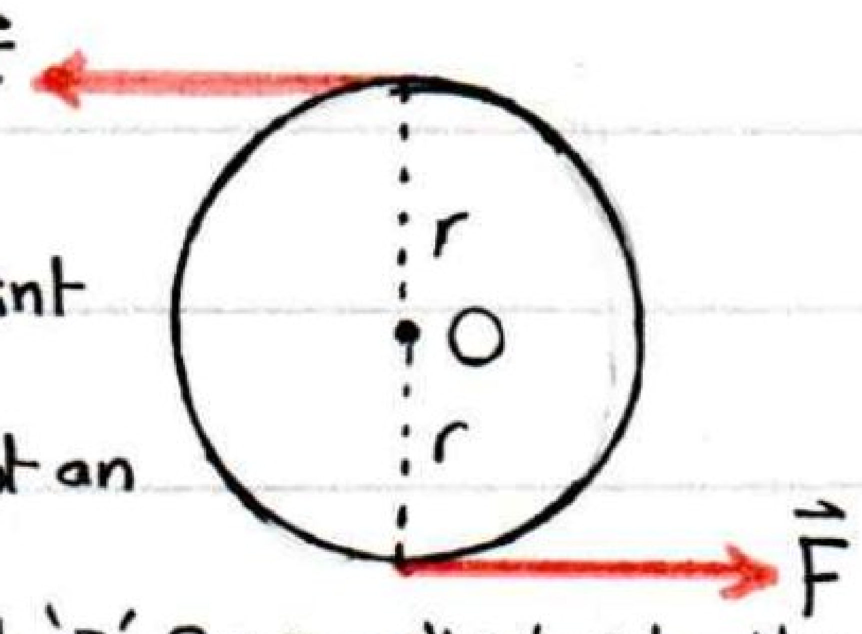
27	November 2022 Week . 8 .	Chapter 9

9-1 The Conditions for Equilibrium:



A wheel is fixed at point 'o' and can rotate about an axis that passes through 'O' perpendicular to the page. What is the net force acting on it?

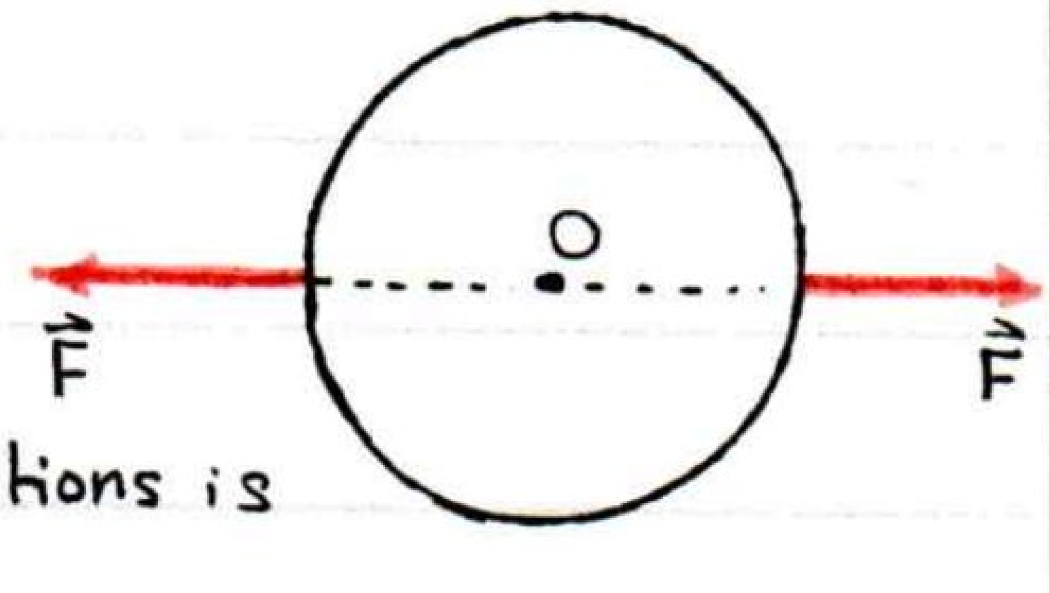
* $\Sigma F = F - F = 0$ (The wheel does NOT move translationaly).

Does the wheel rotate about point O?

* $\tau_{net} = rF\sin 90^\circ + rF\sin 90^\circ = 2rF = DF$ *

(The wheel rotats counterclockwise, so the wheel has rotational motion).

* when an object is Not at rest, which has translational or rotational motion or both, it is said Not to be in static equilibrium. However, to say that an object is in static equilibrium both conditions must be satisfied.

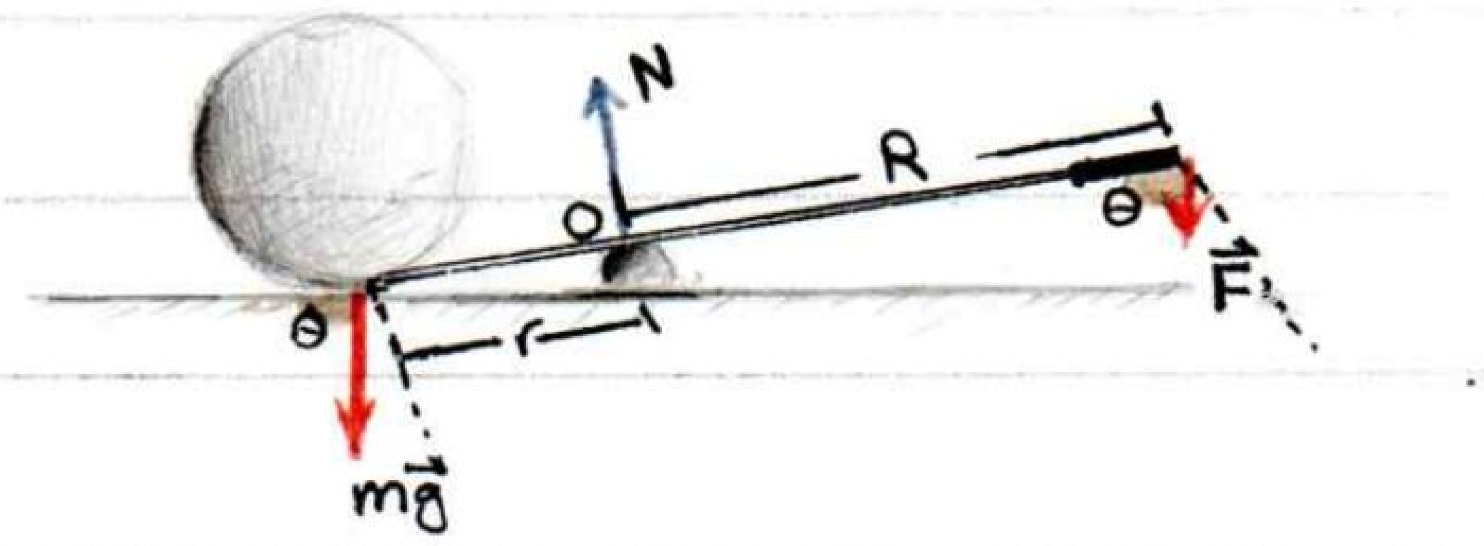


* one way to satisfy both conditions is to draw forces like this, so $\Sigma F = 0$, $\Sigma \tau = 0$.

* when two equal forces act on an object in opposite directions at different points is called the **Couple**.

9-2 Solving statics problems:

* A lever is a simple machine consists of a bar to pry up large objects such as rocks, and a small rock acts as a fulcrum (pivot point)



$\vec{F}$ should be less than $m\vec{g}$ in magnitude since $R > r$ in order to be in equilibrium.

$\vec{F} \rightarrow$ acts to rotate the lever clockwise.

$m\vec{g} \rightarrow$ acts to rotate the lever counterclockwise.

$N \rightarrow$ acts at 'O' but its torque about it is zero.

$$\tau_{net} = \vec{F} R \sin\theta - m\vec{g}\, r \sin\theta = 0$$

$$\frac{R}{r} = \frac{m\vec{g}}{\vec{F}} > 1$$

* Increasing (R) and decreasing (r) we can get best results ↓
* this ratio is called the mechanical advantage.

(MA) → when it's > 1 that means we can lift heavy objects applying a small force (a good lever).

* Your forearm acts as a bad lever, its MA ≪ 1, you have to exert a force much larger than the load force.

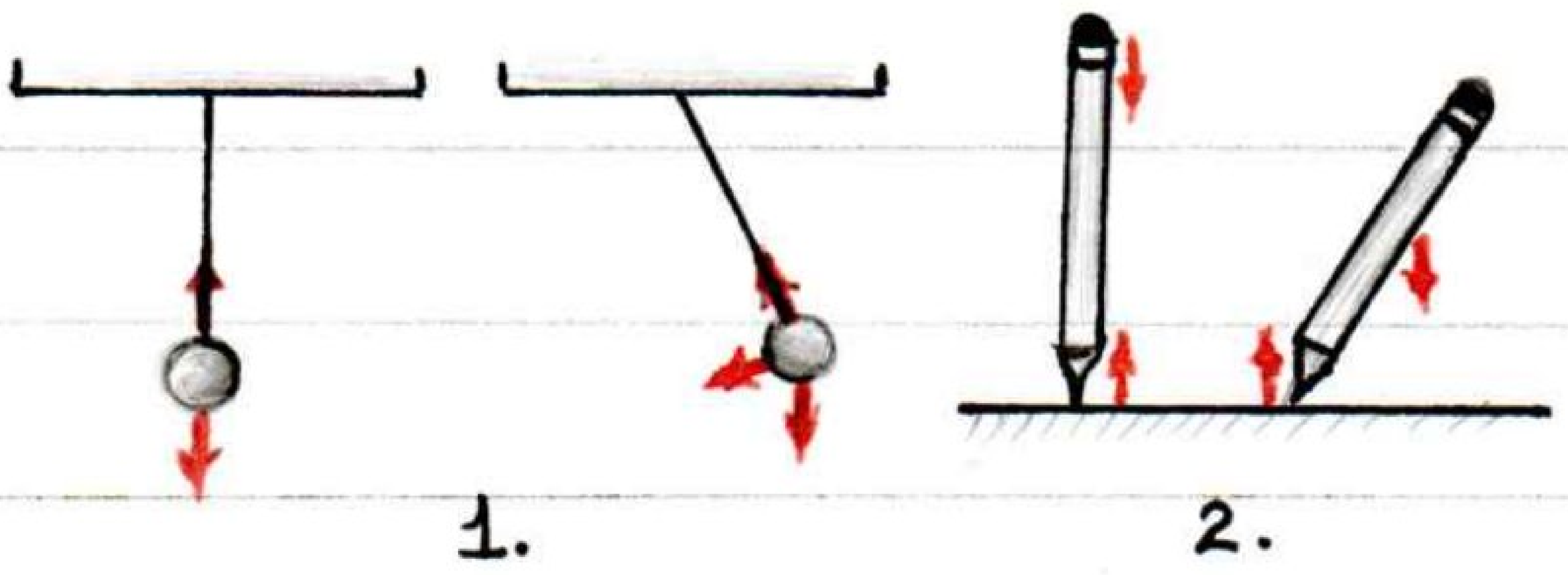
9-4 Stability and Balance :

* If an object is displaced slightly, three possible out-comes might be caused :-

1. Stable equilibrium :- the object returns to its original position.

2. Unstable equilibrium :- the object moves farther from its original position.

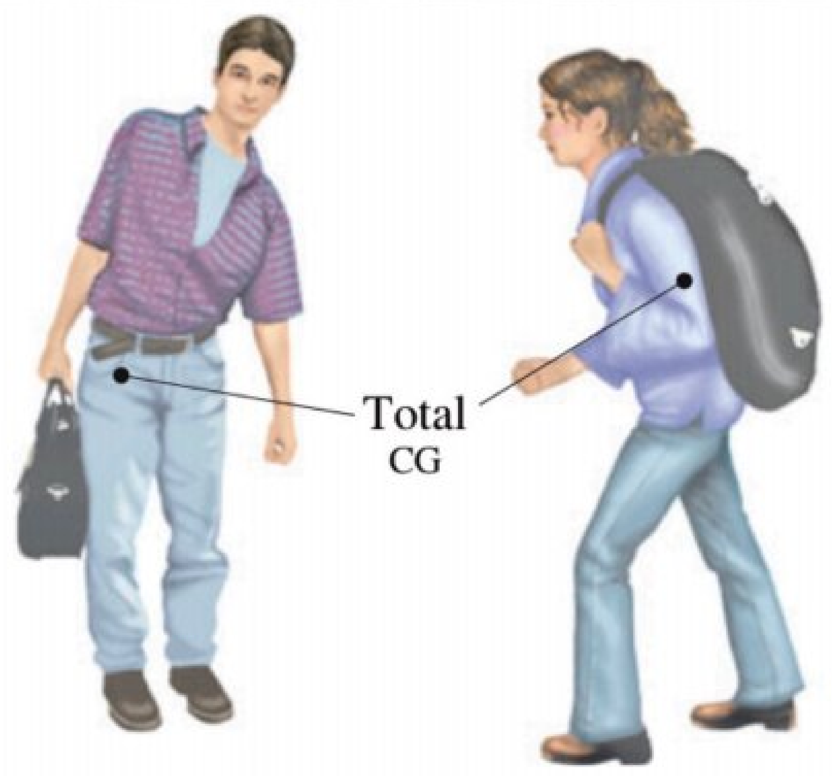
3. Neutral equilibrium :- the object remains in its new position.



3.

* When the center of gravity (CG) is on one side, the torque pulls the object back onto its original base of support. If the obj is tipped further, the (CG) goes past the pivot point and the torque causes the object to topple (the force of gravity acts beyond the area of contanct). If the base is larger, and the CG is lower, the object will be more stable.

* When walking and performing other kinds of movement, a person shifts the body so its (CG) is over the feet, as well as bending over and moving the hips backward in order to carry heavy loads.



9-5 Elasticity; Stress and strain:

In this section we will study the effects of forces, any object changes shape under the action of applied forces. If the forces are great enough, the object will break or fracture.

[1] Elasticity and Hooke's law:-

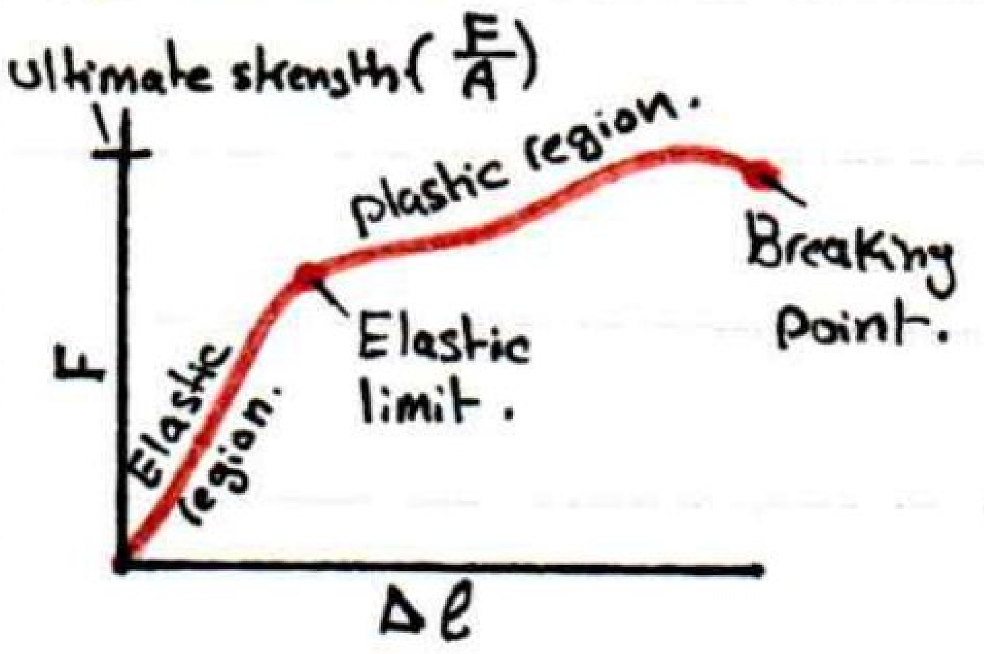
- If a force is exerted on an object, the length of the object changes, this is valid for almost any solid material from iron to bone (up to point).

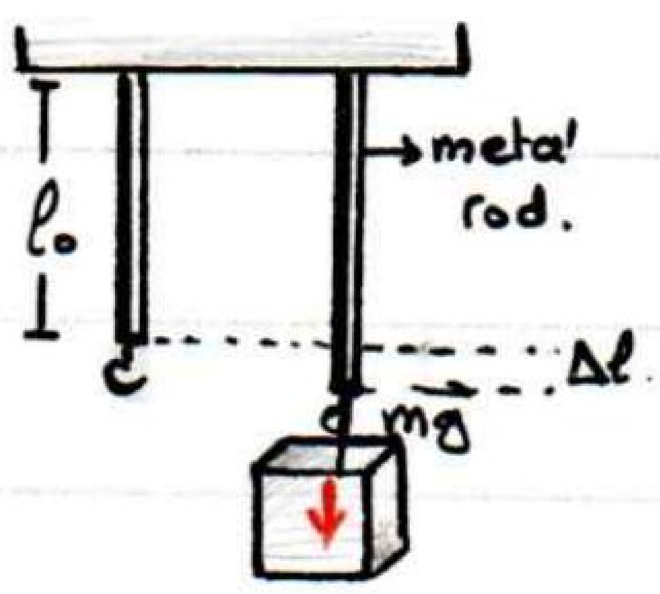
This vertically suspended metal rod, the length changes proportionally to the exerted force:-

$$F \propto \Delta\ell$$

$$* \; F = K\,\Delta\ell. \; *$$

* $\Delta\ell \ll \ell_0$.





- Elastic region: when Hooke's law applies and the object returns to its original length after force is removed. (From the origin to the elastic limit).
- Elastic limit: max value of $\Delta\ell$.
- plastic region: the object becomes permanently deformed (From the elastic limit to the breaking point).
- Breaking point: max applied force without breaking the object.

[2] Young's Modulus:-

- The constant K in the previous equation can be written in terms of the following factors:-

ℓ_0 : the original length of the object.

A : the cross-sectional area.

$\Delta\ell$: the change in length.

F : the applied force.

E : the elastic modulus (Young's modulus).

$$\Delta\ell \propto \frac{F}{A}\,\ell_0$$

$$* \; \Delta\ell = \frac{1}{E}\,\frac{F}{A}\,\ell_0 \; *$$

where $(\Delta\ell)$ is: proportional to the (ℓ_0) of the object. and inversely proportional to (A) of the object.

* Note: The value of (E) depends only on the type of the material (It does NOT depend on the shape or size of it).

* (E) has a unit of N/m^2.

TABLE 9–1 Elastic Moduli

Material	Young's Modulus, E (N/m^2)	Shear Modulus, G (N/m^2)	Bulk Modulus, B (N/m^2)
Solids			
Iron, cast	100×10^9	40×10^9	90×10^9
Steel	200×10^9	80×10^9	140×10^9
Brass	100×10^9	35×10^9	80×10^9
Aluminum	70×10^9	25×10^9	70×10^9
Concrete	20×10^9		
Brick	14×10^9		
Marble	50×10^9		70×10^9
Granite	45×10^9		45×10^9
Wood (pine) (parallel to grain)	10×10^9		
(perpendicular to grain)	1×10^9		
Nylon	$\approx 3 \times 10^9$		
Bone (limb)	15×10^9	80×10^9	
Liquids			
Water			2.0×10^9
Alcohol (ethyl)			1.0×10^9
Mercury			2.5×10^9
Gases†			
Air, H_2, He, CO_2			1.01×10^5

†At normal atmospheric pressure; no variation in temperature during process.