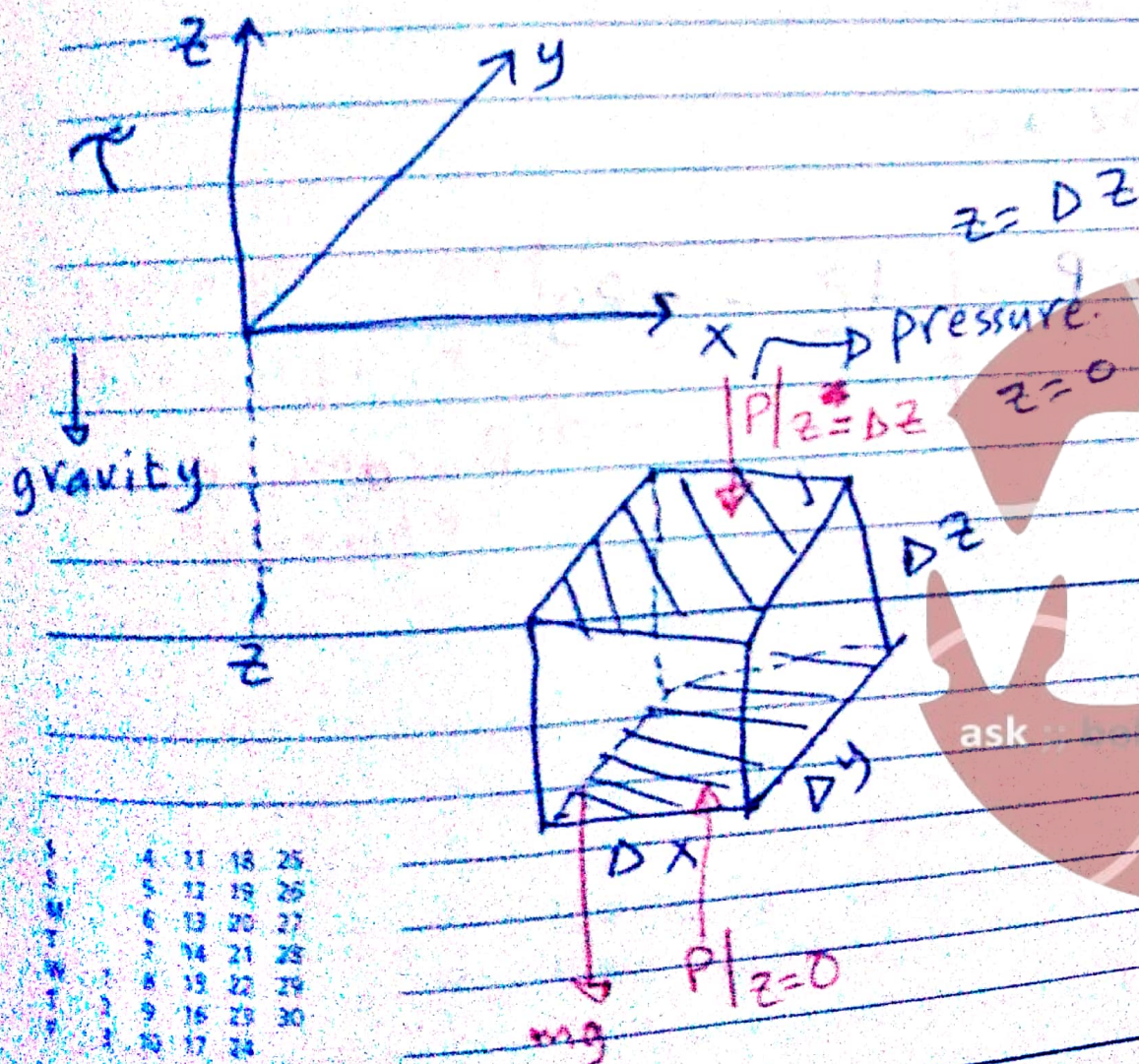
*ch2:- Fluid statics

Basic Equation of Fluid statics.

- For a simple Fluid at rest, the pressure at any point in the Fluid is the same in all directions: "No shear stresses".

* In any direction $\Sigma F = 0$

consider an elemental volume of Fluid at rest.



ملاحظات

ask & recieve

2010

gravity ↓

$$\sum F_z = +P|_{z=0} \Delta x \Delta y - P|_{z=\Delta z} \Delta x \Delta y -$$

$$P \cdot (\Delta x \Delta y \Delta z) g = 0$$

÷ $\Delta x \Delta y \Delta z$ and rearrange.

$$\frac{P|_{z=0} - P|_{z=\Delta z}}{\Delta z} = -\rho g$$

Limit $\Delta z \rightarrow 0$

$$\text{Limit}_{\Delta z \rightarrow 0} \frac{\Delta P}{\Delta z} = \boxed{\frac{dP}{dz} = -\rho g}$$

Basic equation
of liquid statics

"Barometric
equation".

ask :: believe & recieve

ملاحظات

* Notes :-

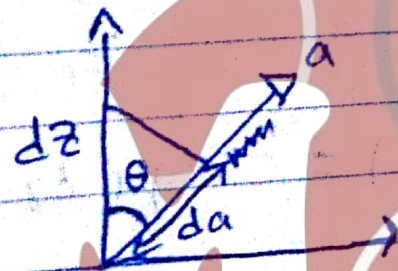
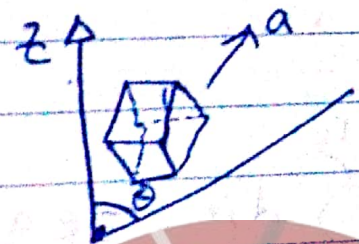
① Barometric equation is correct For Fluids at rest or Fluids with no shear stresses on the vertical surface.

i.e :- if it is not moving at all or moving in the x and y directions. or if it is moving with a uniform velocity in the z-direction.

② Direction of change in pressure is not vertical.

$$\frac{dp}{da} = \frac{dz}{da} \cdot \left(\frac{dp}{dz} \right)$$

$$= \frac{dz}{da} (-\rho g)$$



Liquid pressure is the same everywhere.

③ Free surface of a liquid exposed to the atmosphere is practically a horizontal plane. Pressure is the same everywhere on the surface.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	8	15	22	29
Th	9	16	23	30
F	10	17	24	

* pressure - depth relationships :-

From basic equation -

$$\int dp = - \int \rho g dz$$

Relation between ρ , g and z

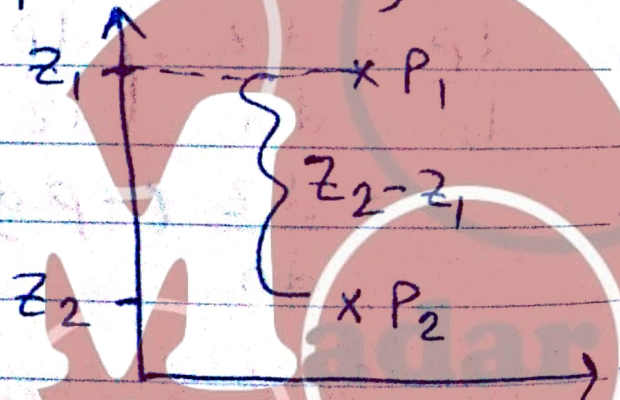
- g is practically constant on the surface of the earth.

~~density~~ - ρ may change with z . Appropriate expression which describes the variation must be included.

* Liquid :-

ρ is ~~practically~~ constant

$$\int_{P_1}^{P_2} dp = - \rho g \int_{z_1}^{z_2} dz$$

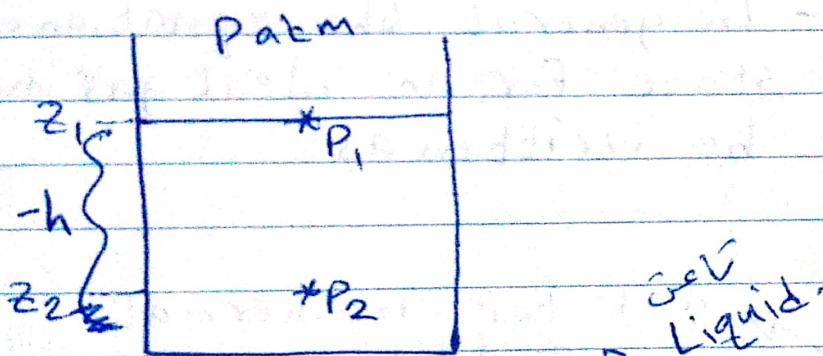


$$(P_2 - P_1) = - \rho g (z_2 - z_1)$$

ask :: believe & recieve

ملاحظات

- In problems involving a Free surface



$$P_2 \text{ gauge} = + \rho g h \quad (\text{on liquid.})$$

16/2

* Gases? c depends on absolute temp and pressure under which they exist.

- For air and other real gases at conditions far from the liquid phase, the ideal gas law can be used.

$\Rightarrow$ Gas constant.

$$p \hat{v} = RT$$

absolute pressure $\rightarrow$ specific molecular volume $(\frac{v}{n})$ $\rightarrow$ absolute temperature.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

WEEK 39

16

September

THURSDAY

7 Shawwal 1431 H

$$PV = nRT$$

adiabatic
Energy
exchang of energy

أيلول

الخميس

7 شوال 1431 هـ

$$C = \frac{P M_w}{RT}$$

- In general the equation of state for an ideal gas may be written as:

$$P \hat{V}^n = \text{const.} = C$$

n is +ve
number

n=1 For isothermal conditions.

Isentropic
(frictionless
and adiabatic)

$$n = k = \frac{C_p}{C_v}$$

$$= 1.4$$

air

أيلول

الجمعة

8 شوال 1431 هـ

17

September

FRIDAY

8 Shawwal 1431 H

adiabatic
with Friction

n < k expansion
n > k compression

$$P \left(\frac{RT}{P} \right)^n = C \rightarrow P^{1-n} \cdot T^n = C$$

$$\left(\frac{P_1}{P_2} \right)^{1-n} = \left(\frac{T_2}{T_1} \right)^n$$

$$= \frac{C}{P^n}$$

S		4	11	18	25
S		5	12	19	26
M		6	13	20	27
T		7	14	21	28
W	1	8	15	22	29
T	2	9	16	23	30
F	3	10	17	24	

WEEK 38

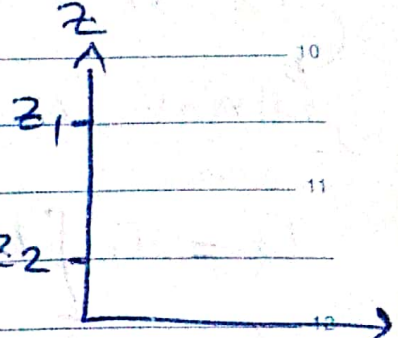
260 - 105

2010

$$\Rightarrow T_1 = T_2$$

① Isothermal perfect gas.

$$dP = -\rho g dz = -\left(\frac{PM_w}{RT_1}\right) g \cdot dz$$

$$\int_{P_1}^{P_2} \frac{dP}{P} = -\frac{Mg}{RT_1} \int_{z_1}^{z_2} dz$$


$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{gM}{RT_1} (z_2 - z_1)$$

$$P_2 = P_1 \exp\left(-\frac{gM}{RT_1} \Delta z\right)$$

كما زاد Δz بزداد

exp

P_2 يزداد مع

الارتفاع لكن العلاقة ليست

خطية بل exp

في العلاقة K ثابتة
② Isentropic

$$\left(\frac{P}{\rho^n}\right) = c_2$$

$$P V^n = c_1$$

$$\frac{P}{\rho^n} = c_2$$

$$c_2 = \frac{c_1}{M_w}$$

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

$$dp = -\rho g dz$$



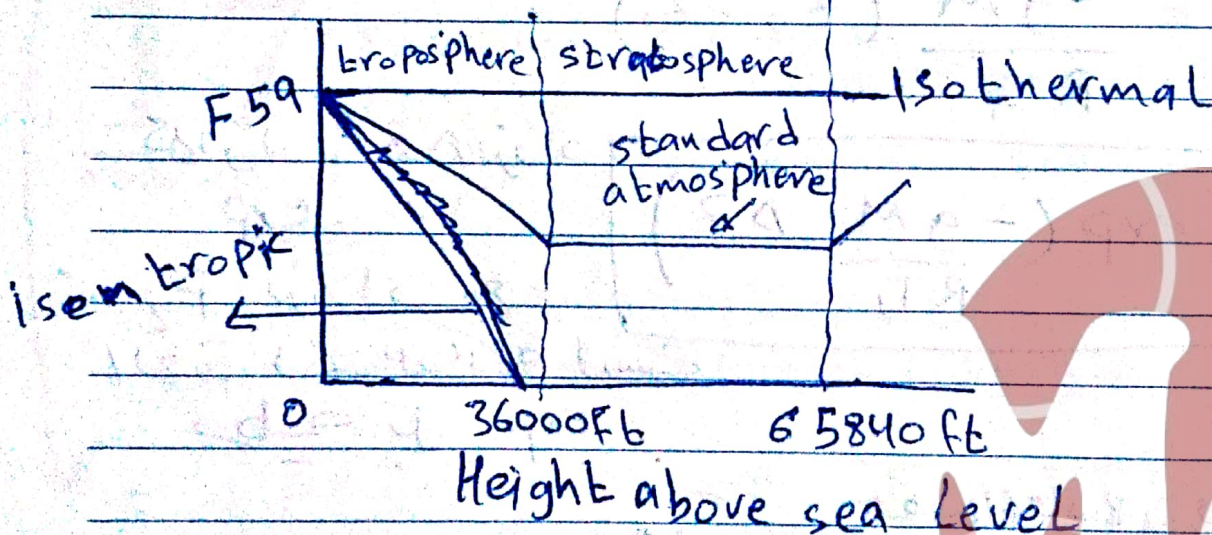
$$P_2 = P_1 \left[1 - \frac{k-1}{k} \cdot \frac{g M_w}{R T_1} \Delta z \right]^{\frac{k}{k-1}}$$

↪ not linear.

$$T_2 = T_1 \left[1 - \frac{k-1}{k} \cdot \frac{g M_w}{R T_1} \Delta z \right]$$



- linear



* pressure Forces on surfaces :-

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

static Fluids exert normal pressure Forces on surfaces adjacent to them.

- elemental area $\rightarrow$

$$\square dA$$

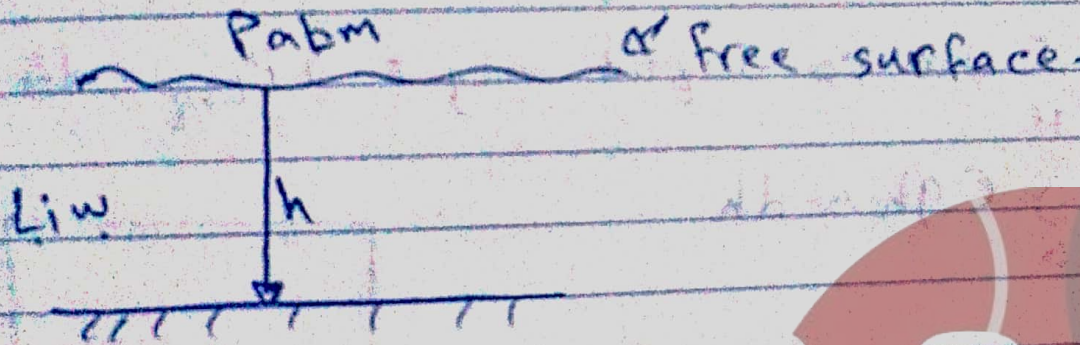
يعني كثر مساحة

- For an elemental area, the true exerted is $d\vec{F} = p d\vec{A}$

- plane surfaces:-

ALL $d\vec{F}$ vectors point in the same direction.

Horizontal Plane surface السطح الأفقي



$$P_{\text{absolute}} = P_{\text{atm}} + P_{\text{liquid}}$$

p is constant.

$$F = \int (P_{\text{atm}} + P_{\text{liquid}}) dA = (P_{\text{atm}} + P_{\text{liq}}) \int dA$$

$$F_{\text{net}} = F_{\text{due to liquid on li}} = P_{\text{liquid}} A$$

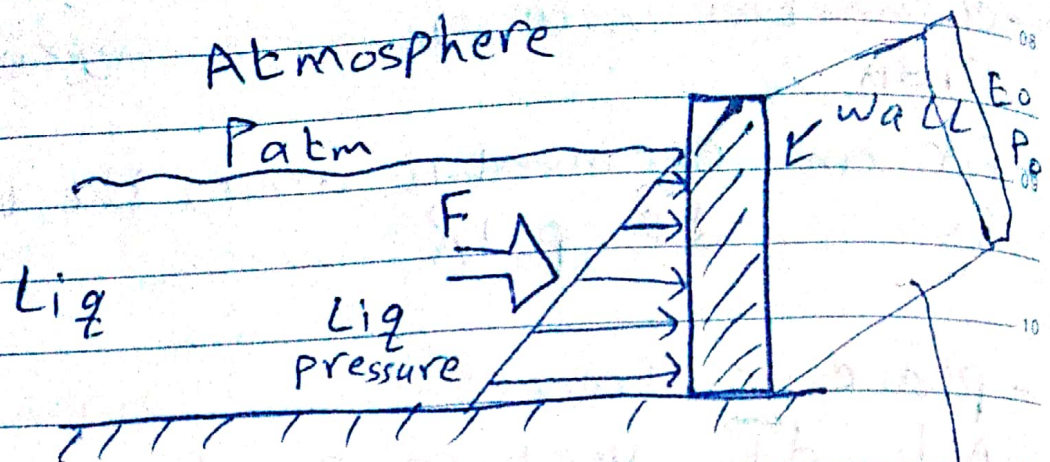
$$= \rho g h A = \text{wt of fluid above surface.}$$

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

WEEK 30

200 - 100

2010

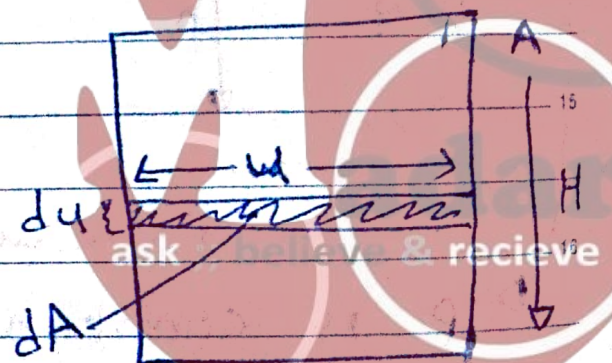


$$F = \int P dA = \int (P_{atm} + P_{Liq}) \cdot dA$$

$$= P_{atm} \cdot A + \int P_{Liq} \cdot dA$$

$$F_{Liq} = F \text{ due to Liquid only} = \int P_{Liq} \cdot dA$$

$$= \int_0^H \rho g h \cdot w \cdot dh$$



$$= \rho g w \int_0^H h dA = \rho g w \left[\frac{h^2}{2} \right]_0^H$$

$$= \rho g w \frac{H^2}{2}$$

Net force on vertical surface.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

$$P_0 = P_{atm}$$

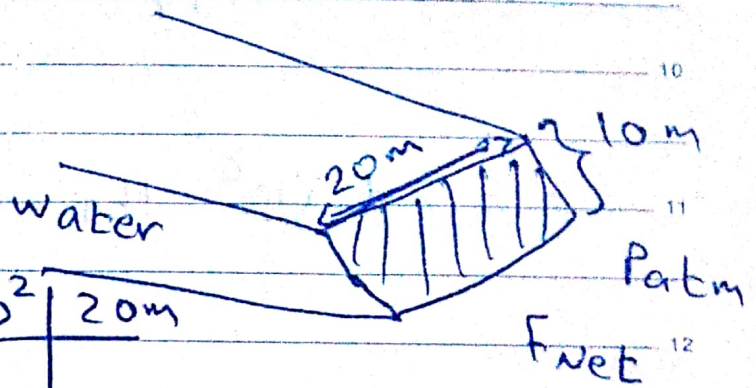
$$F_{net} = P_{atm} \cdot A + \rho g S h w d h - P_0 \cdot A$$

$$= \rho g w S h d h$$

$$F_{net} = \frac{\rho g H^2 w}{2}$$

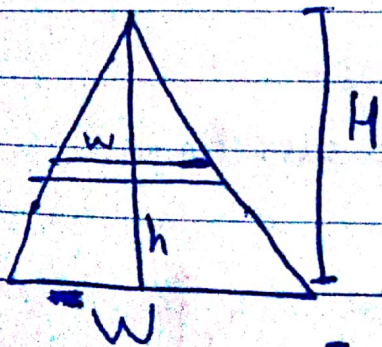
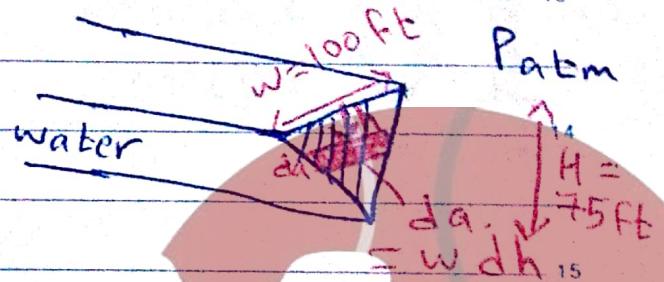
$$= \frac{1000 \text{ Kg} / \text{m}^3 \cdot 9.81 \text{ m} \cdot \text{s}^{-2} / 2 \cdot 10^2 \cdot 20 \text{ m}}{2}$$

$$= 9.81 \times 10^6 \text{ N}$$



$$F_{net} = \int P dA = \int \rho g h \cdot dA$$

$$= \rho g S h \cdot w d h$$



$$\frac{H-h}{H} = \frac{w}{W}$$

$$w = 100 \left(1 - \frac{h}{H} \right)$$

$$F = \rho g \int_0^H h \times 100 \left(1 - \frac{h}{H} \right) dh$$

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

THURSDAY

الخميس

٢٠ رمضان ١٤٣١ هـ

Ramadan 1431 H

السؤال H = 75 ft

$$= 100 \rho g \left[\frac{h^2}{2} - \frac{h^3}{3H} \right]_0^H = 100 \rho g H^2 \left[\frac{1}{2} - \frac{1}{3} \right]$$

$$= 100 \times 62.3 \frac{\text{lbm}}{\text{ft}^3} \times 32.2 \frac{\text{ft}}{\text{s}^2} \times (75)^2 \text{ ft}^2 \times \frac{1}{6}$$

$$\frac{16 \text{ ft s}^2}{32.2 \text{ lbm ft}}$$

$$= 5.84 \times 10^6 \text{ lbf}$$

252 - 113

10

September
FRIDAY

1 Shawwal 1431 H

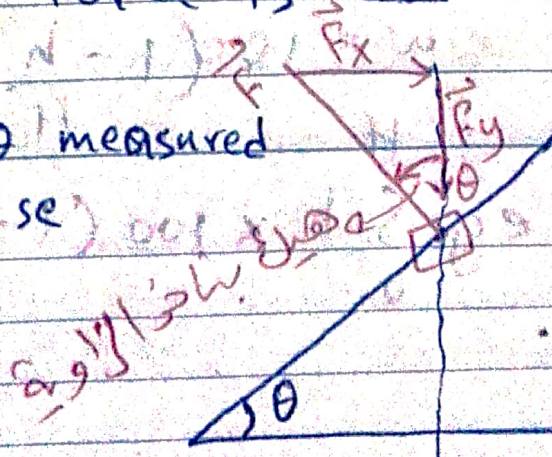
أيلول

الجمعة

١ شوال ١٤٣١ هـ

* Inclined plane surface:-
pressure Force is $\perp$ to surface

convention? θ measured
anti clockwise



ask, believe & recieve

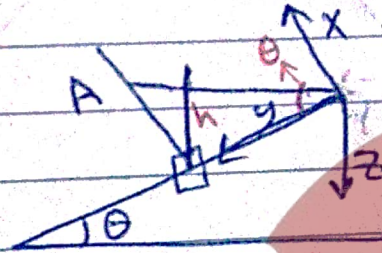
S	4	11	18	25
S	5	12	19	26
M	6	13	20	27

$Sdf = SPdA$; all df vectors point in the ~~same~~ same direction and make angle θ with vertical.

Net Force $dF_x = p \sin \theta dA$ $\theta < \frac{\pi}{2}$ F_y -ve
 $dF_y = p \cos \theta dA$ $\pi > \theta > \frac{\pi}{2}$ F_y +ve

Note: In many cases it is easier to work with centroids (first moment of area).

$h = y \cdot \sin \theta$
 $F_{net} = \int p \sin \theta dA$



$= \int p \sin \theta dA$
 $= p \sin \theta \int y dA = p \sin \theta \times \frac{\sum y dA}{\sum dA}$

y = coordinate of centroid of plane area.

$= \frac{\sum y dA}{\sum dA}$

$F_{net} = p \sin \theta y_c A$
 p at centroid
 y_c depth of centroid he.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

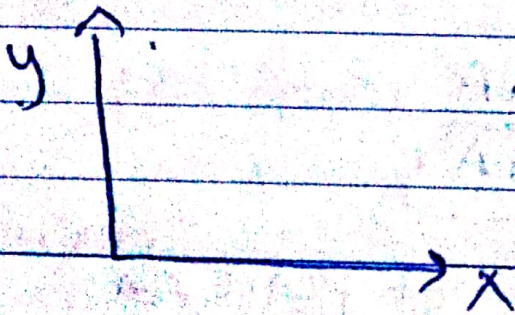
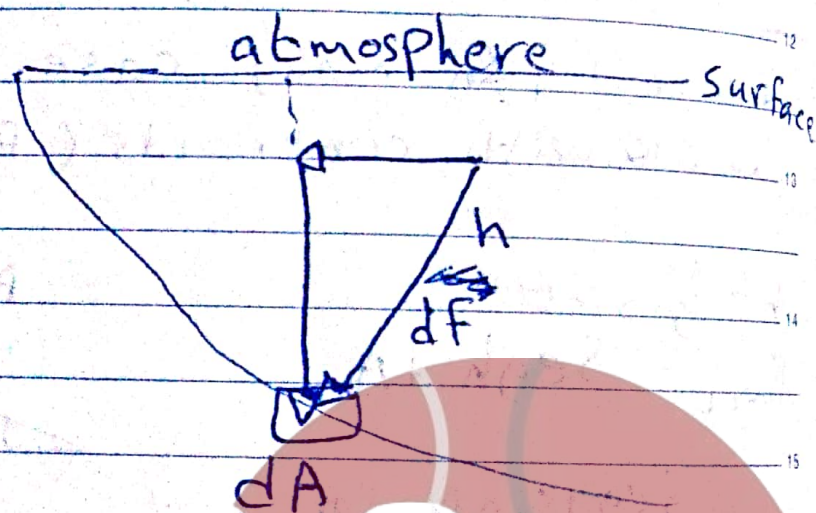
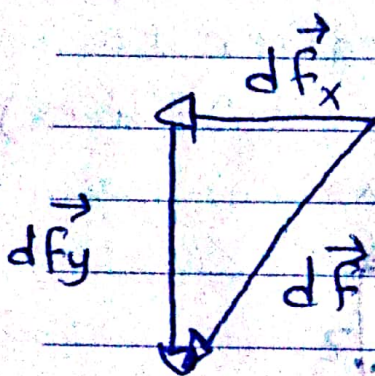
* pressure Forces on curved surfaces:

whether curved or plane

$$dF = P \cdot dA$$

$$dF \perp dA$$

For curved surfaces dF vectors are not all in the same direction.



$$F_x = \int dF_x = \int P \sin \theta dA$$

$$F_y = \int dF_y = - \int P \cos \theta dA$$

There are correct For any kind of surface.

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

WEEK 37

250 - 115

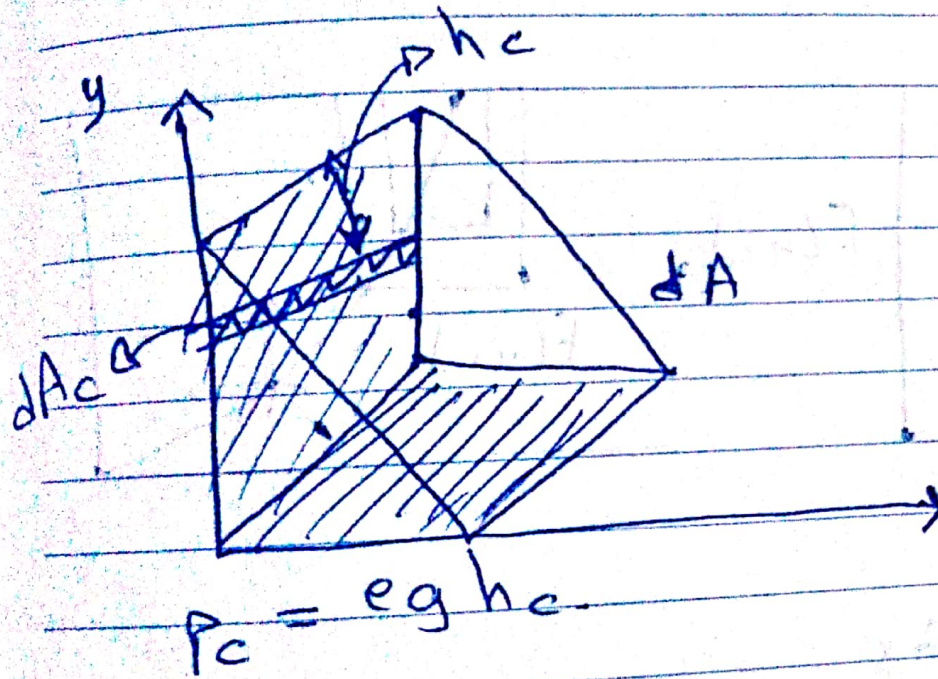
- Notes:

① $\sin \theta dA = dA_x$ x projection of dA

② $\cos \theta dA = dA_y$ y

③ $F_x = \int P dA_x$
 $= P_c A_x$

P_c : pressure at centroid of dA_x



④ vertical component:

$dF_y = - P_c dA \cos \theta$

y projected area.

$= - \rho g h dA \cos \theta$

ρ : Density
 h : depth
 dV : volume

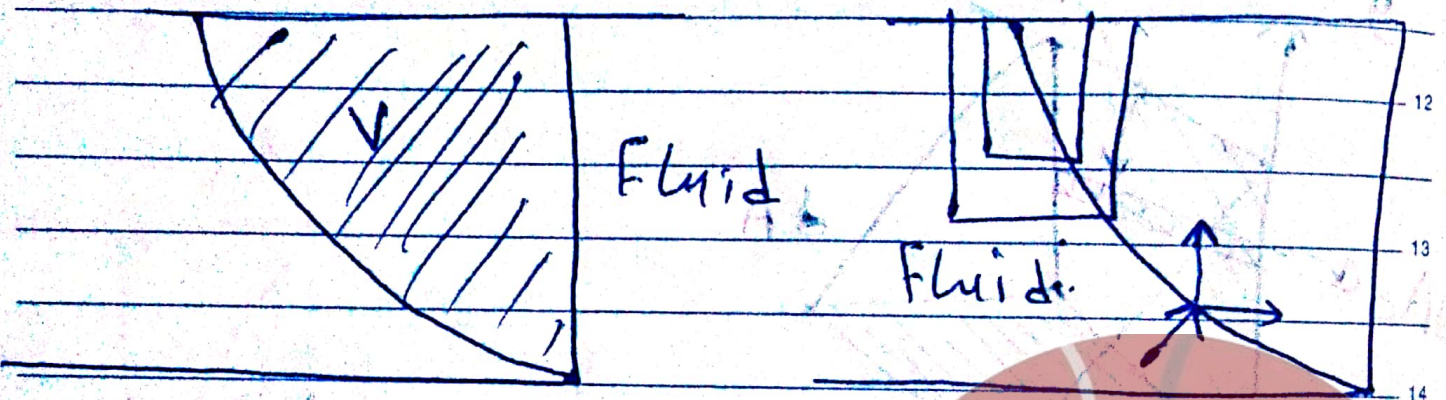
$\rho \times \text{Density} \rightarrow m \times g \rightarrow \text{weight}$

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

$$dF_y = \pm \rho g dv$$

$$\therefore F_y = \pm \rho g v$$

weight of Fluid.



In x

project $\rightarrow Ax$

find $\rightarrow h_c$ for Ax

$$F_x = \rho g h_c Ax$$

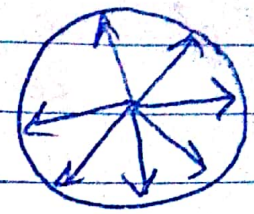
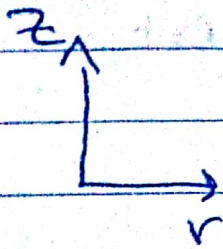
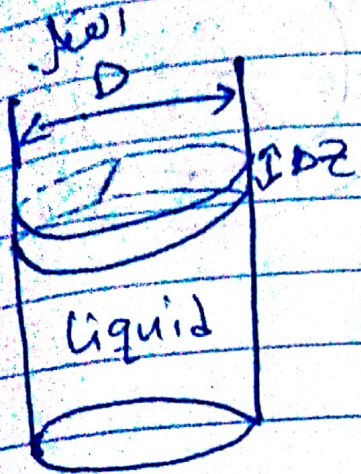
For gases :- $F_x = P_{gas} \times Ax$

$$dF_x = P_{gas} dA \sin \theta$$

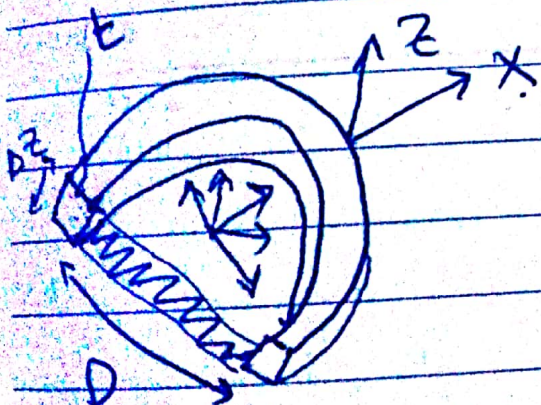
S		4	11	18	25
S		5	12	19	26
M		6	13	20	27
T		7	14	21	28
W	1	8	15	22	29
T	2	9	16	23	30
F	3	10	17	24	

WEEK 37

pressure vessels and piping :-



Liquid force is ~~radial~~ radial; but we are interested in x direction.



At equ. $\rightarrow \sum F_x = 0$

~~p Δz~~ $p D \Delta z = 2 (\sigma_{\text{tensile}} t)$

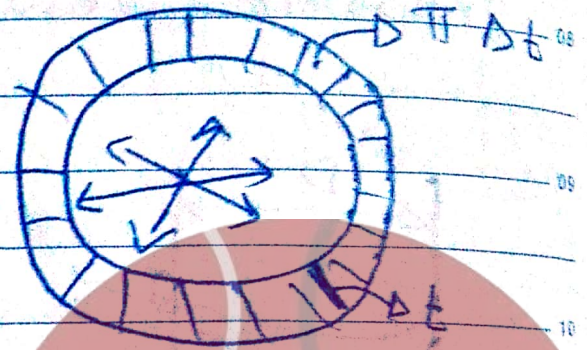
Gauge pressure.

$$t = \frac{p D}{2 \sigma_{\text{tensile}}}$$

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	1	8	15	22
T	2	9	16	23
F	3	10	17	24

similar For sphere

$$P \frac{\pi D^2}{4} = \sigma_{\text{tensile}} \pi \Delta t$$



*Note:

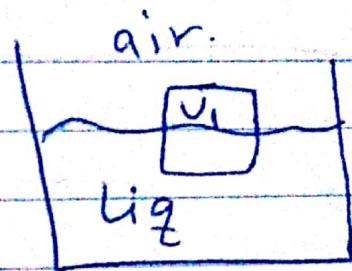
$$e_2 = e_{\text{air}}$$

$$e_{\text{air}} \ll e_{\text{liq}}$$

$$e_1 = e_{\text{liq}}$$

$$e_2 g v_2 \ll e_1 g v_1$$

$$F_y \approx e_1 g v_1$$



*Floating bodies

Buoyant Force: F_b

$$F_b = F_z = W_{\text{body}}$$

$$= e_{\text{body}} v_{\text{body}} g$$

$$v_{\text{body}} = v_1 + v_2$$

$$e_{\text{body}} v_{\text{body}} g = e_1 g v_1 + e_2 g v_2$$



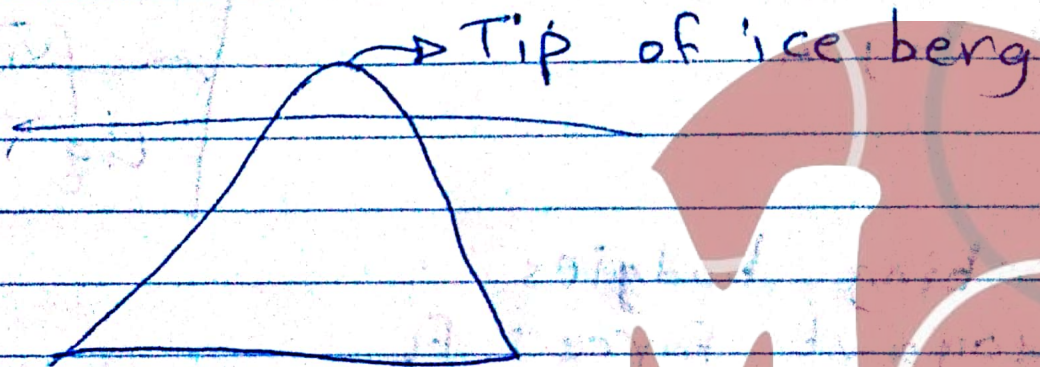
$$v_2 = v_{\text{body}} - v_1$$

$$e_{\text{body}} v_{\text{body}} g = e_1 g v_1 + e_2 g (v_{\text{body}} - v_1)$$

S	4	11	18	25
S	5	12	19	26
M	6	13	20	27
T	7	14	21	28
W	8	15	22	29
T	9	16	23	30
F	10	17	24	

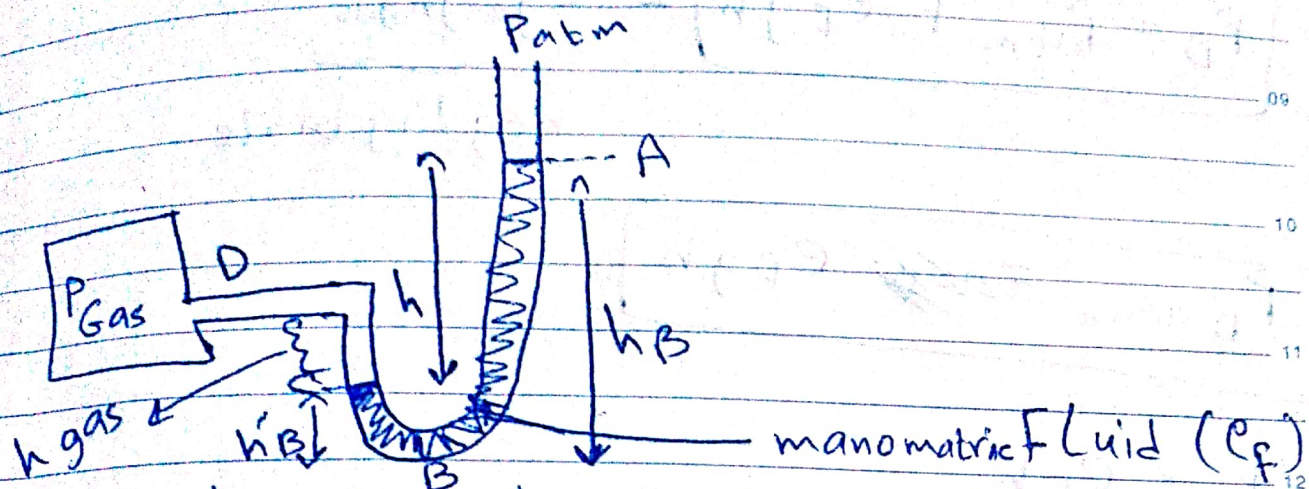
$$V_{\text{body}} (\rho_{\text{body}} - \rho_2) g = V_1 (\rho_1 - \rho_2) g$$

$$\frac{V_1}{V_{\text{body}}} = \frac{(\rho_{\text{body}} - \rho_2) g}{(\rho_1 - \rho_2) g} = \frac{\rho_{\text{body}} - \rho_2}{\rho_1 - \rho_2}$$



ask, believe & recieve

Simple type: used for gases at Low Pressure.



General procedure: start with known pressure; and work backwards to the desired pressure.

A: $P_A = P_{atm}$

B: $P_B = \rho_f g h_B + P_A$

C: $P_C = P_B - \rho_f g h'_B$

D: $P_D = P_C - \rho_{gas} g h_{gas}$

$$P_D = P_{atm} + \rho_f g h_B - \rho_f g h'_B - \rho_{gas} g h_{gas}$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 36

$$P_D = P_{atm} + \rho_f g h - \underbrace{\rho_{gas} g h_{gas}}_{\text{neg Lig table.}}$$

$$P_{D \text{ gauge}} = \cancel{\rho_{atm}} \rho_f g h$$

$$P \propto \rho_f h$$

① * Gas pressure difference types:-
~~Differential type~~

Gas
 ρ_{gas}

$$P_1 > P_2$$

* Neglecting gas static pressure.

$$P_A = P_{A'}$$

$$P_A = P_1$$

$$P_{A'} = P_2 + \rho_f g h$$

manometric
 Fluid (ρ_f)

$$P_1 = P_2 + \rho_f g h$$

$$\cancel{P_1} \cdot P_1 - P_2 = \rho_f g h$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 36

241 - 124

2010

August
SATURDAY

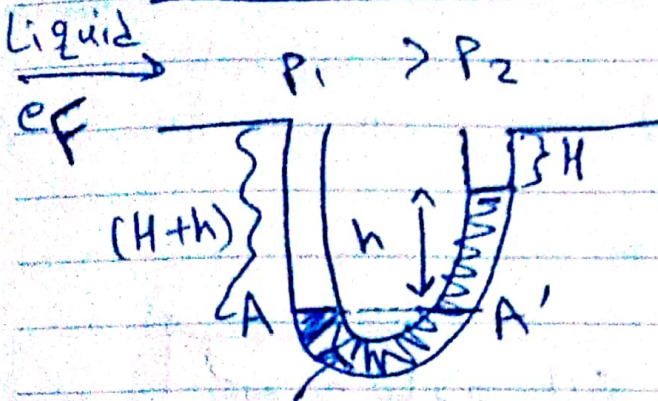
18 Ramadan 1431 H

$f \rightarrow$ manometric
 $F \rightarrow$ Liquid.

آب
السبت 28

18 رمضان 1431 هـ

② * Differential type [used for Liquid ΔP]
 $\hookrightarrow$ Difference in densities.



$$P_A = P_{A'}$$

$$P_A = P_1 + \rho_F g (H+h)$$

$$P_{A'} = P_2 + \rho_f g h + \rho_F g H$$

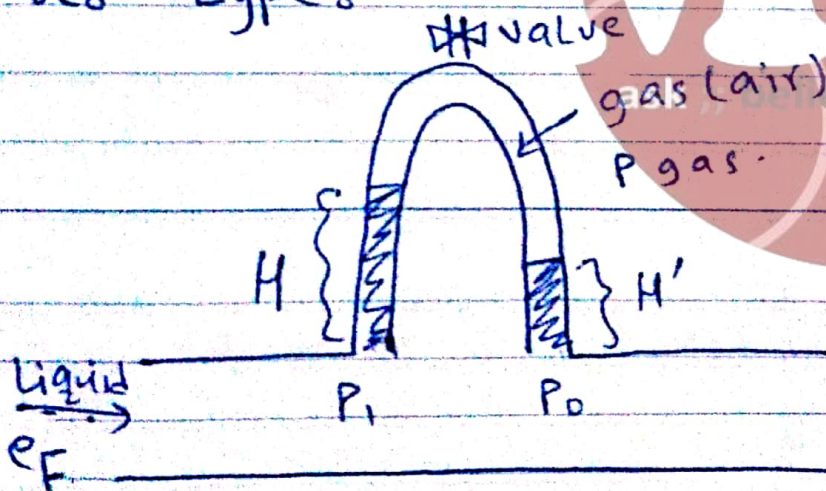
manometric
fluid ρ_f

$$P_1 + \rho_F g (H+h) = P_2 + \rho_f g h + \rho_F g H$$

$$P_1 - P_2 = -\rho_f g h - \rho_F g h$$

$$= (\rho_f - \rho_F) g h = \Delta \rho g h$$

③ Inverted type:-



ملاحظات

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 36

240-125

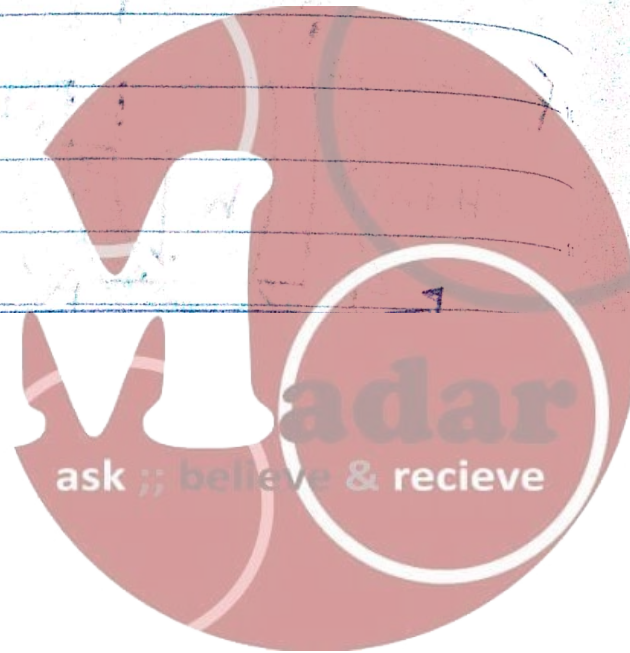
2010

$$P_1 = \rho_f g H + P_{\text{gas}}$$

$$P_2 = \rho_f g H' + P_{\text{gas}}$$

$$P_1 - P_2 = \rho_f g (H - H')$$

$$(P_1 - P_2) = \rho_f g h$$

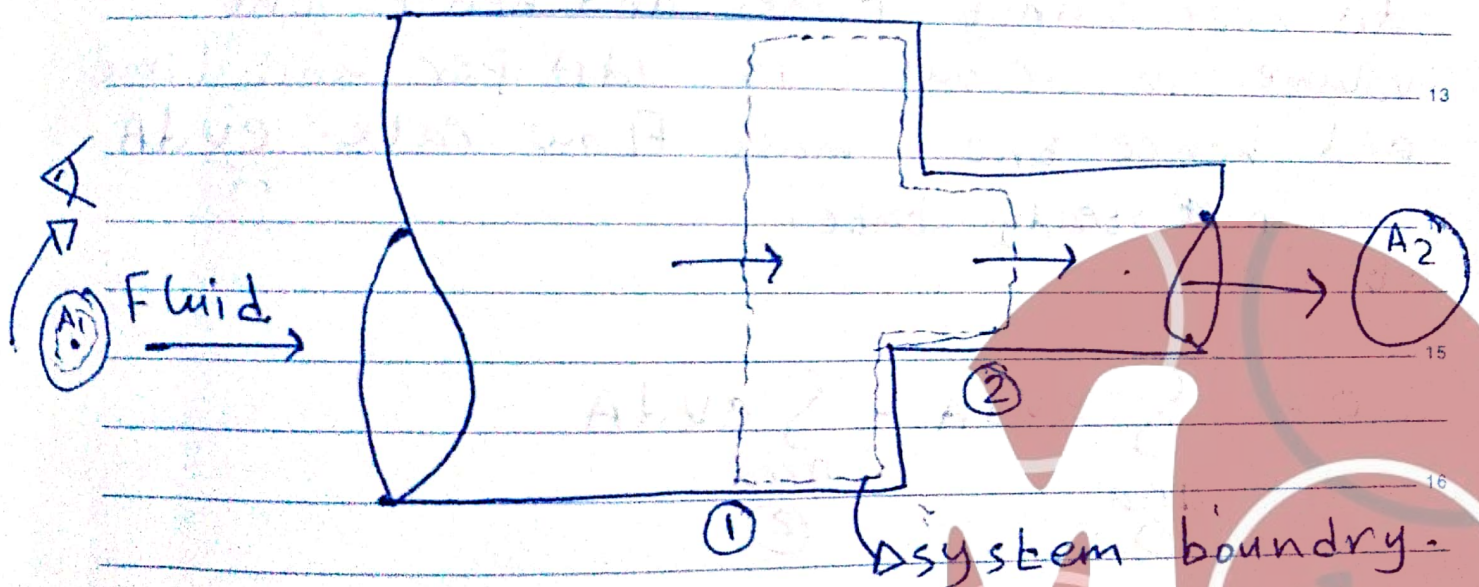


* Balance equation . معادلات التوازن

~~at steady state~~

- steady state مع الحالة المستقرة
- uniform متجانس

- Macroscopic steady state Mass balance



at s.s

Mass Flow = mass Flow rate at ②
rate at ①

Areas A_1 and A_2 are $\perp$ to Flow.

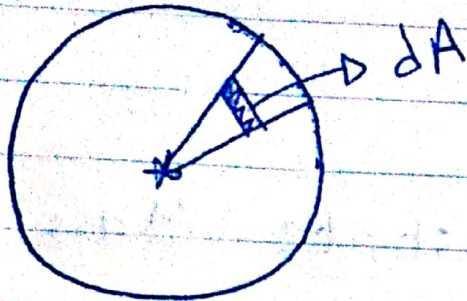
S	1	8	15	22	29
S	2	9	16	23	30
M	3	10	17	24	31
T	4	11	18	25	
W	5	12	19	26	
T	6	13	20	27	

WEEK 35

237 - 128

2010

- The velocity is not the same at every point on the areas A_1 and A_2 .



Let v = uniform velocity over a small ~~elemental~~ elemental area dA .

The fluid moves a distance v through dA over a unit time and hence the volume in or out is $v dA$ per unit time and hence the mass Flow rate. $\rho v dA$
 at s.s. $\rightarrow$ steady state.

$$0 = \int_{\text{area ①}} \rho v dA - \int_{\text{area ②}} \rho v dA$$

$$\therefore \int_{\text{area ①}} \rho v dA = \text{constant} \rightarrow \text{mass is conserved}$$

S	1	8	15	22	29
S	2	9	16	23	30
M	3	10	17	24	31
T	4	11	18	25	
W	5	12	19	26	
T	6	13	20	27	

- In terms of average velocities

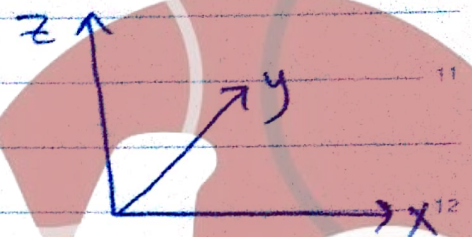
$$\rho_1 v_1 A_1 = \rho_2 v_2 A_2 = \dot{m} = \text{mass Flow rate}$$

$$= \text{constant}$$

$$(V_{\text{average}}) = \frac{\int v dA}{\int dA} = \frac{\text{volumetric flow rate}}{\text{Area.}}$$

↳ not velocity (volumetric flow rate)

$$\frac{\iint v(z, x) dz dx}{\iint dz dx}$$

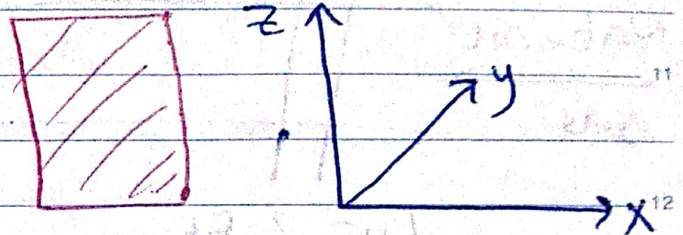


ask ;; believe & recieve

$$(V_{\text{average}}) = \frac{\int v dA}{\int dA} = \frac{\text{volumetric flow rate}}{\text{Area.}}$$

↳ not velocity (volumetric flow rate)

$$\frac{\iint v(z, x) dz dx}{\iint dz dx}$$



Notes: ① For ~~Laminar~~ Laminar Flow v varies over the area $\perp$ to while for turbulent flow it may be considered constant [Most industrial ~~flow~~ Flows are turbulent].

② For ~~constant~~ constant $e_1 = e_2 = e = \text{const.}$

$$\cancel{\rho_1} v_1 A_1 = \cancel{\rho_2} v_2 A_2 \rightarrow v_1 A_1 = v_2 A_2$$

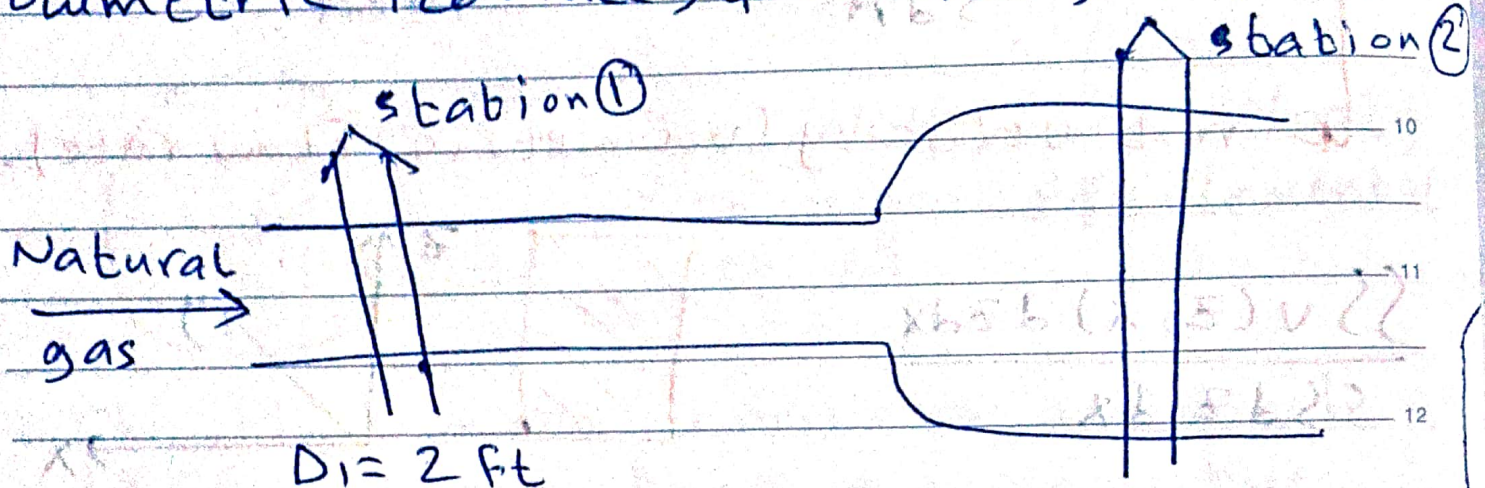
S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 35

235 - 130

ask & recieve

Units ? mass Flow rate in kg/s , lbm/s
volumetric Flow rate, Q m^3/s , ft^3/s



$$D_1 = 2 \text{ ft}$$

$$P_1 = 800 \text{ psia}$$

$$T_1 = 70^\circ \text{ F}$$

$$V_1 = 50 \text{ ft/s}$$

$$D_2 = 3 \text{ ft}$$

$$P_2 = 500 \text{ psia}$$

$$T_2 = 70^\circ \text{ F}$$

$$V_2 = ?$$

at s.s $\rho_1 V_1 A_1 = \rho_2 V_2 A_2$

$$V_2 = \left(\frac{\rho_1}{\rho_2} \right) \left(\frac{A_1}{A_2} \right) \cdot V_1$$

$$\frac{A_1}{A_2} = \left(\frac{\pi D_1^2 / 4}{\pi D_2^2 / 4} \right) = \left(\frac{D_1}{D_2} \right)^2$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

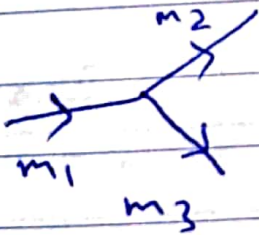
$$e = \frac{P \cdot M}{R \cdot T} \quad \text{ideal gas} \rightarrow \frac{e \cdot T}{P} = \frac{M}{R} \rightarrow$$

$$\frac{e_1 T_1}{P_1} = \frac{e_2 T_2}{P_2} \rightarrow \frac{e_1}{e_2} = \frac{P_1}{P_2}$$

$$\Rightarrow u_2 = \left(\frac{P_1}{P_2} \right) \left(\frac{D_1}{D_2} \right)^2 \cdot u_1 = \left(\frac{800 \text{ Psia}}{500 \text{ Psia}} \right) \left(\frac{2 \text{ ft}}{3 \text{ ft}} \right)^2 \cdot 50 \frac{\text{ft}}{\text{s}}$$

volume.
 $V = uA$

$$= 35.5 \text{ ft/s}$$

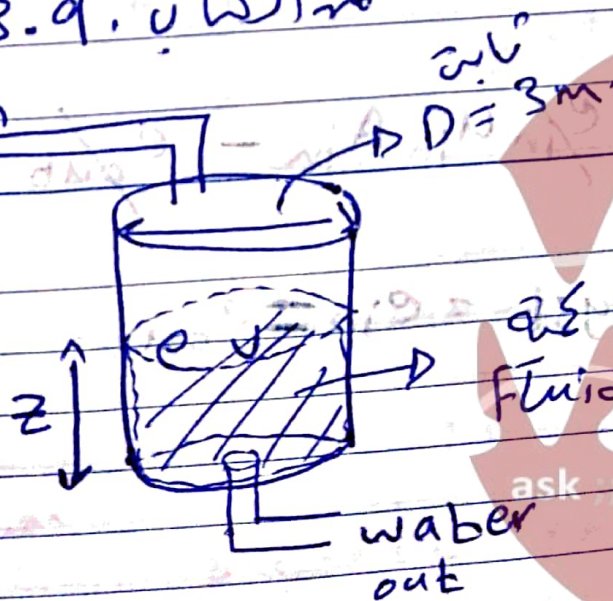


$$m_1 = m_2 + m_3$$

$$m = e \cdot A$$

example 3.9. u (S) in

water in
 $D_{in} = 0.1 \text{ m}$
 $V_1 = 2 \text{ m/s}$



$D_2 = 0.2 \text{ m}$
 $V_2 = 1 \text{ m/s}$

S	7	14	21	28
S	1	8	15	22
M	2	9	16	23
T	3	10	17	24
W	4	11	18	25
T	5	12	19	26
F	6	13	20	27

- is the level rising or falling? At what rate?

not s.s

Mass balance:

$$\left(\frac{dm}{dt}\right)_{\text{system}} = \text{mass in} - \text{mass out}.$$

$$= \dot{m}_{\text{in}} - \dot{m}_{\text{out}}$$

231 - 134

20 August
FRIDAY

10 Ramadan 1431 H

الجمعة

١٠ رمضان ١٤٣١ هـ

$$m = \rho V$$

$$\dot{m} = \rho u A$$

$$\frac{d(\rho V)_{\text{system}}}{dt} = \rho_{\text{in}} u_{\text{in}} A_{\text{in}} - \rho_{\text{out}} u_{\text{out}} A_{\text{out}}$$

$$\dot{e}_{\text{sys}} = \dot{e}_{\text{in}} \pm \dot{e}_{\text{out}}$$

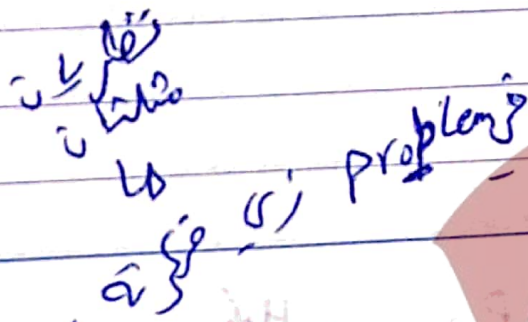
S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 34

$$= 0.0157 - 0.0314 = -0.0157 \text{ m}^3/\text{s}$$

$\frac{dv}{dt} = \frac{d(Az)}{dt} \Rightarrow A \frac{dz}{dt}$ معدل تغير الارتفاع مع الزمن

$$= \frac{1}{\frac{\pi 3^2 m^2}{4}} \times (-0.0157 \text{ m}^3 \text{ s}^{-1}) = -0.0022 \text{ m s}^{-1}$$



- لوفاف في مالقة في حارة و بسال مني

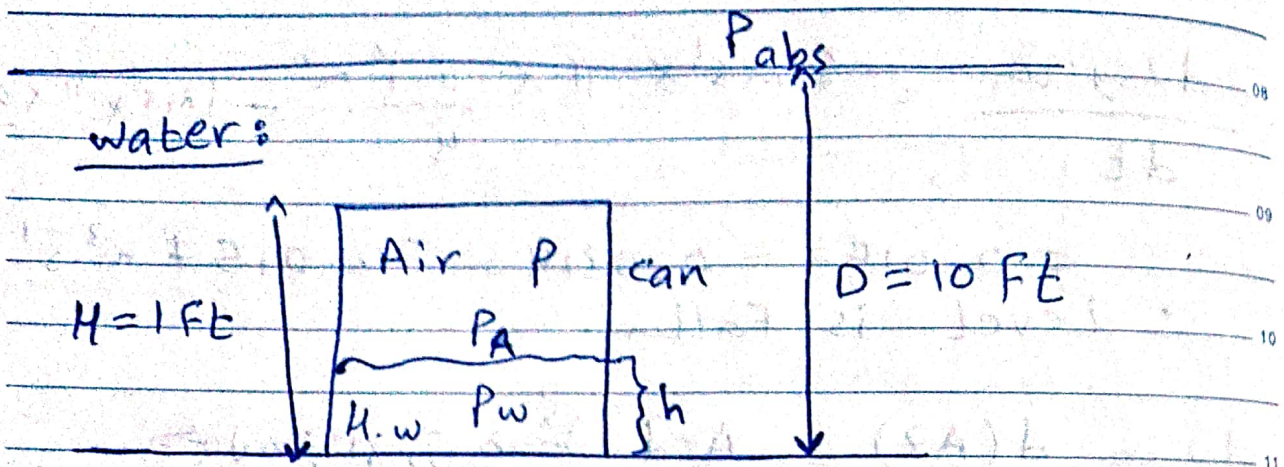
بِسْمِ تَرْكِزِ اَللّٰهِ بِالْخِزَانَةِ رُحْمَا اَمَّا قَدْ

$$m = \frac{C}{V}$$

↳ concentration

(salt balance)

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	



$P_a = P_w$ at interface

*originally the pressure inside the can = P_{atm}

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$T_1 = T_2$$

$$P_1 = P_{atm}$$

$$V_1 = H \cdot A$$

$$V_2 = (H - h) \cdot A$$

$$P_a = P_{atm} - \frac{H \cdot \rho \cdot g}{(H - h) \cdot \rho \cdot g}$$

$$P_a = P_{atm} \cdot \frac{H}{H - h}$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 34

August
MONDAY

6 Ramadan 1431 H

1 Ft = 12 in → حفظ

آب
الاثنين 16

6 رمضان ١٤٣١ هـ

$$P_w = P_{atm} + \rho g (D - h)$$

$$\therefore P_{atm} + \rho g (D - h) = P_{atm} \frac{H}{(H - h)}$$

$$h^2 - \left[\frac{P_{atm}}{\rho g} + (D + H) \right] h + DH = 0$$

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$a = 1$$

$$b = - \left[\frac{P_{atm}}{\rho g} + (D + H) \right]$$

$$c = DH$$

← هنا خواص الجواب

$$\frac{P_{atm}}{\rho g} = 14.7 \frac{\text{lb}_f}{\text{in}^2} \times \frac{144 \text{ in}^2}{1 \text{ Ft}^2} \times \frac{32.2 \text{ lb}_m \cdot \text{Ft}}{\text{lb}_f \cdot \text{s}^2}$$

$$\frac{1}{62.3 \frac{\text{lb}_m}{\text{Ft}^3}} \times 32.2 \frac{\text{Ft}}{\text{s}^2}$$

ملاحظات

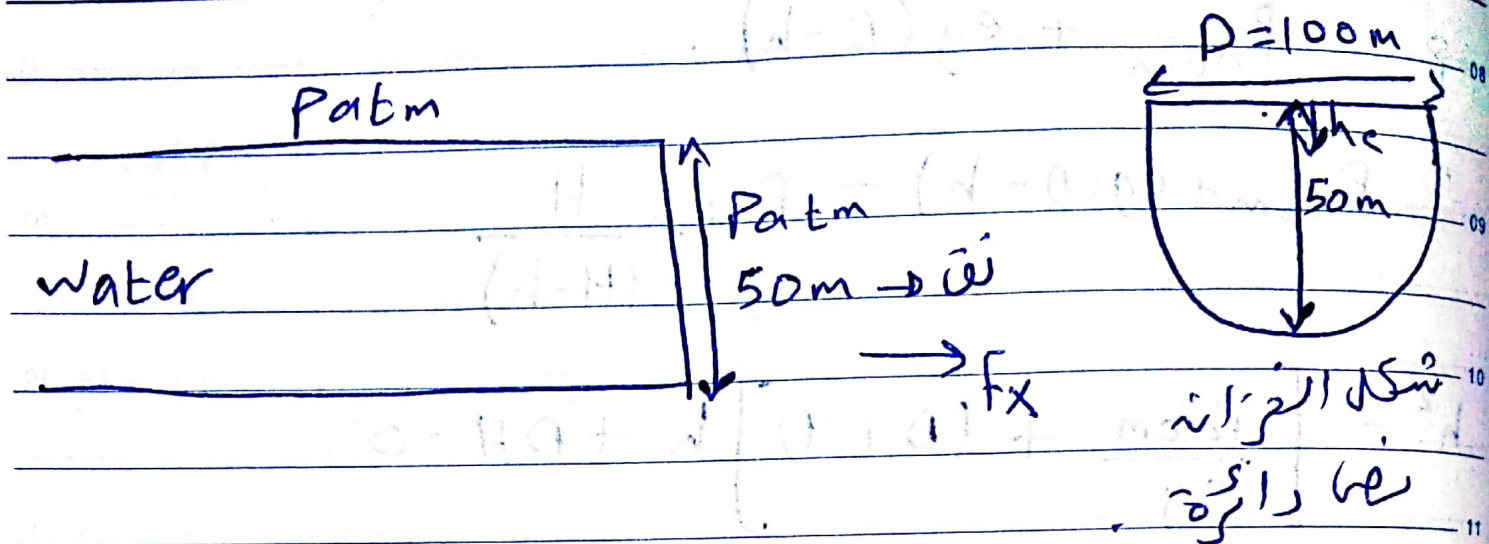
ask, believe & recieve

$$= \frac{14.7 \times 144}{62.3} \text{ Ft}$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 34

2010



$$F_x = \int dF_x = \int p \sin \theta dA.$$

$$p = \rho g h$$

centroid.

$$F_x = P_c A_x.$$

$P_c = p$ at centroid.

$A_x = x$ -projected area.

$$P_c = \rho g h_c$$

$h_c =$ centroid.

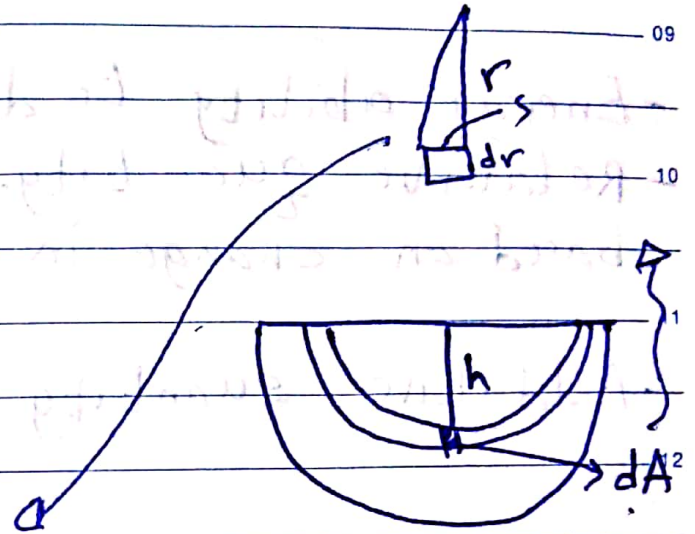
$$h_c = \frac{2D}{3\pi} = \frac{4R}{3\pi}$$

$$A_x = \frac{\pi R^2}{2}$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

$$F_x = \left(eg \frac{4R}{3\pi} \right) \times \frac{4R^2}{2}$$

$$F_x = \frac{2}{3} eg R^3$$



$$F_x = \int eg h dA$$

$$\Delta A = s \Delta r = r \cdot \sin \theta \Delta r = r \Delta \theta \Delta r$$

$$dA = r d\theta dr$$

$$h = r \sin \theta$$

$$r = 0 \rightarrow R$$

$$\theta = 0 \rightarrow \pi$$

$$F_x = \int_0^{\pi} \int_0^R eg r \sin \theta \cdot r dr d\theta$$

$$= - \left[\frac{eg R^3}{3} \cos \theta \right]_0^{\pi}$$

$$F_x = \frac{2}{3} eg R^3$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

* First Law of Thermodynamics. (T/D)
 ≡ Law of conservation of Energy.

- Energy: ability to do work [Abstract term]
- Relative quantity. [all calculation are based on change in energy].
- Additive quantity.

224 - 141

13 August
FRIDAY

3 Ramadan 1431 H

الجمعة

٣ رمضان ١٤٣١ هـ

- Forms of Energy: subject to some restrictions,
 all forms of energy are ~~interconvertible~~ interconvertible.
 [restrictions apply to direction of conversion].

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

ask, believe & recieve

ملاحظات

- Internal Energy U (unspecific internal energy).

- Kinetic Energy KE (ke : $KE/\text{unit-mass}$)

- Potential Energy PE (pe : $PE/\text{unit-mass}$)

- In Fluid mechanics (Engineering problems).

PE = energy that a body possesses due to its position in gravitational field.

- Electrostatic energy.

- magnetic energy.

- surface.

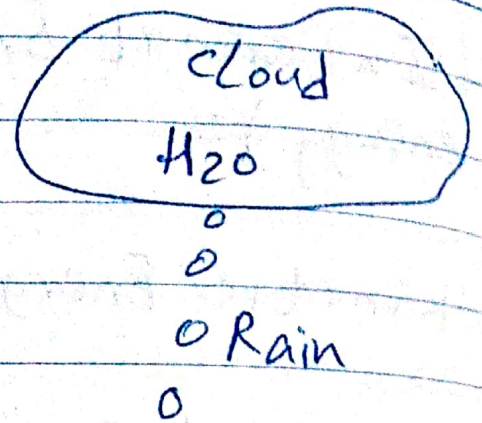
- Nuclear.

- In conventional Fluid mechanics problems we deal with KE and PE .

S	7	14	21	28
S	1	8	15	22
M	2	9	16	23
T				30

ask : believe & recieve

* **Energy Transfer** -
 • Heat: Energy in transit.
 Energy transfer $\dot{M}$
 due to ΔT

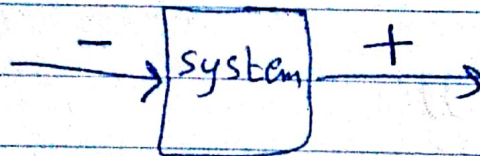


* **Work**: Energy transferred
 to or from an object.

Lake H₂O

ex: $\text{work} = \int F \cdot dx$ x : distance.

$$F = PA \rightarrow \text{work} = \int P A dx = \int P dV \quad \text{injection work.}$$



* **Radiation**: Energy transferred as electromagnetic waves.

Energy $\propto \Delta T^4$

* **Energy balance**

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

08

$$\text{Accumulations} = \text{Flow in} - \text{Flow out} + \text{creation} - \text{Destruction}$$

Energy can
neither be created
nor destruction.

11

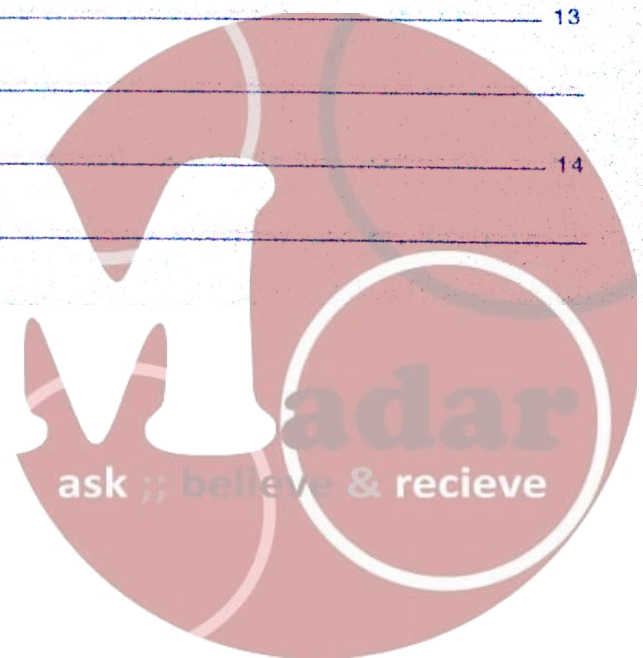
Excluding electrostatic magnetic
surface and nuclear energies.

12

$$EB \rightarrow \text{Accumulation} = \text{Flow in} - \text{Flow out}$$

13

14



EB $\Rightarrow$

$$d[m(u + pe + ke)]_{\text{system}} = \left\{ (u + pe + ke)_{\text{in}} dm_{\text{in}} + dQ_{\text{in}} \right. \\ \left. + (u + pe + ke)_{\text{out}} dm_{\text{out}} + dQ_{\text{out}} \right\}$$

Heating
or cooling
in +ve
out -ve

Flow by matter

Accumilation =

+ dw_{in}

+ dw_{out}

↓
mechanical work (various forms).

in +ve

out -ve.

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 33
221 - 144

2010

ask :: believe & recieve

$$d[m(u+pe+ke)]_{\text{system}} = (u+pe+ke)_{\text{in}} dn_{\text{in}} - (u+pe+ke)_{\text{out}} dn_{\text{out}}$$

$$+ dQ + dw$$

$$dQ = dQ_{\text{in}} - dQ_{\text{out}}$$

$$dw = dw_{\text{in}} - dw_{\text{out}}$$

- closed system at s.s i-

$$0 = dQ + dw \rightarrow dw = -dQ$$

$$0 = dQ - dw \rightarrow dw = +dQ$$

dw = injection work + all other forms of mechanical work.

$$dw = dw_{\text{inj}} + dw_{\text{a/o}}$$

$$dw = \left[\frac{P}{e} dm_{\text{in}} - \frac{P}{e} dm_{\text{out}} \right] + dw_{\text{a/o}}$$

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

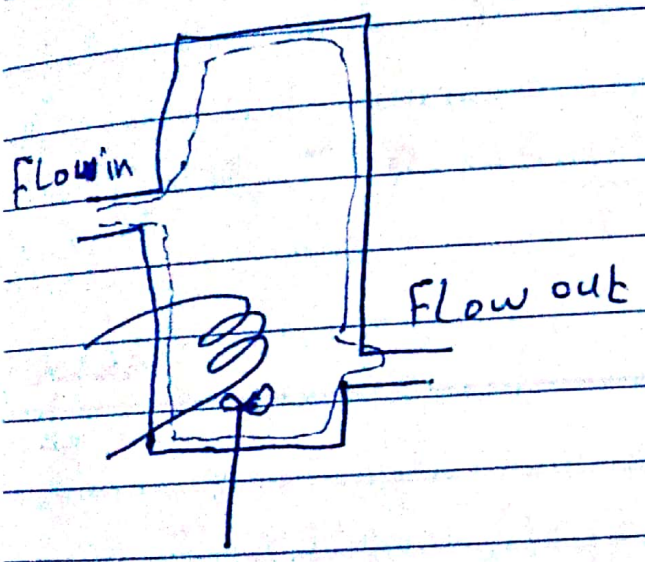
$$dw_{\text{inj}} = \underbrace{P \cdot \underbrace{v}_{dr}}_{\frac{P}{e} dm}$$

Assumptions:

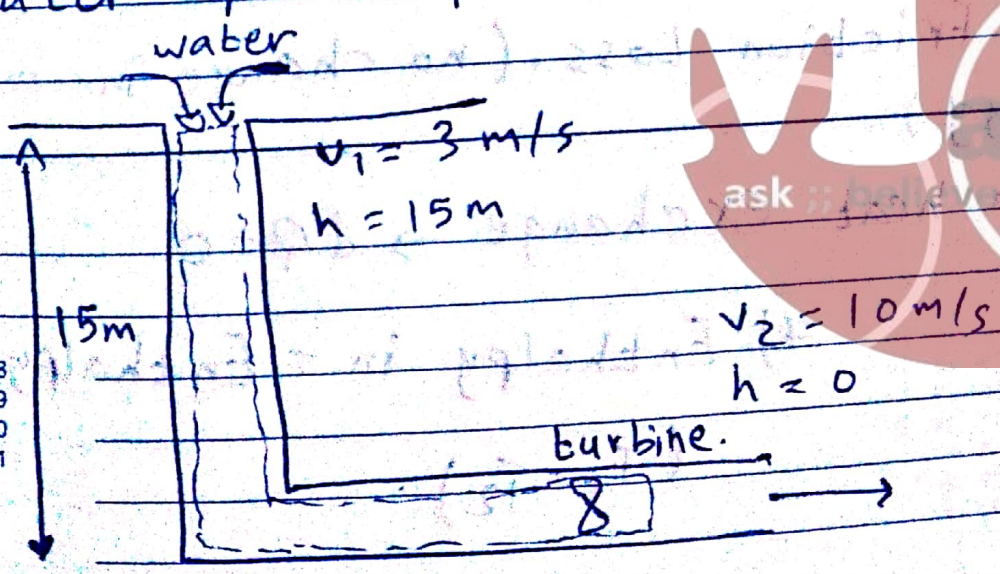
$$d[m(u + \frac{P}{\rho} + ke)]_{\text{sys}} = \overbrace{(u + \frac{P}{\rho} + pe + ke)}^h d m_{\text{in}} -$$

$$\overbrace{(u + \frac{P}{\rho} + pe + ke)}^h d m_{\text{out}} + d\dot{Q} + d w_{\text{a/o}}$$

h : enthalpy.



Exe water power plant.



S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

work done by plant / kg of water.?

* Assumptions:-

- 1) s.s $\rightarrow$ Accumelation ~~is~~ $\rightarrow 0$.
- 2) homogeneous.
- 3) no chemical rxn.

6 August
FRIDAY

25 Shaaban 1431 H

الجمعة

٢٥ شعبان ١٤٣١ هـ

4) $d_{min} = d_{m out} = d_m$

5) no Friction Loss. (no change in internal energy)

6) no heat exchange $\rightarrow dQ = 0$

7) Enthalpy in = Enthalpy out
($T_1 = T_2$).

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 32

218 - 147

2010

$$0 = (P_e + K_e)_{in} - (P_e + K_e)_{out} \frac{dw_{a/o}}{dm}$$

$$\frac{dw_{a/o}}{dm} = - \left[g(z_1 - z_2) + \frac{1}{2}(v_1^2 - v_2^2) \right]$$

$$= - \left[\frac{9.81 \text{ m}}{\text{s}^2} (15 \text{ m} - 0 \text{ m}) + \frac{1}{2} \left(\frac{3^2 \text{ m}^2}{\text{s}^2} - \frac{10^2 \text{ m}^2}{\text{s}^2} \right) \right]$$

$$= -10.165 \frac{\text{m}^2}{\text{s}^2} \equiv (\text{J/kg})$$

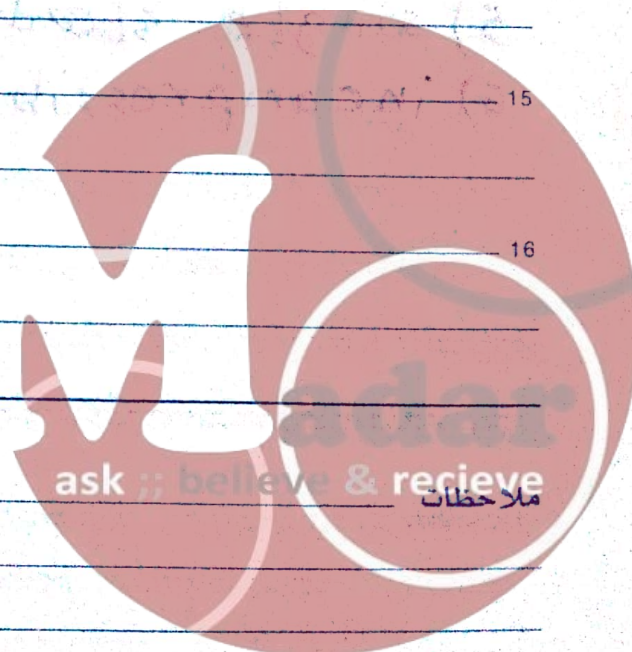
$$\frac{\text{m}^3}{\text{s}^2} \times \text{kg} = \left(\text{kg} \cdot \frac{\text{m}}{\text{s}^2} \right) \cdot \text{m}$$

F x dist.

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 32

215 - 149



CH5 Bernoulli's Equation (BE)

- BE $\equiv$ Energy balance at steady state and incompressible Flow.

- under the following assumptions:

- 1) Electrostatic, magnetic and surface energies are negligible and no nuclear reaction
- 2) contents of system are uniform.
- 3) IN and out Flows are uniform.
- 4) g is constant.
- 5) single steady state.
- 6) incompressible Fluid.

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	

August
MONDAY

21 Shaaban 1431 H

آب
الاثنين

2

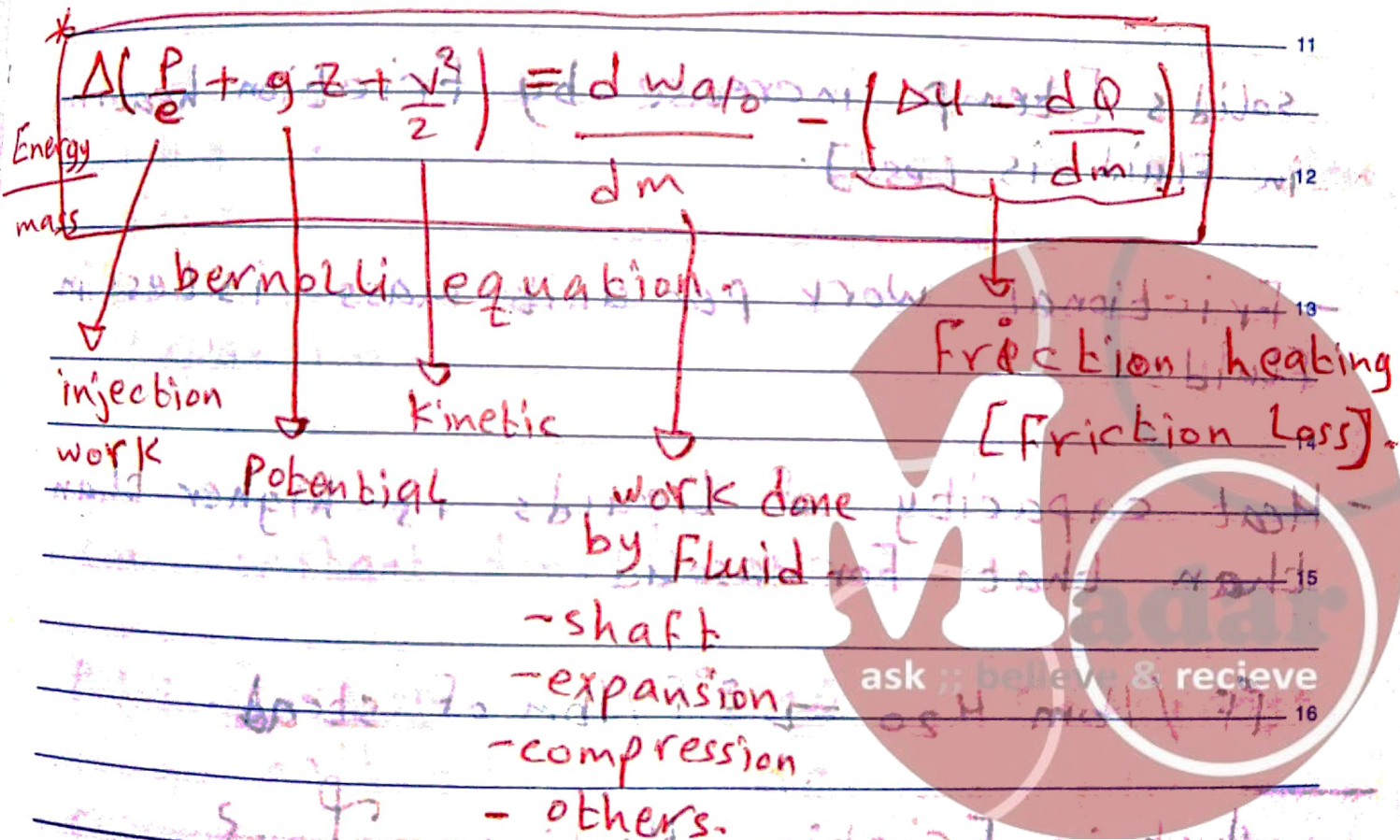
٢١ شعبان ١٤٣١ هـ

in +ve
out -ve

$$\left(u + \frac{p}{\rho} + gz + \frac{v^2}{2} \right)_{in} - \left(u + \frac{p}{\rho} + gz + \frac{v^2}{2} \right)_{out} + \frac{dQ}{dm}$$

$$+ dW_{a/o} = 0$$

Rearrange: $\Delta \left(u + \frac{p}{\rho} + gz + \frac{v^2}{2} \right) = dW_{a/o} - dQ$



ملاحظات

* Friction Heating, $\mathcal{F}$

- General?

Friction heating effects in fluids are less than friction heating effects in solids [temp increase by friction heating in fluid is less].

- Frictional work per unit mass is less in fluids.

- Heat capacity of liquids is higher than that for a solid.

$1^\circ\text{F}/\text{lbm H}_2\text{O} \Rightarrow 8^\circ\text{F}/\text{lbm of steel}$

* what is Friction Heating, $\mathcal{F}$?

Involves conversion into internal energy of some other kind of energy

(PE, KE) or external work

(injection, shaft work or change in volume)

S		7	14	21	28
S	1	8	15	22	29
M	2	9	16	23	30
T	3	10	17	24	31
W	4	11	18	25	
T	5	12	19	26	
F	6	13	20	27	

WEEK 32

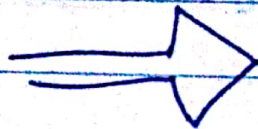
213 - 152

- Increase in internal energy is industrially useless.

$\therefore$ Friction heating $\equiv$ Friction Loss [Note energy does not disappear].

Energy in valuable form

Pe, ke, injection, expansion.



Energy of useless form

(~~increased~~ internal energy).

For constant density materials.

$$\Delta u = \frac{\text{Friction heating}}{\text{unit mass}} + \frac{dQ}{dm}$$

Rearrange.

$$Q_f = \Delta u - \frac{dQ}{dm}$$

S	3	10	17	24	31
S	4	11	18	25	
M	5	12	19	26	
T	6	13	20	27	
W	7	14	21	28	
T	1	8	15	22	29
F	2	9	16	23	30

Notes

- $f = 0 \Rightarrow$ frictionless Flow.
- f For real Fluid Flow problems is always +ve.
- $f = -ve \Rightarrow$ Assumed direction of Flow is incorrect.

210 - 155

30

July
FRIDAY

18 Shaaban 1431 H

تموز
الجمعة

18 شعبان 1431 هـ

Important $\rightarrow$ For real Flows, Friction losses signify decrease in p, z, v , work extracted by a turbine or increase in work done by a pump or combination.

S	3	10	17	24	31
S	4	11	18	25	
M	5	12	19	26	
T	6	13	20	27	
W	7	14	21	28	
T	1	8	15	22	29
F	2	9	16	23	30

WEEK 31

211 - 154

2010

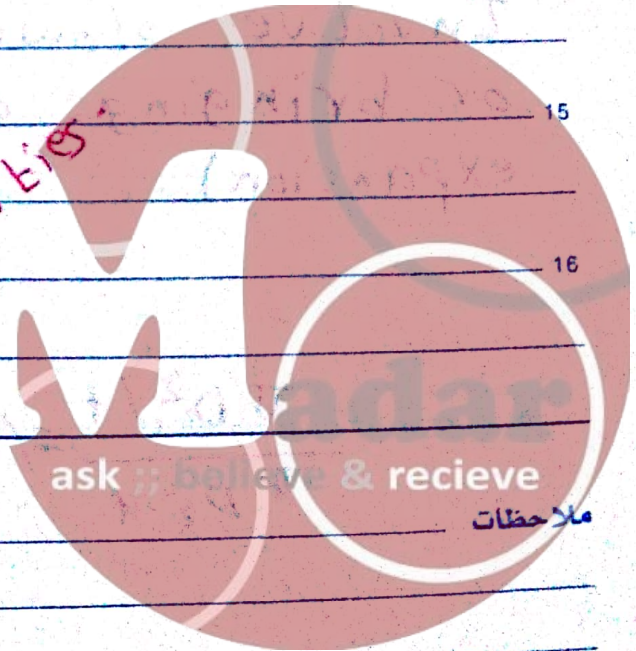
- بالتحويل مع المعادلة السابقة

$$\Delta \left(\frac{p}{\rho} + gz + \frac{v^2}{2} \right) = \hat{w} - \mathcal{F}$$

Energy destruction term.

Note: Incompressible Fluid $\equiv$ changes in density are negligible.

all steady flows of liquids.
most steady flows of gasses at low velocities



S	3	10	17	24	31
S	4	11	18	25	
M	5	12	19	26	
T	6	13	20	27	
W	7	14	21	28	
T	8	15	22	29	
F	9	16	23	30	

WEEK 21

Zero Flow (static fluid).

$$BE \Rightarrow \Delta\left(\frac{P}{\rho} + gz\right) = 0$$

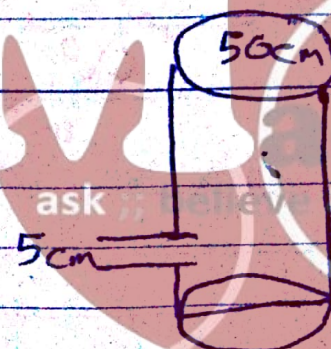
* Applications of Bernoulli's Equation?

$$\Delta\left(\frac{P}{\rho} + gz + \frac{v^2}{2}\right) = \hat{w} - \oint$$

- Diffusers and sudden expansions?

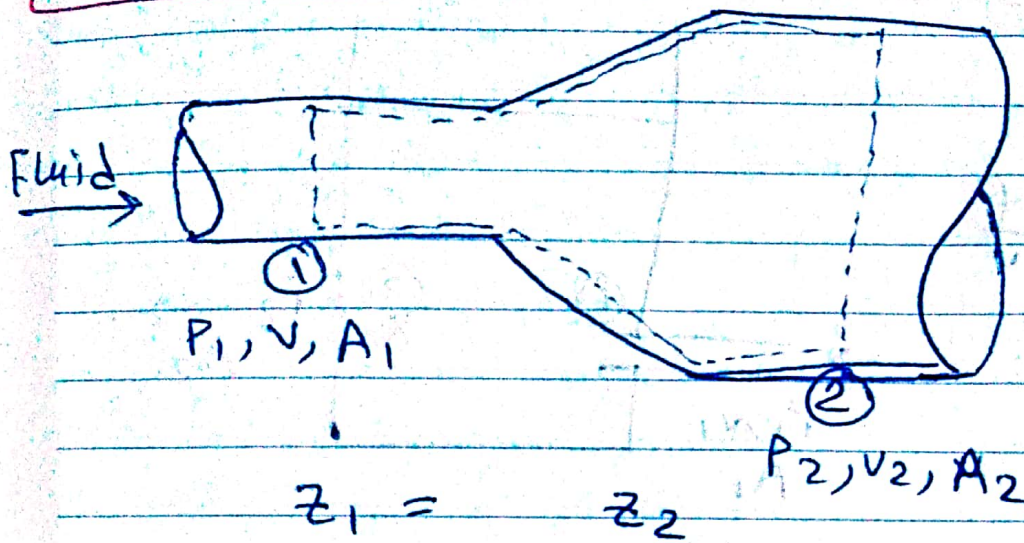
Involve slowing down a fluid (diffusers) or bringing a fluid to a halt (sudden expansion).

$$\frac{V D_1^2/4}{V D_2^2/4} = \left(\frac{5}{50}\right)^2$$



S	3	10	17	24	31
S	4	11	18	25	
M	5	12	19	26	
T	6	13	20	27	
W	7	14	21	28	
T	1	8	15	22	29
F	2	9	16	23	30

* Diffusers



* Bernoulli's Equation :

$$\left(\frac{P_2 - P_1}{\rho} \right) + \left(\frac{v_2^2 - v_1^2}{2} \right) = - \mathcal{F}$$

* CE: constant $\rho \rightarrow v_2 = v_1 \cdot \left(\frac{A_1}{A_2} \right)$

$$\therefore (P_2 - P_1) = \rho \frac{v_1^2}{2} \left[1 - \left(\frac{A_1}{A_2} \right)^2 \right] - \rho \mathcal{F}$$

Analysis:

- $v_1 < v_2 \rightarrow$ decrease in KE
- KE $\rightarrow$ injection work + friction loss
- $P_2 > P_1 \rightarrow$ pressure recovery
- usually pressure recovery $\approx 90\%$ of friction loss situation.

S	3	10	17	24	31
S	4	11	18	25	
M	5	12	19	26	
T	6	13	20	27	
W	7	14	21	28	
T	1	8	15	22	29
F	2	9	16	23	30

WEEK 31

207 - 158

$$\mathcal{F} = \frac{1}{10} \text{ decrease in KE.}$$

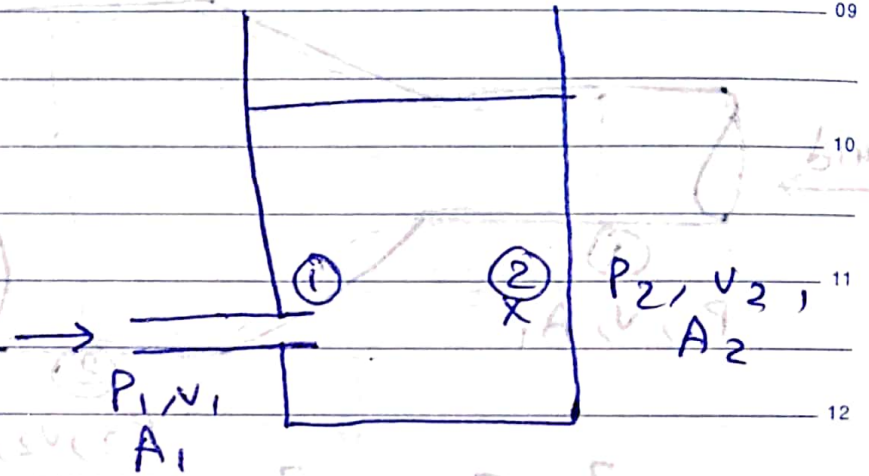
2010

* sudden expansion $\phi \rightarrow 0$

$$\left(\frac{P_2 - P_1}{\rho} \right) = \frac{v_1^2}{2} - \phi$$

$$v_2 = v_1 \cdot \left(\frac{A_1}{A_2} \right)$$

$\uparrow \approx 0$



$$v_2 \rightarrow 0$$

point ② is far from inlet so that $v_2 \approx 0$

$$(P_2 - P_1) = \rho \frac{v_1^2}{2} - \phi$$

* Analysis:

~~* Analysis:~~ similar to diffuser $\left(\frac{A_1}{A_2} \right)^2 \approx 0$

ϕ is much larger than that for diffuser.

S	3	10	17	24	31
S	4	11	18	25	
M	5	12	19	26	
T	6	13	20	27	
W	7	14	21	28	
T	1	8	15	22	29
F	2	9	16	23	30

• ALL KE $\rightarrow$ internal energy.

• From experiments

ϕ = decrease in KE per unit mass.

WEEK 31

206 - 159

2010

2. $p_2 = p_1 \Rightarrow$ no pressure recovery. 08

$p_{at} \text{ ~~the~~ inlet ~~the~~ } = p \text{ in fluid into which it flows.}$ 09

