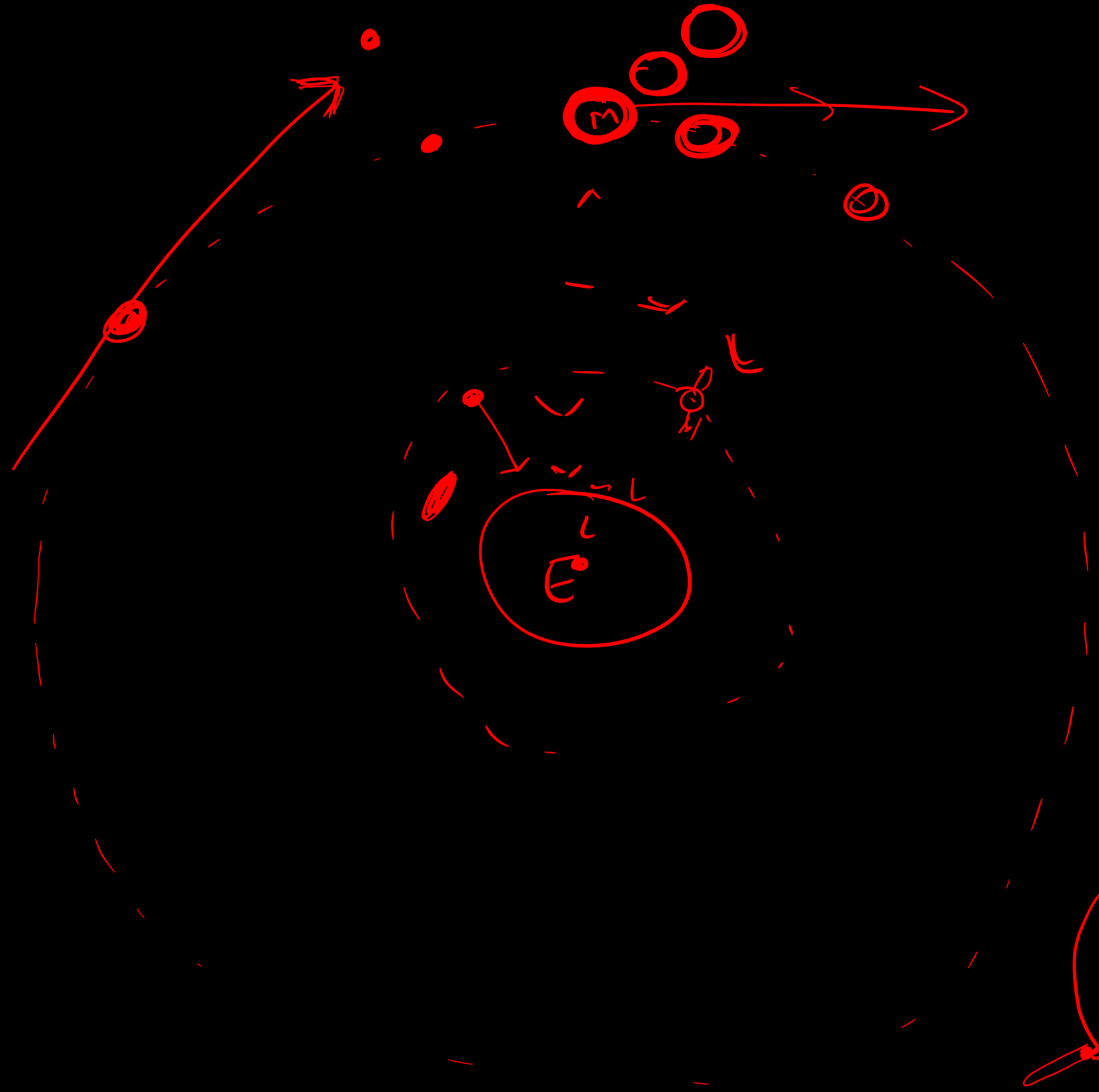
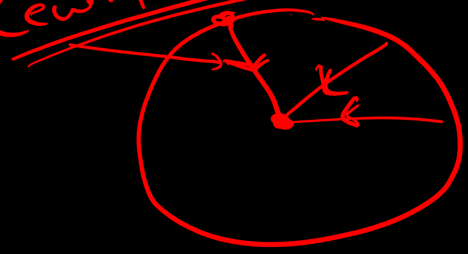
Gravitation

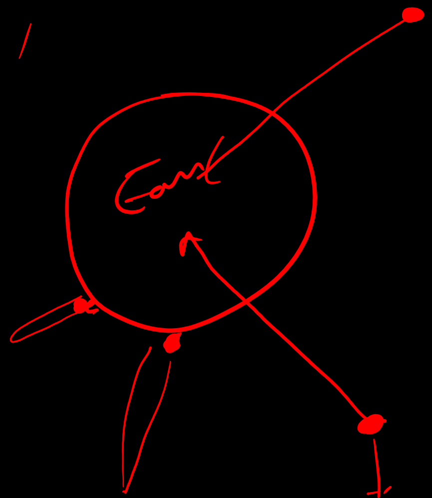
Chapter 10

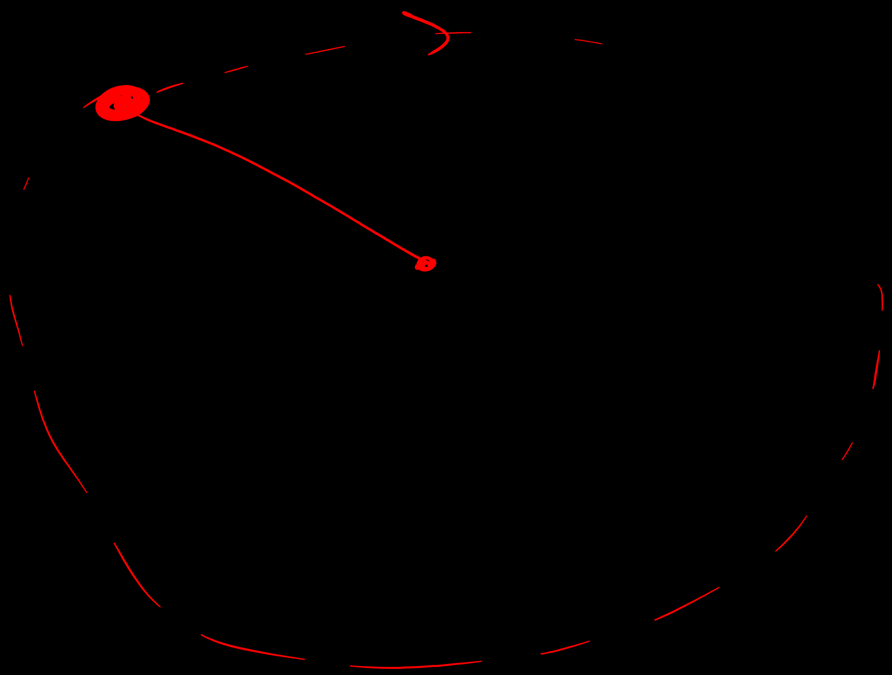


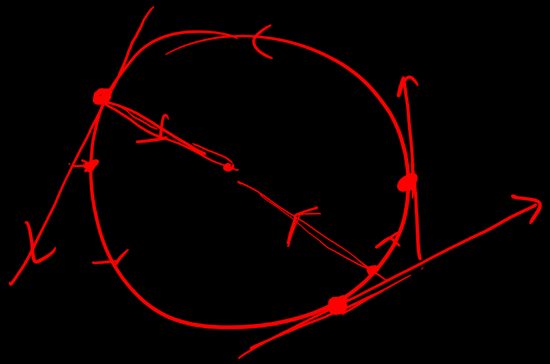
Gravitational force

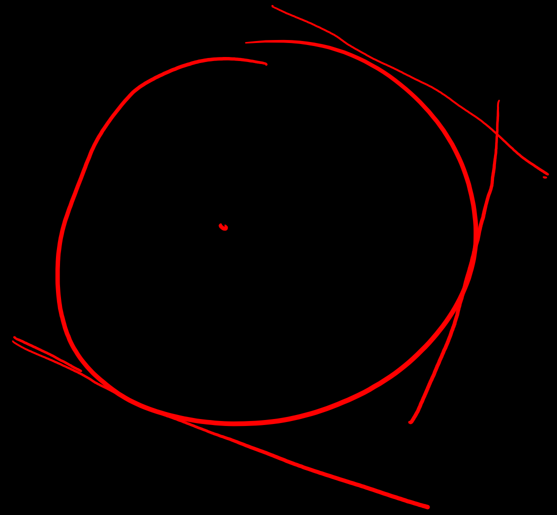
Centripetal force

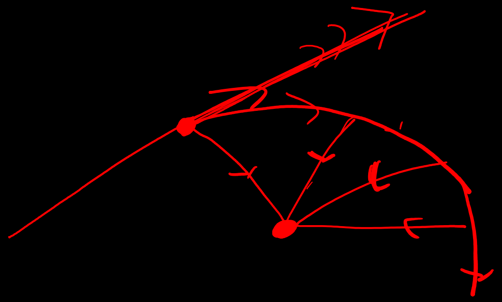


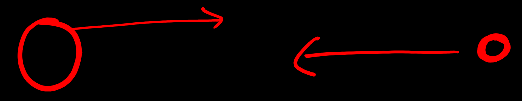


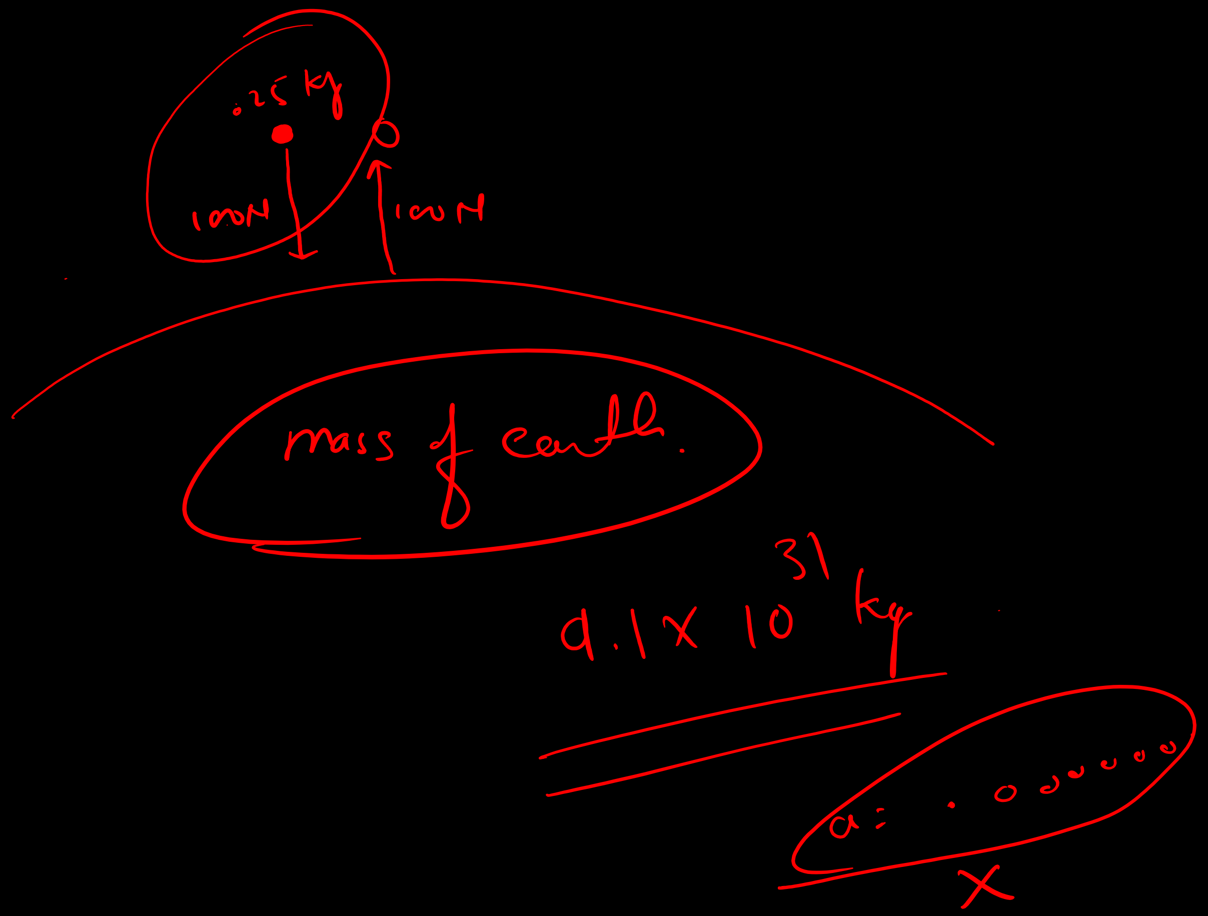








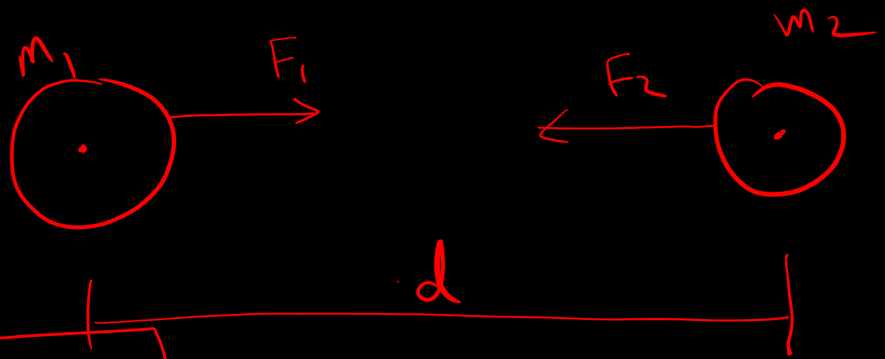



.25 kg
100N
100 N
mass of earth.
9.1 x 10^31 kg
a = .000000

Universal law of gravitation

"Every object in this universe attracts every other object with a force. This force is directly proportional to product of their masses and inversally proportional to square of distance between them."

$F_1 = F_2 = F$

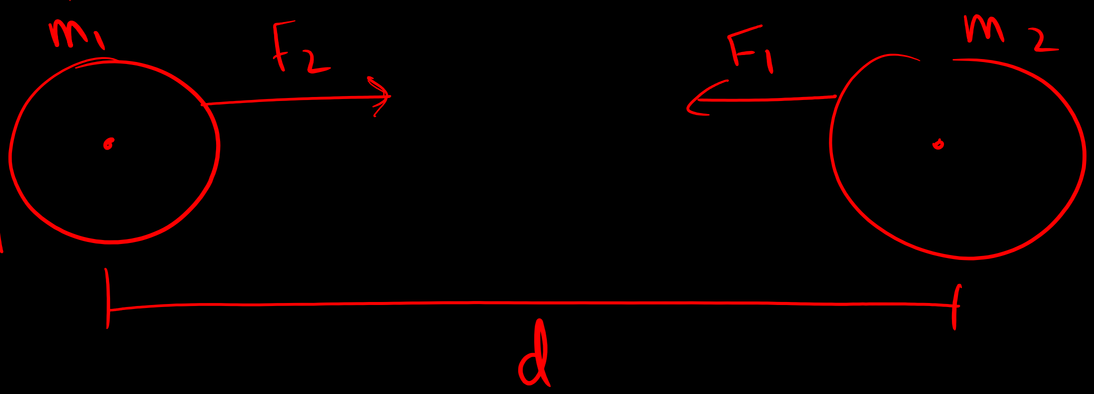


$F \propto m_1 m_2$

$$F \propto \frac{1}{d^2}$$

$$G = 6.673 \times 10^{-11}$$

$$G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$$



$$F = \frac{G m_1 m_2}{d^2}$$

$$F \propto m_1 m_2 \quad \text{— (I)}$$

$$F \propto \frac{1}{d^2} \quad \text{— (II)}$$

$$F \propto \frac{m_1 m_2}{d^2}$$

$$F = G \frac{m_1 m_2}{d^2}$$

G: Universal gravitation constant

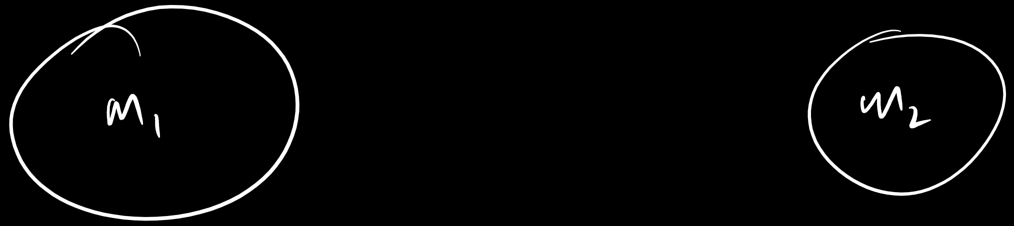
$$G = \frac{F d^2}{m_1 m_2}$$

$$= \frac{Nm^2}{kg^2}$$

$$= Nm^2kg^{-2}$$

Find unit of G using formula $F = \frac{G m_1 m_2}{d^2}$

$$G = \frac{F d^2}{m_1 m_2} = \frac{N\ m^2}{kg \times kg}$$



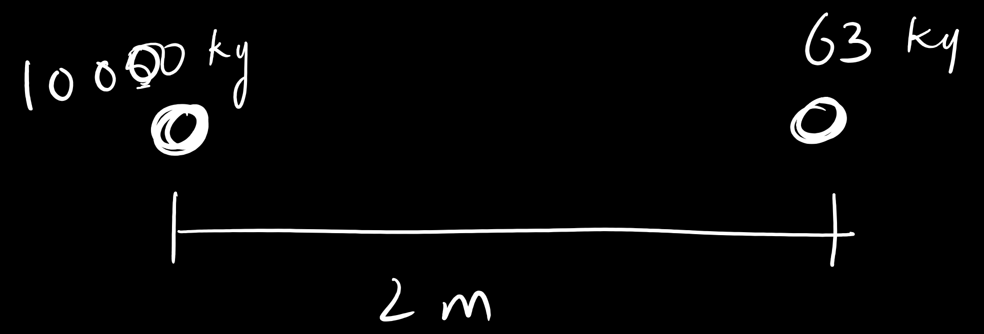
$$= \frac{N m^2}{kg^2} = N m^2 kg^{-2}$$

$$= N m^2 / kg^2$$

$$G = 6.673 \times 10^{-11}\ N m^2 kg^{-2}$$

"Universal Gravitation Constant"

Attractive in nature



6.7×10^{-11}

$$F = \frac{G \times 50 \times 63}{(2)^2}$$

$$= \frac{6.673 \times 10^{-11} \times 50 \times 63}{4}$$

12.5

25

2

$$F = 5254.99 \times 10^{-11}\ N$$

$$= 0.0000000525499\ N$$

$$\approx 0.000000005\ N$$

$$F = 0.00000005\ N$$

$$= 0.005\ N$$

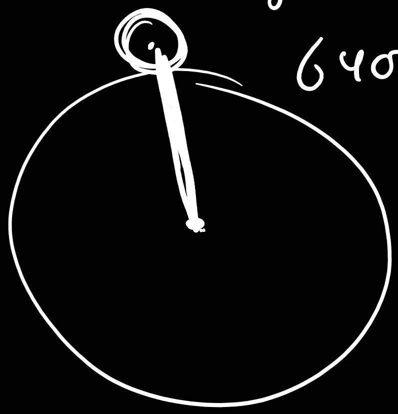
6400 km

6×10^{24} kg → 500 N

.2 kg

6×10^{24} kg

50 kg



6400 km = 6400000 m

6×10^{24} kg.

$$F = \frac{6.7 \times 10^{-11} \times 50 \times 6 \times 10^{24}}{6400000 \times 6400000}$$

6400000 = 6.4×10^{6}

$$6.4 \times 10^{6} \text{ m} \times 6.4 \times 10^{6}$$

$$= \frac{6.7 \times 10^{-11} \times 50 \times 6 \times 10^{24}}{6.4 \times 6.4 \times 10^{12}}$$

$$= 50 \times 10^{-11} \times 10^{24} \times 10^{-12}$$

$$F = 50 \times 10 \approx 500 \text{ N}$$

550 N

200 N

Gravitational force of earth on moon.

$m_e = 6 \times 10^{24}$ kg

$m_m = 7.4 \times 10^{22}$ kg

$(3.84 \times 10^{8}\ m)^2$

$$F = \frac{6.7 \times 10^{-11} \times 6 \times 10^{24} \times 7.4 \times 10^{22}}{(3.84)^2 \times 10^{16}}$$

$= \quad \times 10^{20}$

$\frac{10^{35}}{10^{16}}$

10^{19}

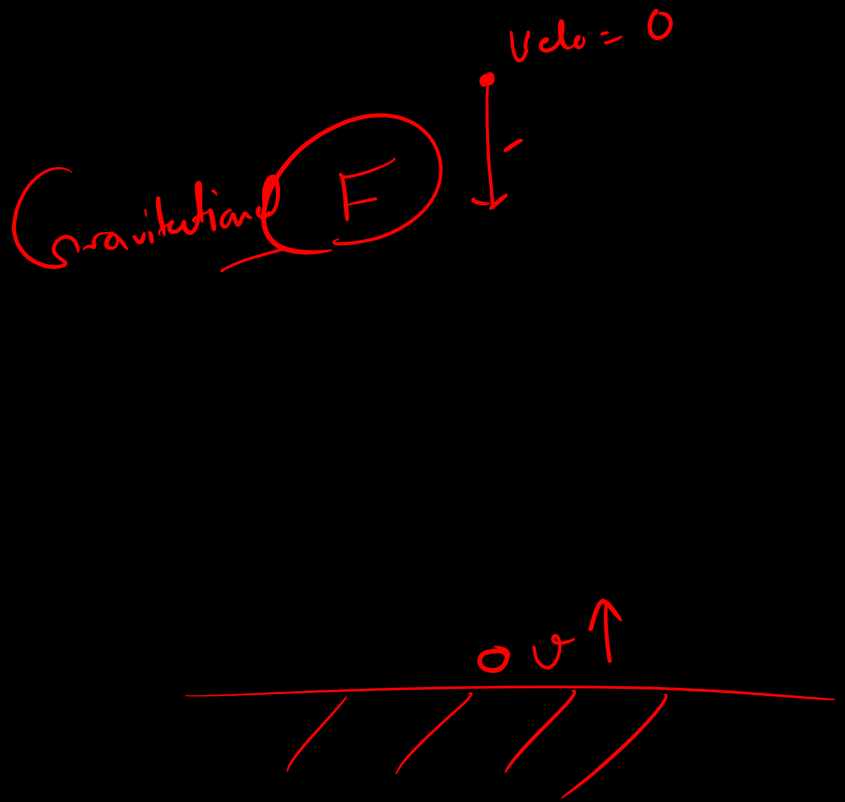
$= 2.02 \times 10^{20}$ N

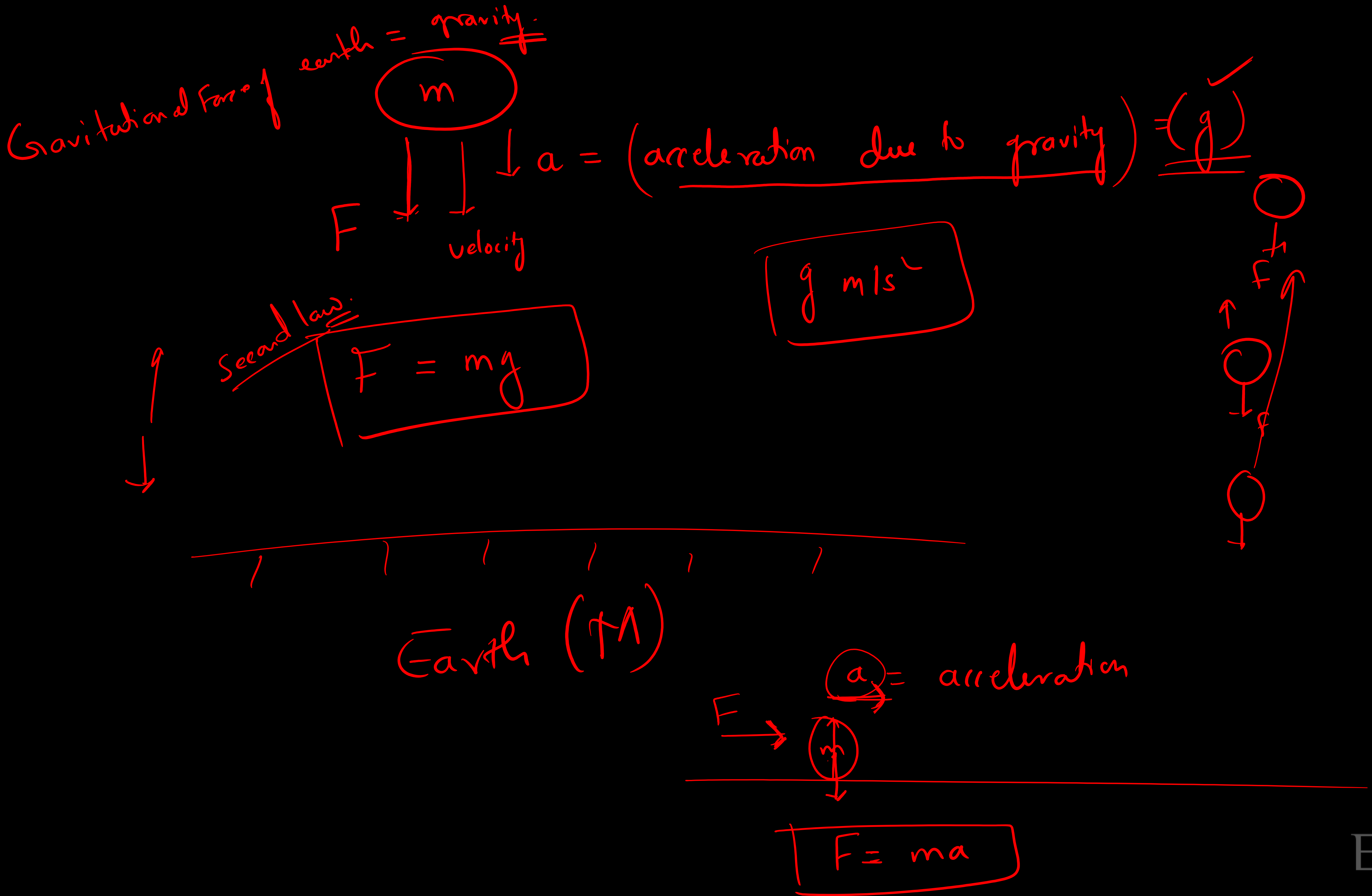
Importance of Universal law of gravitation.

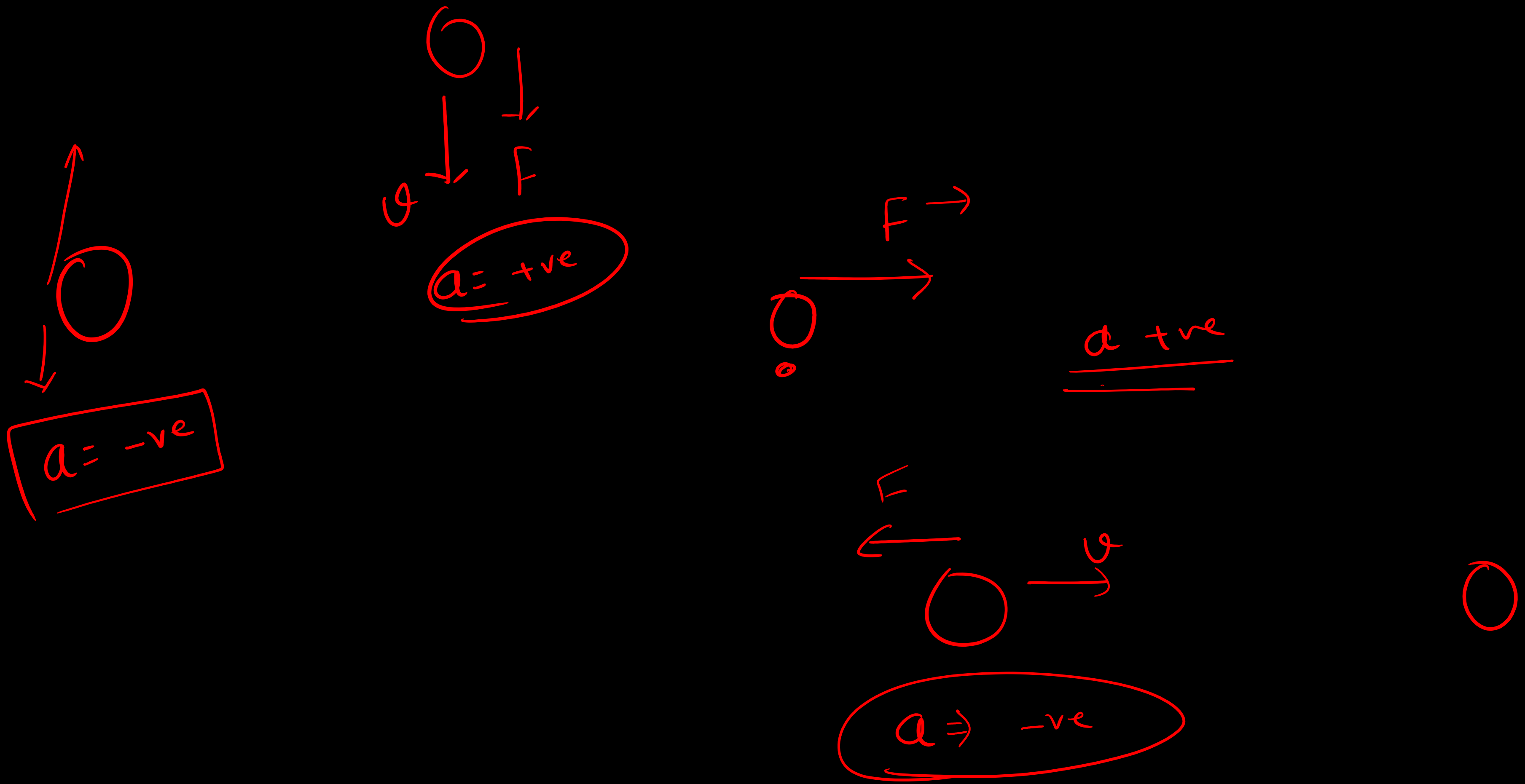
- motion of planet around sun,
- motion of moon around planets.
- we can calculate exact force of gravitation between any two objects in the universe.
- formation of tide due to gravitational force of moon & sun.
- It explains why we are bound to the surface of earth.

Free fall :→

When an object falls only under the influence of gravitational force, the motion of object is called Free fall.

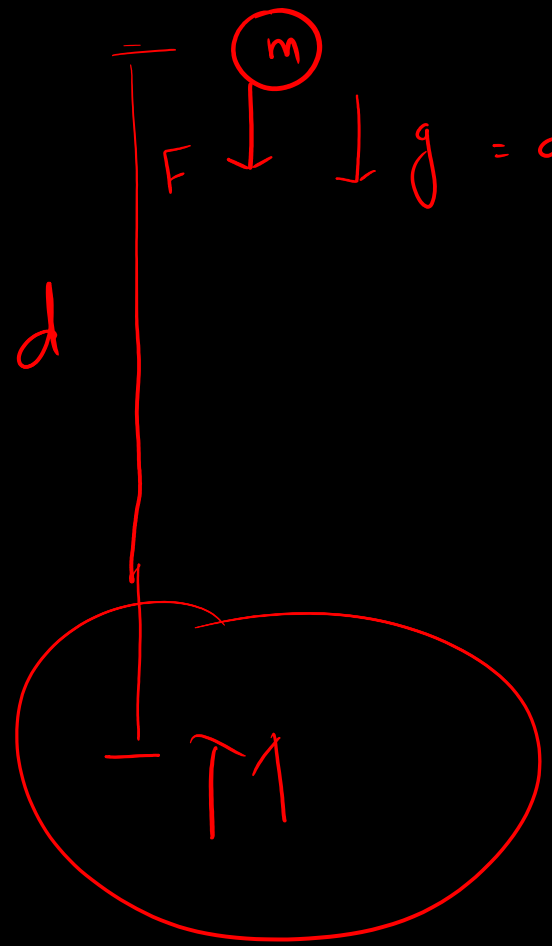



Gravitational Force of earth = gravity.
m
F
velocity
a = (acceleration due to gravity) = (g)
g m/s²
Second law:
F = mg
f
f
Earth (M)
a = acceleration
F
m
F = ma


a= -ve
v
F
a= +ve
F
a +ve
F
v
a ⇒ -ve

Second law.

$$F = mg \quad \text{--- (1)}$$



$\downarrow g$ = acceleration due to gravity.

$$F = \frac{GMm}{d^2} \quad \text{--- (11)}$$

from (1) & (11)

$$mg = \frac{GMm}{d^2}$$

$$g = \frac{GM}{d^2}$$

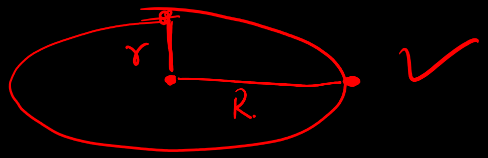
g +ve $\downarrow$

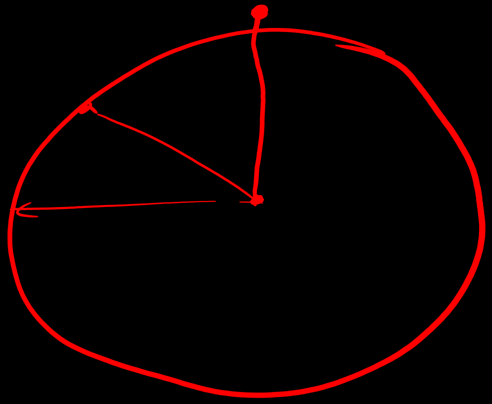
g −ve $\uparrow$

$$g = \frac{GM}{d^2}$$

when $d \simeq R$

$$g = \frac{GM}{R^2}$$

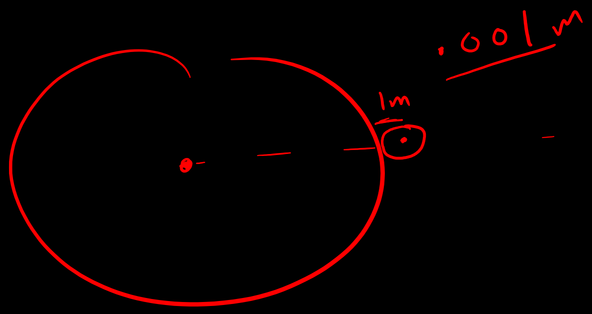


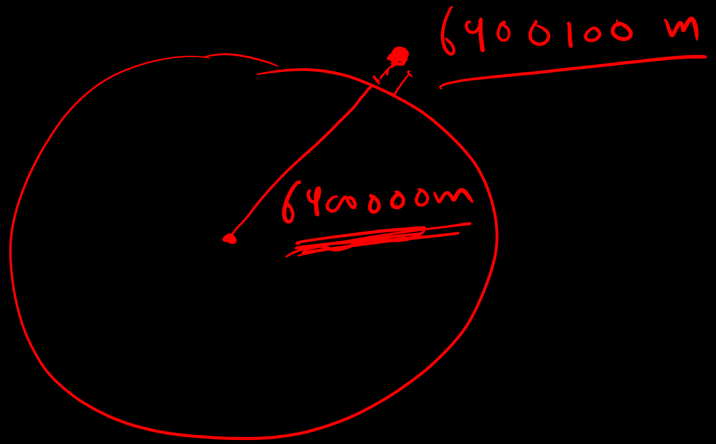


$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6400000)^2} = \sim 9.8\ ms^{-2}$$

$= 9.8\ m$

$$g = \sim 9.8\ ms^{-2}$$



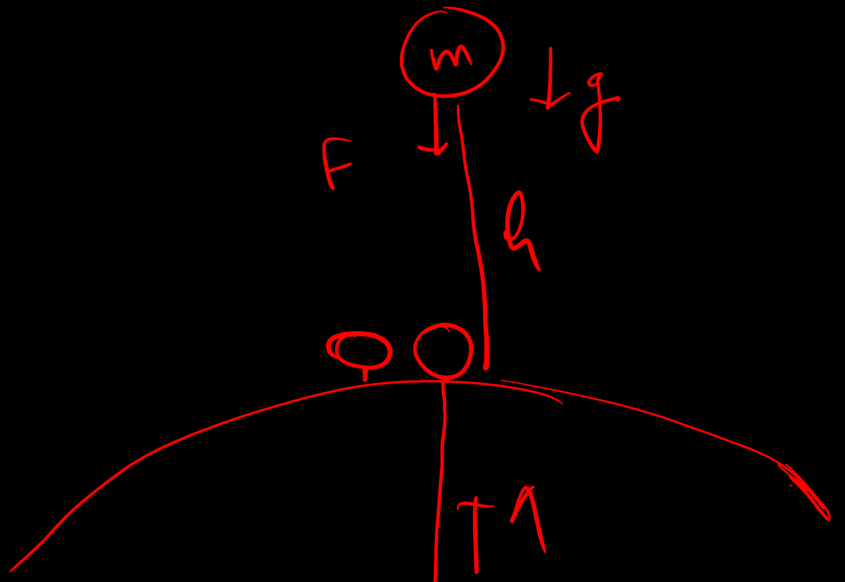


6400.001 km

~6400

$$g = \frac{GM}{d^2}$$

$F = mg$



$F_1 = \frac{GMm}{d^2} = 100\ N$

$F_2 = mg = 100\ N$

$F_2 = F_1$

$mg = \frac{GMm}{d^2}$

$$g = \frac{GM}{d^2} \quad (1)$$

If object is on or near the surface of earth

Sol:

$d \approx R$

$$g = \frac{GM}{R^2}$$

$$= \frac{6.673 \times 10^{-11} \times 6 \times 10^{24} \text{ kg}}{(6400000)^2}$$

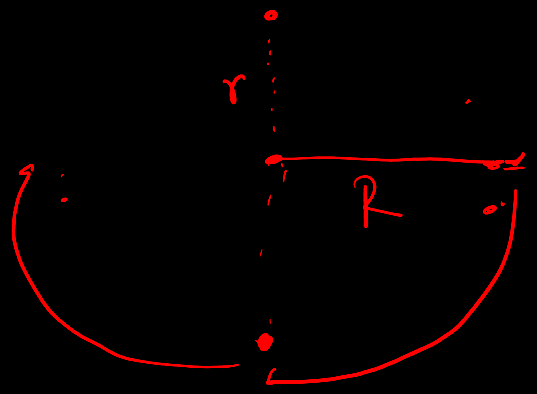
$\times 10$

$(6.4 \times 10^6)^2$

$(6.4)^2 \times 10^{12}$

$$\frac{6.673 \times 60}{6.4 \times 6.4}$$

$g = 9.8 \text{ ms}^{-2}$


r
R

Equation of motion

$\vec{a} \Rightarrow$ uniform

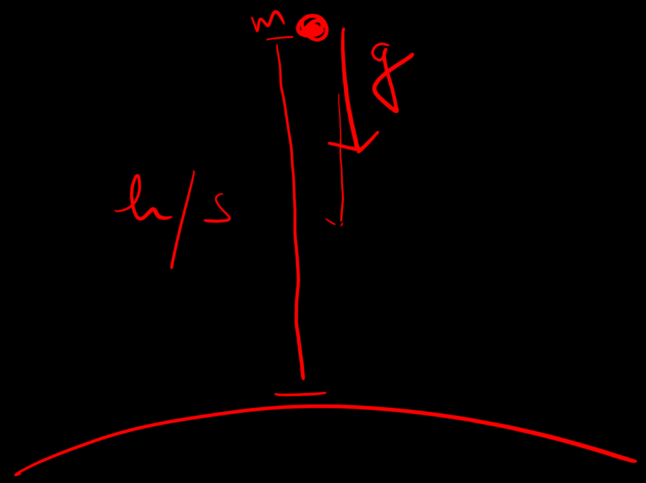
(I) $v = u + at$

(II) $s = ut + \frac{1}{2}at^2$

(III) $2as = v^2 - u^2$

$g \Rightarrow -ve$

$g \Rightarrow +ve$



Equation of motion

(I) $v = u + gt$

(II) $s = ut + \frac{1}{2}gt^2$

(III) $2gs = v^2 - u^2$

An object is thrown vertically upward, and rises to a height of 10 m.
Calculate:
(i) the velocity with which this object was thrown upward.

$v = 0$

$s = 10m$

$g = -9.8\ ms^{-2}$

u

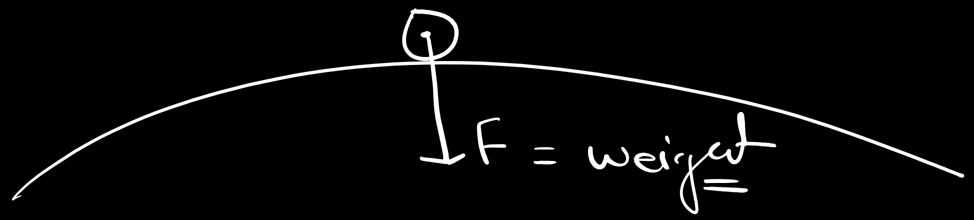
$v^2 - u^2 = 2gs$

$u = \sqrt{196} = 14\ m/s$

(ii) the time taken by the object to reach the highest point.

$t = \frac{v-u}{g} = \frac{14}{9.8} = \sim 1.4$ second

Weight = the force with which earth attracts any object towards its centre.



$F = mg \Rightarrow$ weight

$= 40\,kg \times 10\,m/s^2$

$= 400\,kg\,m/s^2$

$= 400\,N$

Weight = 350 N

10

mass = ?

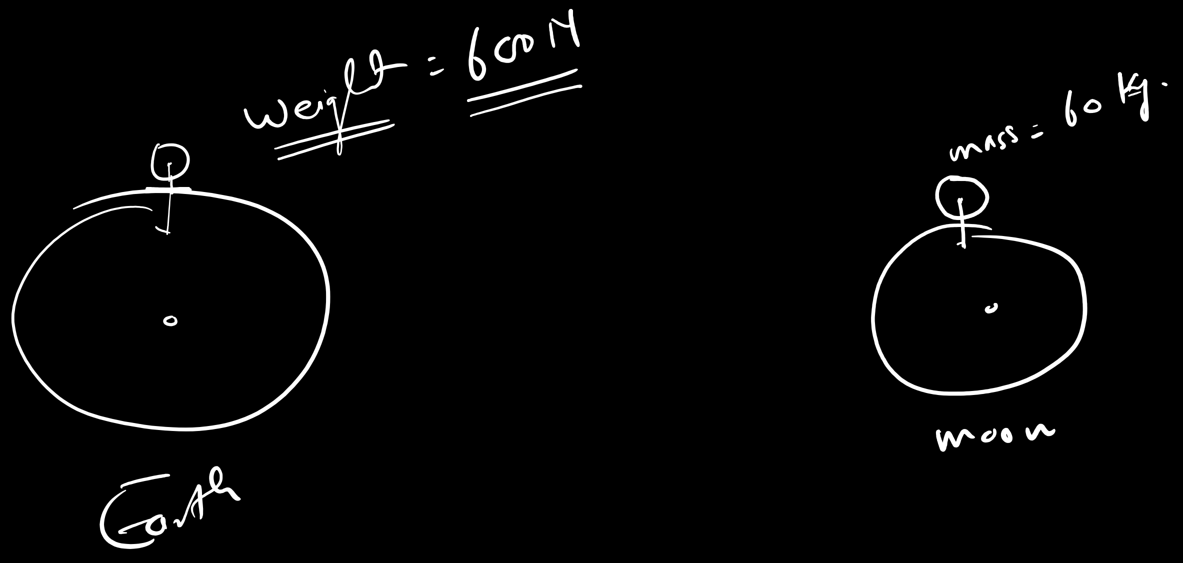
$m = \frac{F}{g} = \frac{350}{10}$

$= 35\,kg$

mass

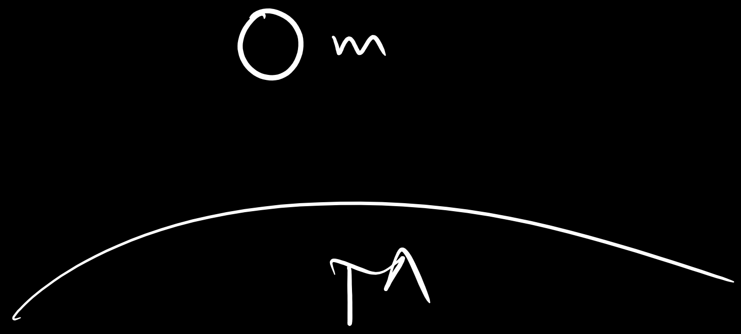
→

mass = 60 kg



Mass : Actual matter content of an object.

Weight



Earth : $g = 9.8\ m/s^2$

$$W = F = mg$$

$$W_e = F = \frac{G M_e m}{R_e^2} \quad \text{--- (I)}$$

$$W_m = \frac{G M_m m}{(R_m)^2} \quad \text{--- (II)}$$

$$\frac{W_e}{W_m} = \frac{\cancel{G} M_e \cancel{m} / R_e^2}{\cancel{G} M_m \cancel{m} / (R_m)^2}$$

$M_e = 5.98 \times 10^{24}$ kg

$R_e = 6.37 \times 10^6$ m

$M_m = 7.36 \times 10^{22}$ kg

$R_m = 1.74 \times 10^6$ m

$$\frac{W_e}{W_m} = \frac{M_e \times (R_m)^2}{M_m \times (R_e)^2}$$

$$= \frac{5.98 \times \cancel{10^{24}}\,10^2 \times (1.74 \times \cancel{10^6})}{7.36 \times \cancel{10^{22}} \times (6.37 \times \cancel{10^6})}$$

$$W_m = \frac{1}{6} W_e$$

$$\frac{W_e}{W_m} = \frac{6}{1}$$

$$W_e = 6\, W_m$$

$$W_m \approx \frac{1}{6} W_e$$

mass of object = 10 kg

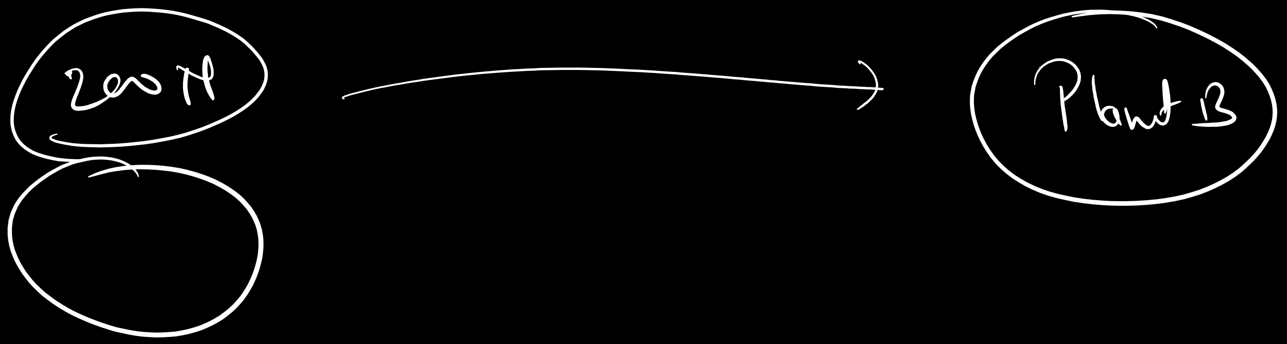
Weight on earth = 98 N } 10×9.8

Weight on moon = $\frac{98}{6}$ N

16.3 N

Gravitational force is 3 of earth's gravit force.

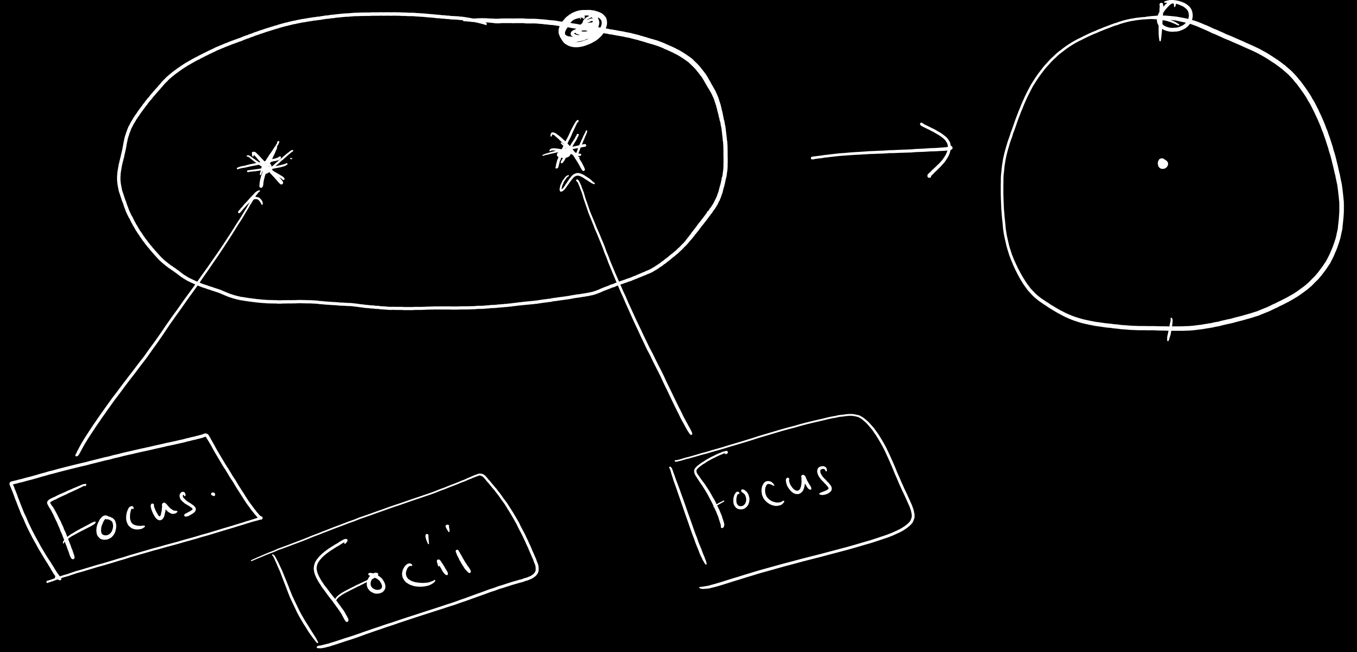
?



Kepler's laws of Planetary motion

3 Law

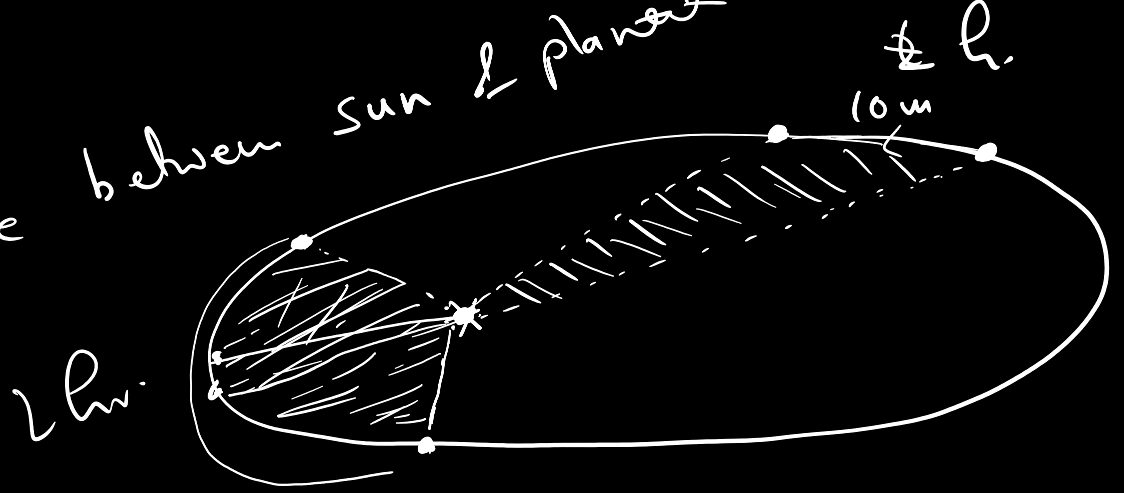
(1) All planet revolves around Sun in an elliptical orbit with sun being at one of its focii

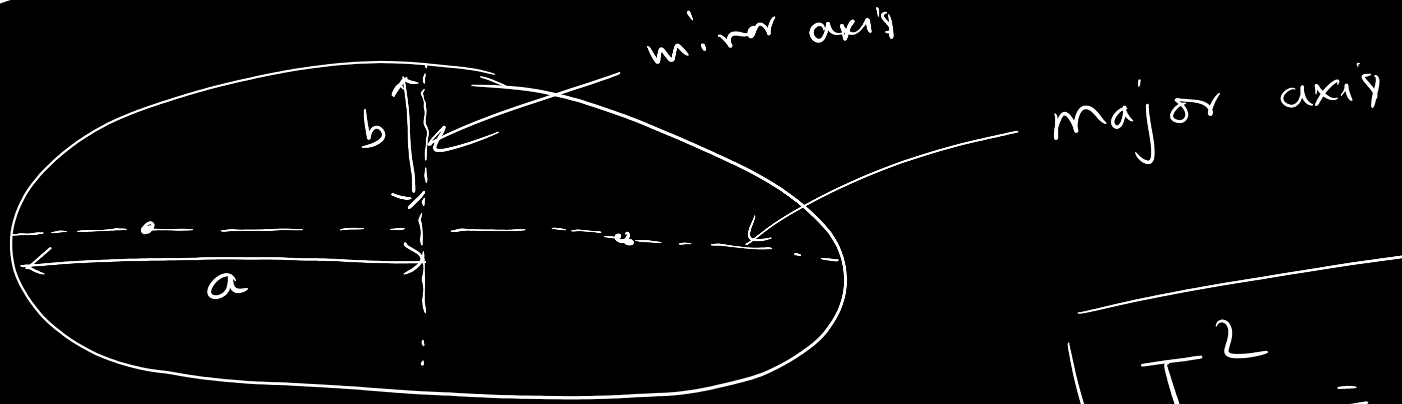


(II) Planets sweeps equal area in equal interval of time.

(III) $T^2 \propto a^3$

- T: Time period of revolution
- a: mean (avg.) distance between sun & planet





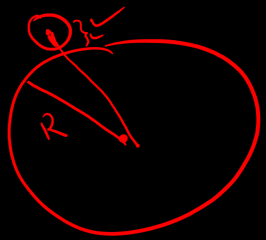
$$\frac{T^2}{a^3} = \text{Constant}$$

$g = ?$

$F = mg$

$$F = \frac{G M m}{d^2}$$

$$G = \frac{F d^2}{m_1 m_2} = \frac{N m^2}{kg^2}$$



$$g = \frac{G M}{R^2}$$

$R = 6.4 \times 10^6 \, m$

$M = 6 \times 10^{24} \, kg$

$G = 6.67 \times 10^{-11} \, N m^2 kg^{-2}$

$$mg = \frac{G M m}{d^2}$$

$$g = \frac{G M}{d^2}$$

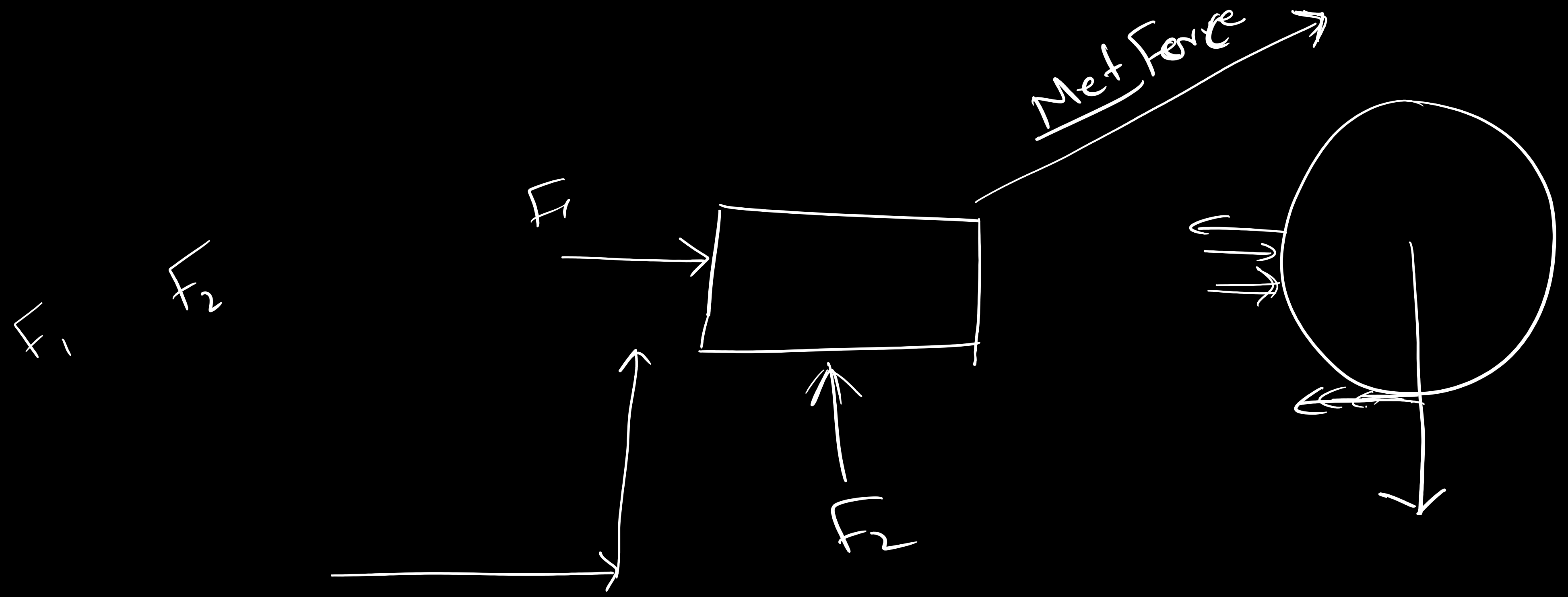
$g = 9.8 \, m s^{-2}$

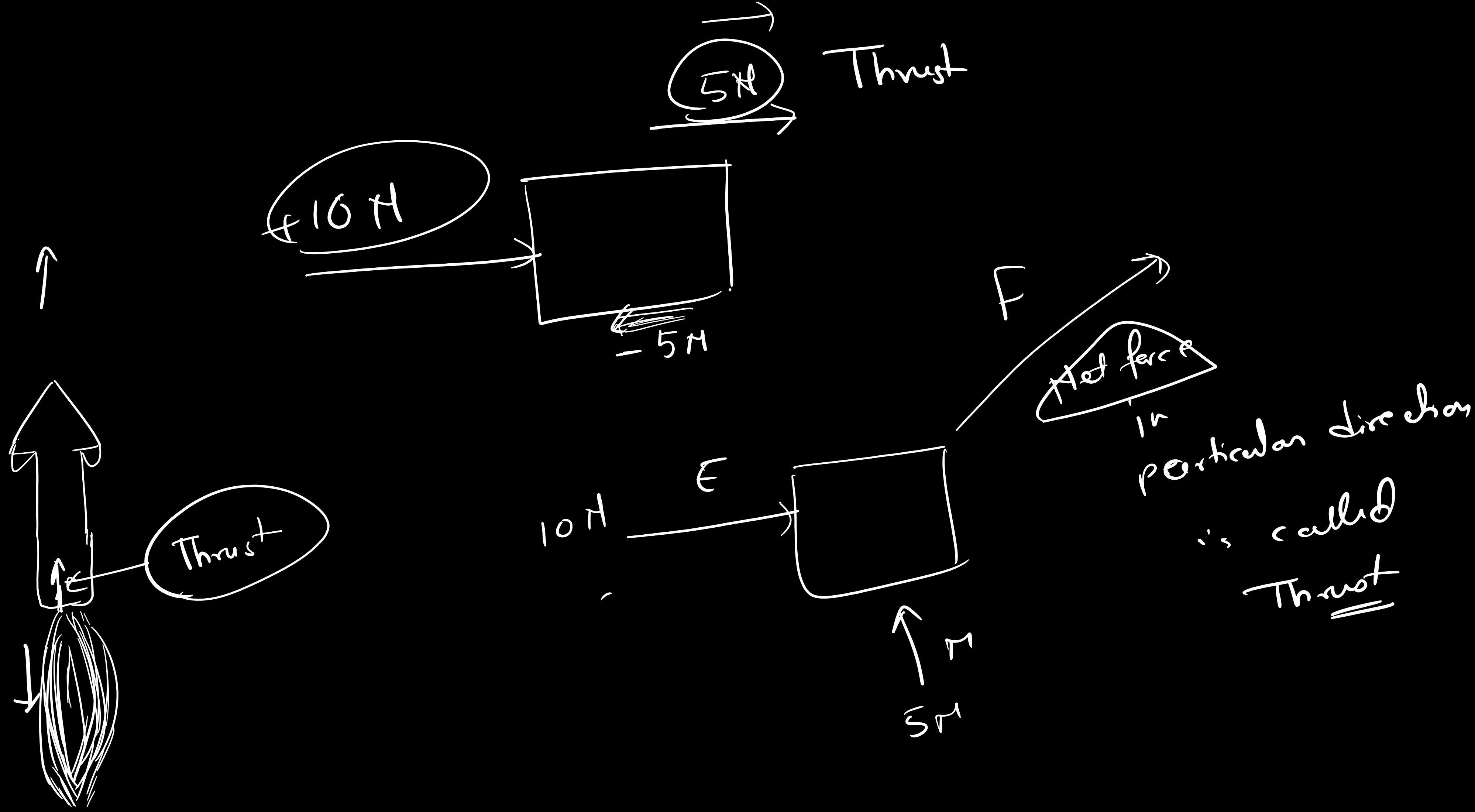
Weight (N)

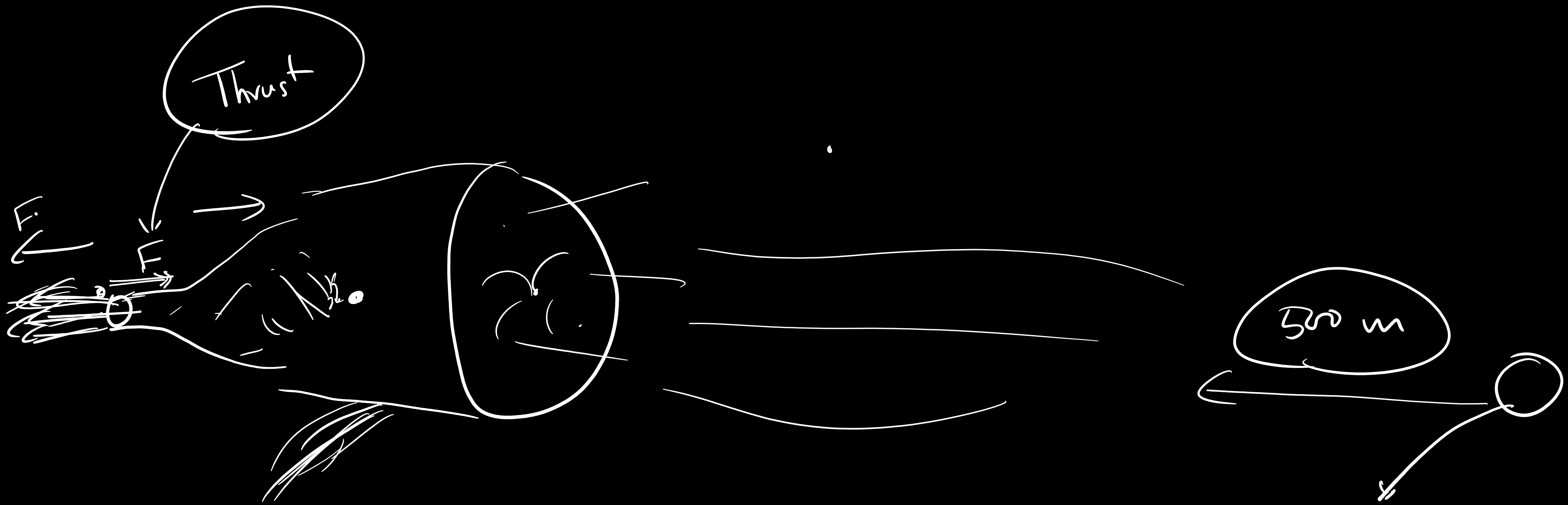
Mass (kg)

weight = kg

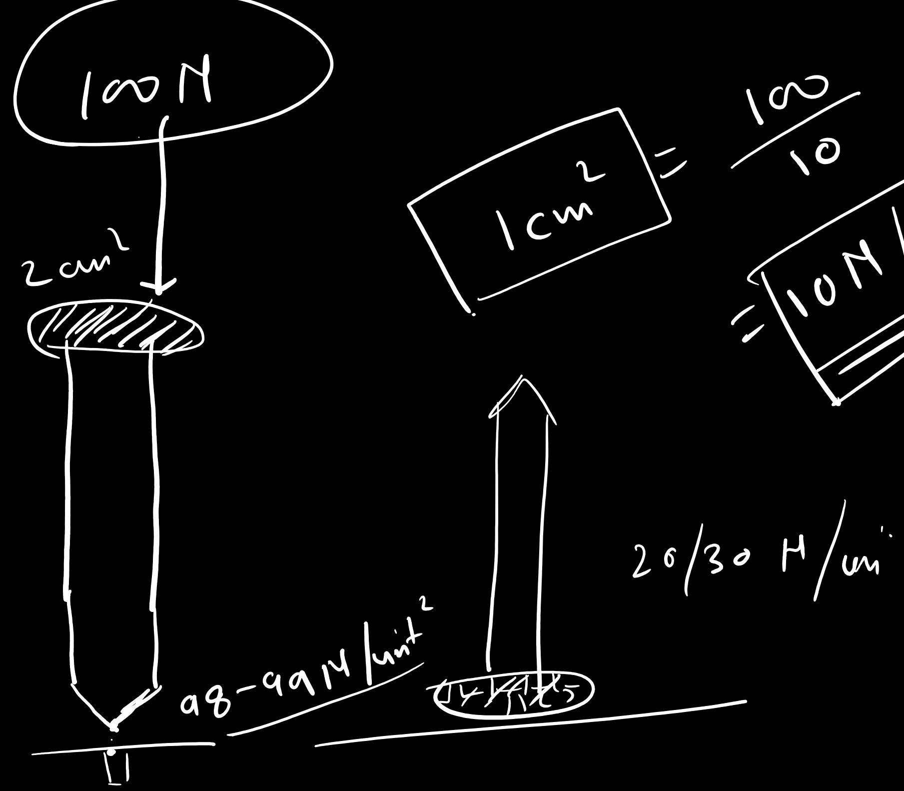
Thrust and Pressure

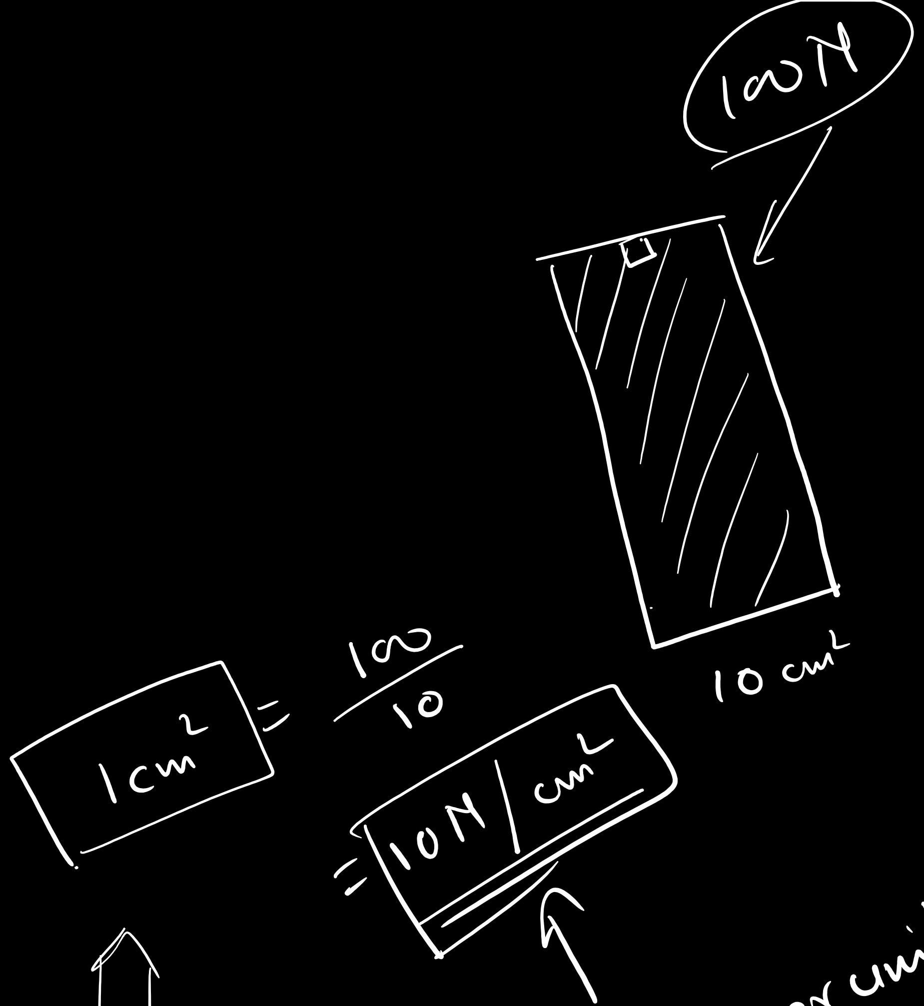


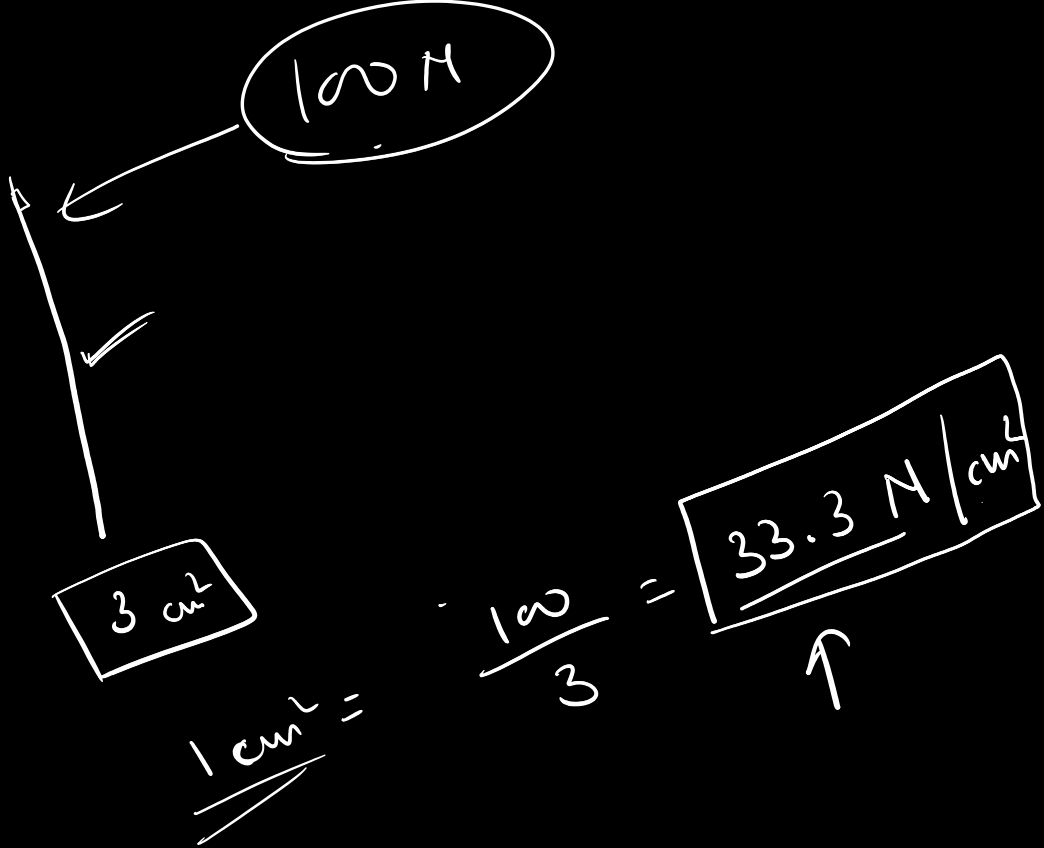

5N
Thrust
+10N
-5N
F
Net force
in particular direction is called Thrust
10N
5N
Thrust


Thrust
F
F
500 m

Pressure

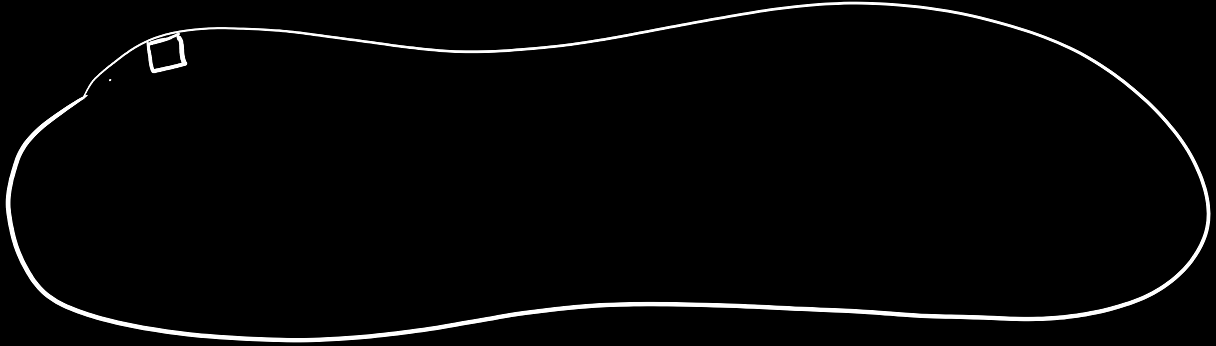




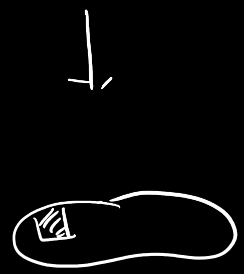


Force per unit area is pressure.

250 N



2050 N



$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{\text{Thrust}}{\text{Area}}$$

$1\ \text{Pa} = 1\ \text{N m}^{-2}$

SI unit = N m^{-2}

= pascal (Pa)

A block of wood is kept on a tabletop. The mass of wooden block is 5 kg and its dimensions are 40 cm x 20 cm x 10 cm. Find the pressure exerted by the wooden block on the tabletop if it is made to lie on the tabletop with its sides of dimensions (a) 20 cm x 10 cm and

(b) 40 cm x 20 cm. = 800 cm^2 = 0.08 m^2

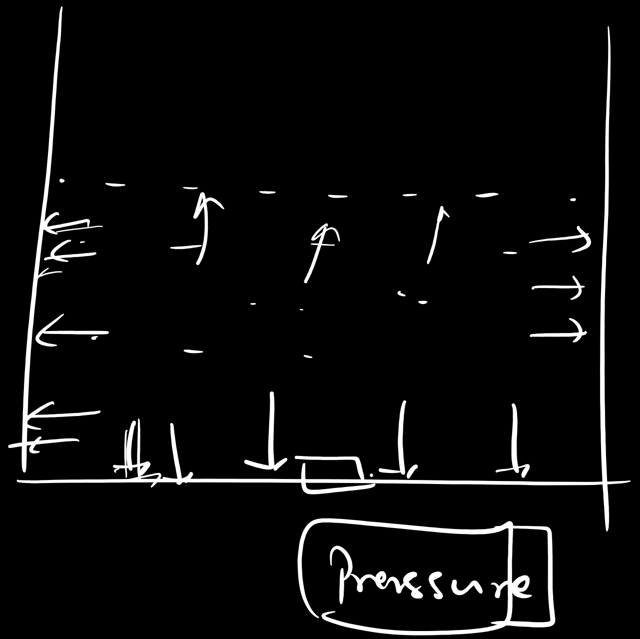
$$P = \frac{\text{Force}}{\text{Area}}$$

Force exerted by object on table top = mg = 5×9.8 = 49 N

a) Surface area of object in contact with table top = 20×10 = 200 cm^2 = 0.02 m^2

$$P_a = \frac{49}{0.02} = \frac{4900}{2} = 2450 \text{ Pa}$$

$$P_b = \frac{49}{0.08} = \frac{4900}{8} = 612.5 \text{ Pa}$$



(liq./gas)

- fluid exerst pressure on the surface of container in which they are kept.

- fluids exert same amt. of pressure in all direction.

Bouyancy : Upthrust / Upward force exterted by fluid on an object is called bouyant force.

This phenomenon is k/a bouyancy.

→ depends on density of fluid.

direct releation

object density > fluid density

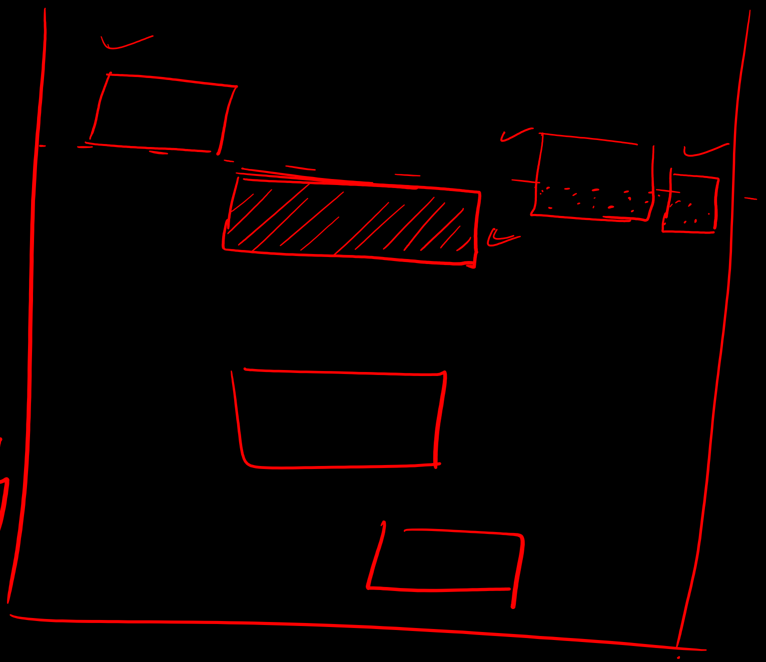
Sink

object density < fluid density

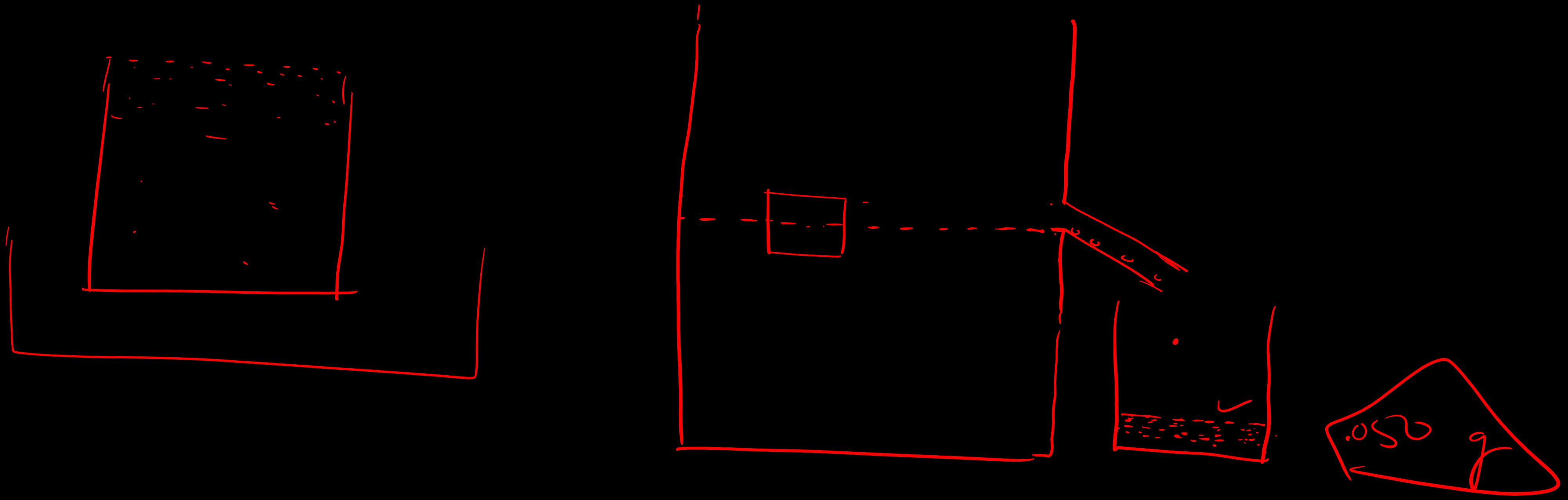
float

object density = fluid density

immersed in fluid



Archimedes



"when object fully or partially immersed in a fluid. the bouyant force experienced by the object is equal to the amt. of fluid displaced by the object"

Relative Density

Density ⇒ " mass per unit volume "

$$D = \frac{\text{mass}}{\text{volume}}$$

SI Unit = $kg\ m^{-3}$

cgs

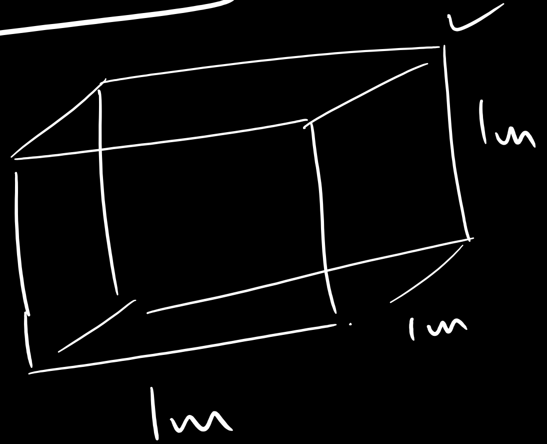
$g\ cm^{-3}$

cgs

cm g s

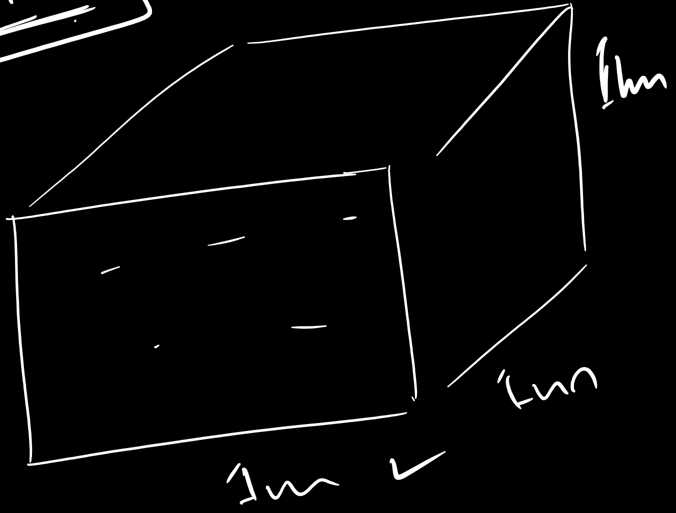
$1.6\ g\ cm^{-3}$

Gold



19300kg

$1 m^3$



$1\ m^3$

$= 1000\ kg$

Density of water = 1 g/cm^3

Substance A ⇒ D_1

Relative density ⇒ Density of any substance with respect to another substance (mostly water)

$S_A = \frac{D_A}{D_w}$

$S_w =$

Relative Density of A = $\frac{D_A}{D_w}$ w.r.t. water.

(A) $D_A \Rightarrow 1344\ kg/m^3$

(B) D_B

123

R.D. of A w.r.t. B $= \dfrac{D_A \rightarrow \cancel{kg\ m^{-3}}}{D_B \rightarrow \cancel{kg\ m^{-3}}}$

R.D. of B w.r.t. A $= \dfrac{D_B}{D_A}$

Relative Density : Unit : **No unit**

(A) D_A

(B) water D_w = 1000 $kg\,m^{-3}$ = $1\,g\,cm^{-3}$

[Standard fluid]

RD of A wrt. water = $\frac{D_A}{1\,g\,cm^{-3}}$ = $\frac{D_A}{1000\,kg\,m^{-3}}$

→ Specific Gravity =)

A → R.D. → 2.39

Ice. = 0.912

91 % immersed

.53

1

Q. Relative density of silver is 10.8. The density of water is 10^3 kg m^{-3}. What is density of silver in SI unit.

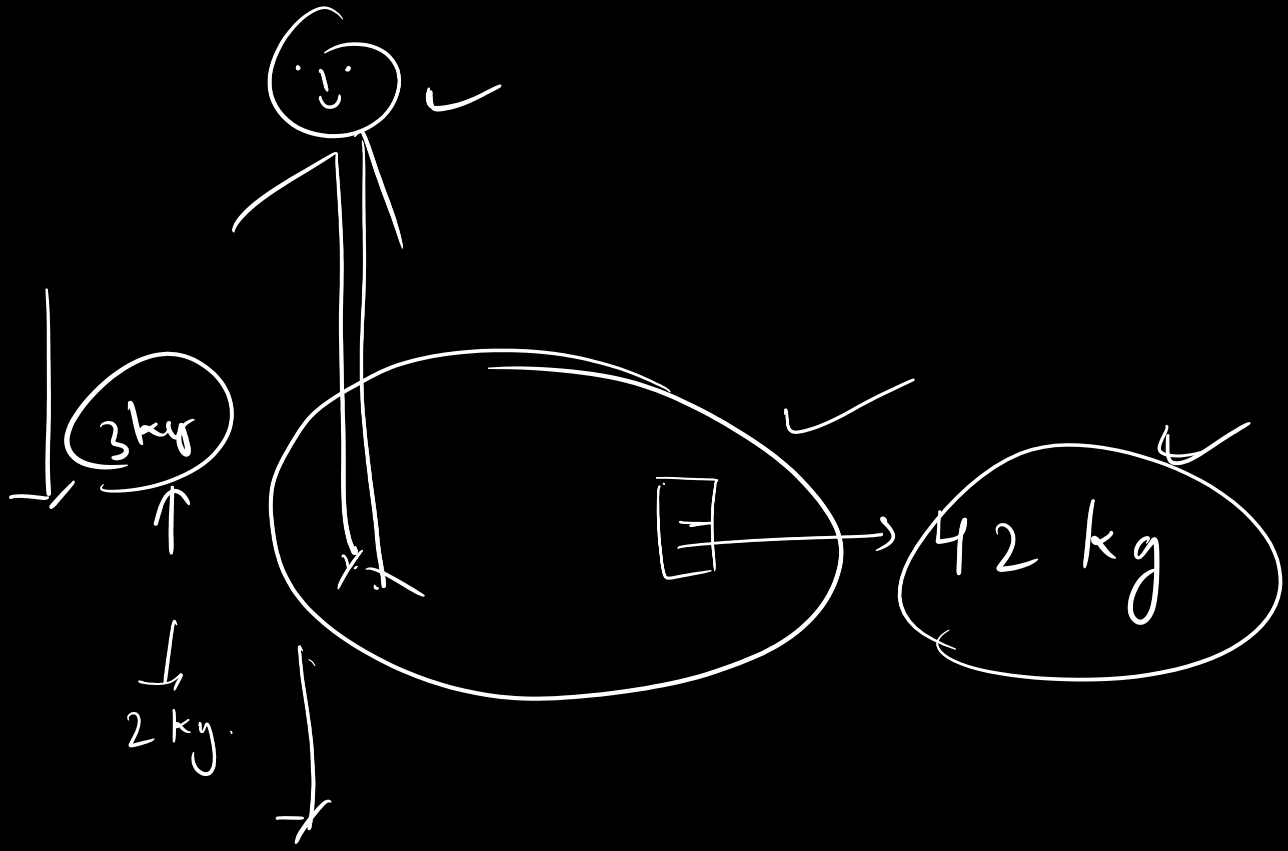
$$\text{Relative density} = \frac{\text{density of Ag}}{\text{density of } H_2O}$$

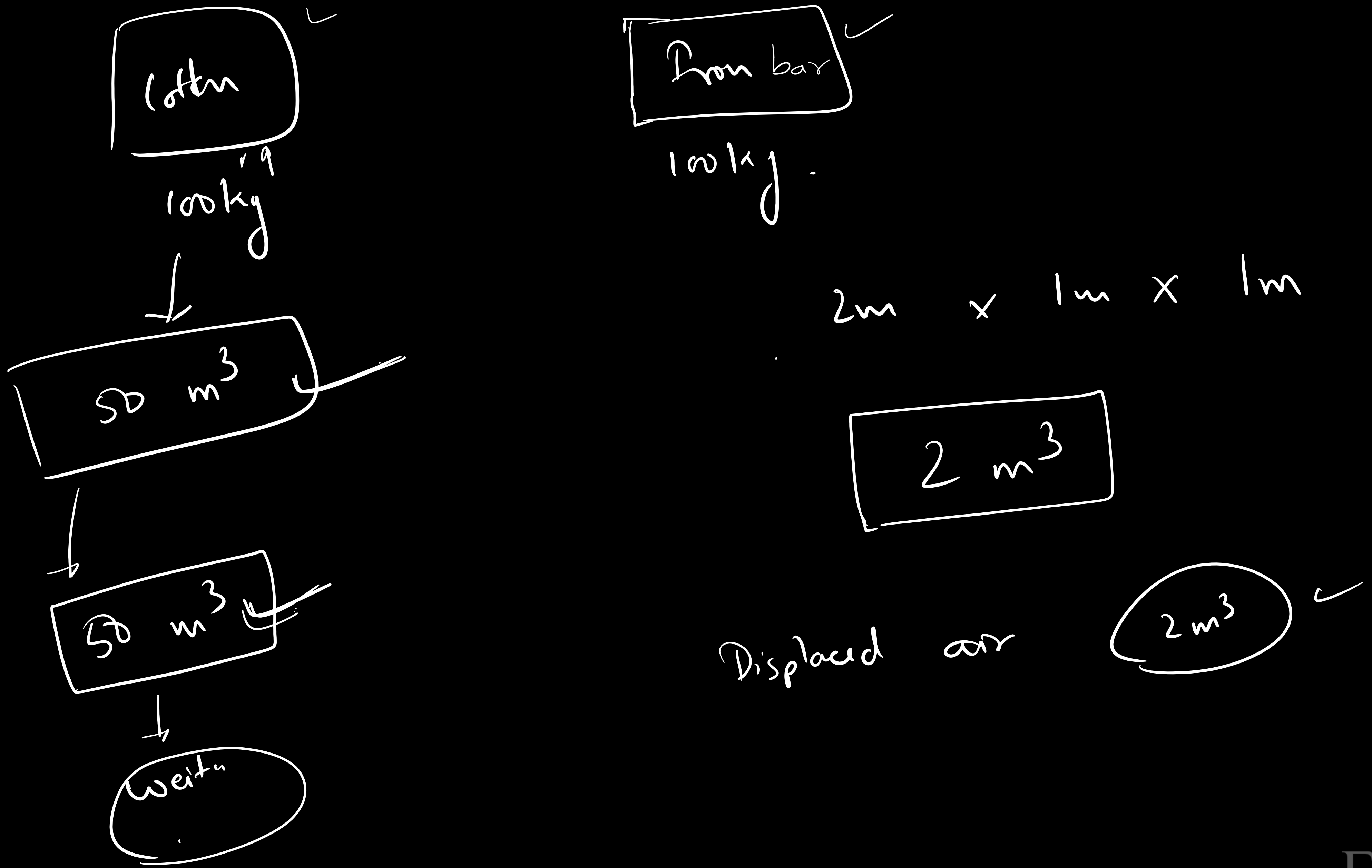
$$10.8 = \frac{\text{density of Ag}}{1000 \text{ kg } m^{-3}}$$

$$D_{Ag} = 10.8 \times 1000 \text{ kg } m^{-3}$$

$$= 10.8 \times 10^3$$

$$= 1.08 \times 10^4 \text{ kg } m^{-3}$$


3kg
2 kg.
42 kg


Cotton
100kg
50 m³
50 m³
Water
Iron bar
100kg
2m x 1m x 1m
2 m³
Displaced air
2 m³

Q. Volume of 50 g of a substance is 20 cm^3. If the density of water is 1 g per cc., and density of an oil is 3 g/cm^3. Substance will float in water or oil?.

$$\text{Density of substance} = \frac{50\,g}{20\,cm^3} = 2.5\ g\,cm^{-3}$$

∵ density of substance is more than water

∴ it will sink in water.

The volume of a 500 g sealed packet is 350 cm^3. Will the packet float or sink in water, if density of water is 1 $g\,cm^{-3}$? What will be the mass of water displaced by this packet.

"Volume of displaced fluid = volume of substance immersed in the fluid.

$$\text{Mass} = \text{Density} \times \text{Vol.}$$

$$= 350\ \cancel{cm^3} \times \frac{1g}{\cancel{cm^3}}$$

$$\boxed{\text{mass} = 350\ g}$$

Q. An object of volume 500 cm^3 is $\frac{1}{3}$rd immersed in a fluid of density 1.5 g/cm^3. Find the mass of fluid displaced by the object.

mass of fluid = $D \times V$

$= 1.5 \times 166.6$ g

$= 249.\ldots$ g

=

$\left(\frac{1}{3} \times 500\right)$ cm^3

volume of displaced fluid = vol. of object immersed in fluid

$= \frac{1}{3} \times 500$ cm^3

$= \boxed{166.6 \ cm^3}$ ✓

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