uud → udd

u → d + e

$\frac{2}{3}$ $-\frac{1}{3}$ $2-\left(\frac{1}{3}\right)$

FORCES, DENSITY AND PRESSURE

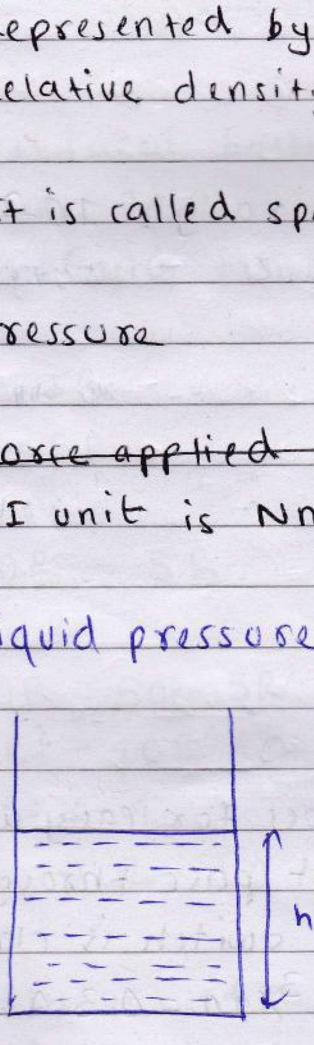
Density

- Mass per unit volume of a substance.
- SI unit is $kg\,m^{-3}$.
- Compactness of molecules or particles in a substance.
- Represented by Rho ρ
- Relative density = $\dfrac{\text{Density of substance}}{\text{Density of } 4^\circ C \text{ pure water}}$
- It is called specific gravity, and is unitless.

Pressure

- ~~Force applied per~~ Perpendicular force per unit area.
- SI unit is Nm^{-2}.

Liquid pressure



$P = F/A$ Liquid exerts pressure because of its weight.

or, $P = mg/A$

or, $P = \dfrac{mg\,\ell}{A \times \ell}$

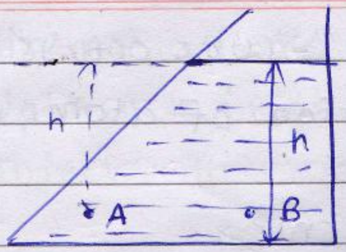
or, $P = \dfrac{mg\ell}{V}$

$\therefore P = \rho g h$ $[\rho g h]$

$\Delta P = \Delta h \rho g$ → This is applicable for most fluids, except for gas in closed container.

For large change in h, g will also change, which ~~will~~ might change density of fluids as well.

Fluids have property to flow, so pressure in fluids are in all directions.



Pressure at A = Pressure at B
If this wasn't true, liquid from B would flow to A, which isn't possible.

$P_{total} = P_{liquid} + P_{atmosphere}$

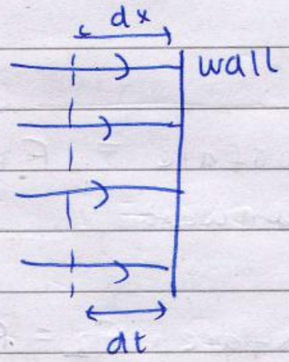
$P_{atmosphere} = 760$ mm of Hg

or, $P = \frac{760}{1000} \times 13600 \times 9.81$ $[13600 = \rho_{mercury}]$

$\therefore P \approx 10^5$ Pa $(1.01 \times 10^5$ Pa$)$

A wind of speed 33 ms^{-1} with 1.2 kgm^{-3} density hits wall of 12m^2 at right angles. What is the approximate force exerted by air on wall.

$F = dp/dt = m\,dv/dt = m/dt \times 33\,dv = V \times \rho \times dv/dt$

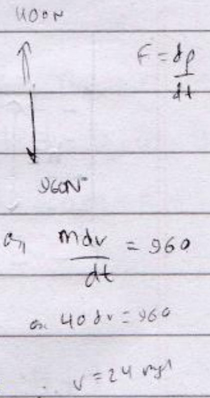


$F = \frac{A \times dx \times dv \times \rho}{dt}$

$= A \times v \times dv \times \rho$

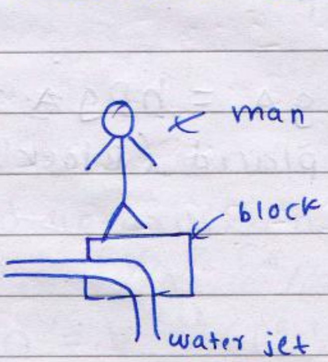
$= 12 \times 33 \times 1.2 \times 33$

≈ 16000 N



dx is distance travelled by wind in time dt

#



Combined mass of man & block = 96 kg.
There is no resultant force on block.
V of water when leaving = ?
$F_{downwards} = F_{upwards} = 960$ N
$mv = 960$ $[m dv/dt = 960]$
or, $40v = 960$ $[m/dt = 40\ kgs^{-1}]$
$\therefore v = 24\ ms^{-1}$

Titanium has 4.5 g cm^{-3} density. A cube of 48 g has 6×10^{23} atoms. Estimate separation of atoms in cube.

Volume of cube = $48/4.5 = 10.67$ cm^3.

Volume of each atom = $\dfrac{10.67}{6 \times 10^{23}} = 1.78 \times 10^{-23}$ cm^3.

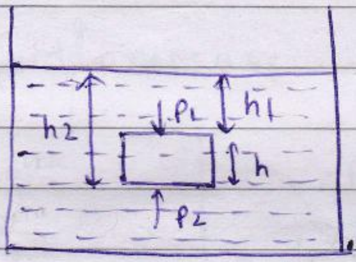
$\frac{4}{3} \pi r^3 = 1.78 \times 10^{-23}$

$\therefore r = 1.61 \times 10^{-8}$ cm

$\therefore$ Separation $= 3.24 \times 10^{-8}$ cm.

Upthrust (Buyoant force)

+ The net force in upward direction acting on a body when it is partially or completely immersed in a fluid. (The force in a fluid)



$P_1 = h_1 \rho g$

Force on upper surface =, $F_1 = P_1 A$

$\therefore F_1 = h_1 \rho g A$ downwards

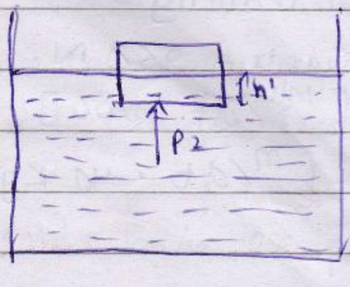
$P_2 = h_2 \rho g$

Force on lower surface, $F_2 = P_2 A$

$\therefore F_2 = h_2 \rho g A$ upwards

Upthrust $= F_2 - F_1 = h_2 \rho g A - h_1 \rho g A = h \rho g A = V \rho g$

where V is volume of fluid displaced. (Block's volume)



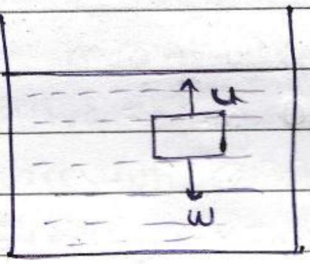
$F_1 = 0$

$F_2 = h' \rho g A$

$\therefore$ Upthrust $= h' \rho g A = V' \rho g$

where V is volume of immersed part of block / volume of displaced fluid.

$U = mg$, where m is mass of displaced fluid. $[V\rho]$
Upthrust is the weight of fluid displaced by an object. This is Archimedes principle.

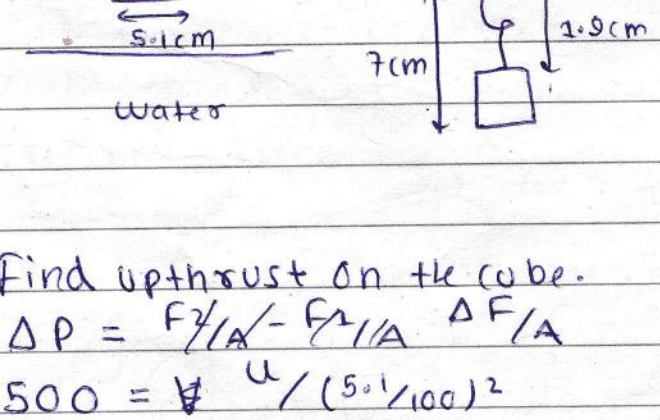


If $W > U$, sinking occurs.
~~mg >~~ $m_{block} > m_{water}$ (Dividing by volume)
~~density~~ $\rho_{block} > \rho_{water}$

If $W < U$, floating occurs
$\rho_{block} < \rho_{water}$.

When $W = U$, true floating occurs. This is law of floatation.

A spring is attached to a fixed point.



a) Calculate difference in pressure exerted by water on top and bottom face of cube.

$\Delta P = P_2 - P_1$
$= dg(h_2 - h_1)$
$= 1000 \times 9.81 \times \left(\frac{7 - 1.9}{100}\right)$
≈ 500 Pa

b) Find upthrust on the cube.

$\Delta P = F_2/A - F_1/A$ $\Delta F/A$
or, $500 = U/(5.1/100)^2$
$\therefore U = 1.30$ N.

c) Calculate force exerted on spring by cube when its in equilibrium in water.

$F + U = W$
or, $F = 4 - 1.3$
$\therefore F = 2.70$ N.

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d) Spring has 30 Nm^{-1} constant. Determine initial height above water surface of base of cube.

$F_{spring} = 2.70$ N

$\therefore e = 0.09m = 9cm$.

$\therefore$ Initial height $= 9 - 7 = \cancel{2cm} = 2.00$ cm

e) Cube in water is released from spring.
Determine initial acceleration of cube.

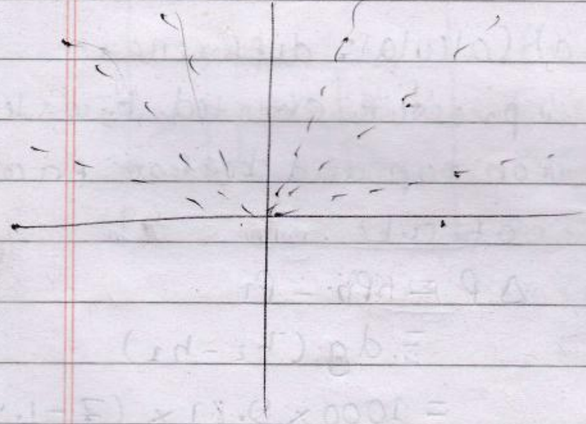
$F_{net} = ma$

$4 - 1.3 = \frac{4}{9.81} a$

$\therefore a = 6.62\ ms^{-2}$

Describe and explain variation of acceleration as cube sinks in water.

Decreases due to drag force.



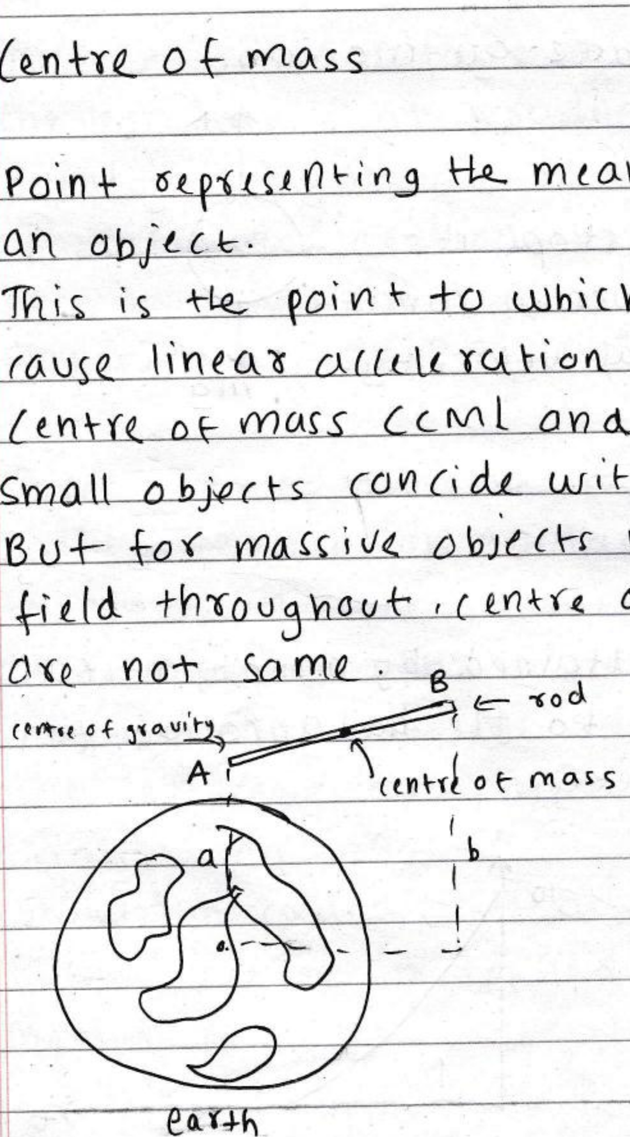
GRAVITATIONAL FORCE

- Force between any two objects because of their masses.
- Attractive
- Has magnitude and direction.
- Centre of gravity is the hypothetical point on a mass where the entire of the gravitational force acts / where all the mass is concentrated.
- Centre of gravity: $W = W_1 + W_2 + W_3 \dots + W_n$

A point / vector with reference to a body through which the total weight of the body appears to act.
A point through which the resultant of the weight vectors of an object act together from.

Centre of mass

- Point representing the mean position of the matter in an object.
- This is the point to which force may be applied to cause linear acceleration and not rotational accelerati
- Centre of mass (CM) and centre of gravity (CG) for small objects concide with each other.
- But for massive objects with ununiform gravitational field throughout, centre of gravity & centre of mass are not same.

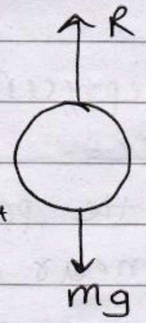


Here point A experiences more force than B as $a < b$, so the more weight is concentrated at A.

VISCOUS / DRAG FORCE

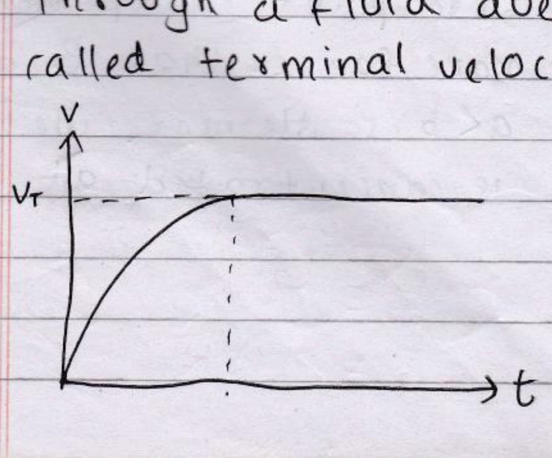
- A force that opposes the relative motion betwoen the layers of fluid / or opposes the motion of any object that moves in the fluid.
- Airplane in flight, swimmer, air bubble moving up in water.
- In opposite direction of motion
- Due to intermolecular force.
- Depends on velocity and shape/size of object.
  $R = Kv^2$
- Can be reduced by streamlined shape. Fish, airplane etc.

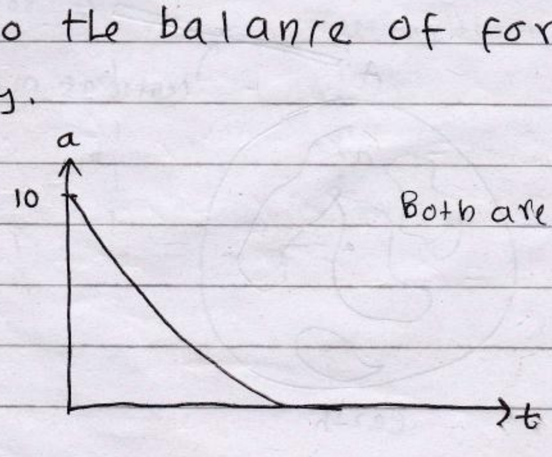
Effect of resistive force on motion.



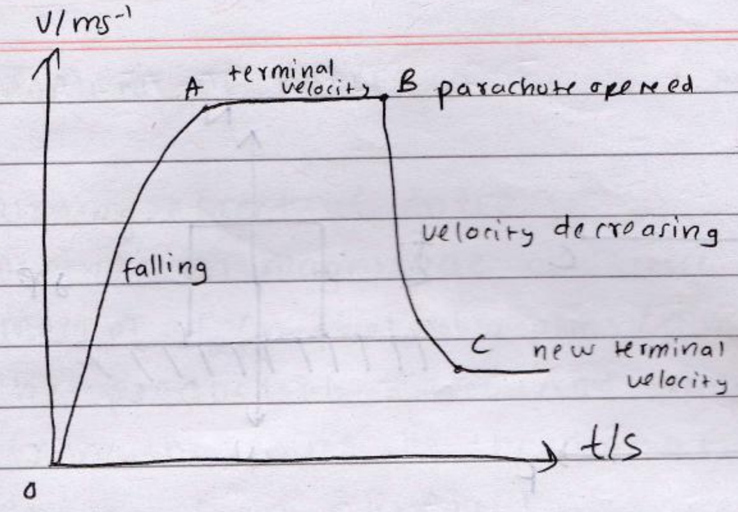
$R = Kv^2$
when $R = mg$, object stops its acceleration and moves in constant speed called terminal velocity.
$Kv^2 = mg$
$\therefore V_{terminal} = \sqrt{\frac{mg}{K}}$

The constant velocity attained by an object falling through a fluid due to the balance of forces is called terminal velocity.





Both are curved.

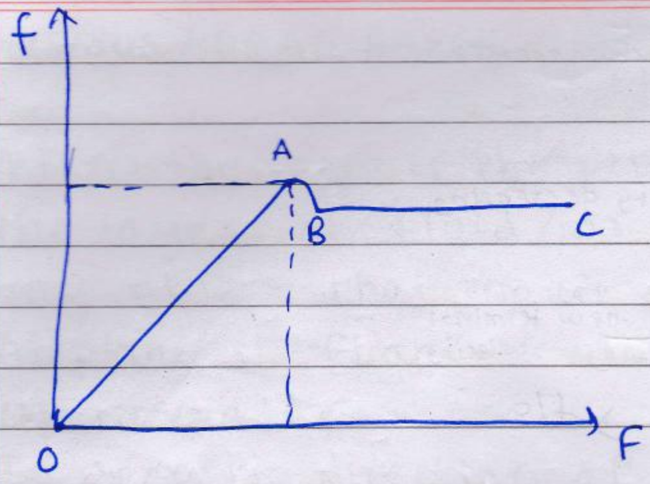


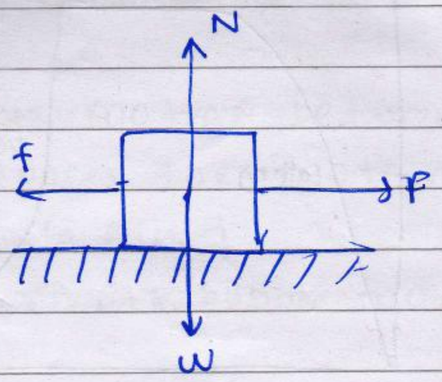
NORMAL REACTION FORCE

- A force that a solid object /surface exerts to prevent solid objects from passing through the surface.
- It is a contact force which is perpendicular to the surface that produces it.
- Equal in magnitude to force object exerts but opposite in direction.

FRICTIONAL FORCE

- Force that opposes the relative motion between two solid surfaces in contact, whene one body tends to move in contact with another body.
- It also opposes the tendency of motion and not only motion. For instance, in an inclined plane the tendency of motion is due to component of weight, $mg\sin\theta$.
- It is also called self adjusting force as it increases with increase in applied force to balance the motion force out.



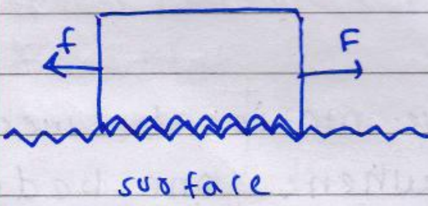


Upto OA → a body is at rest but tends to move.
(static friction)

At A → max. value of static friction, also called limiting friction.

From B → dynamic / Kinetic friction.

Dynamic friction is always less than the limiting friction.
This is because friction is due to roughness of solid surfaces. Projections / depressions / and their interlocks. (at molecular level)



To move this object / change its state of rest, we first need to break interlocks.

But once interlocks are broken, it is slightly easier to move the object. However it takes more force to initially break interlocks.

Thus, dynamic friction is always slightly less than limiting friction.