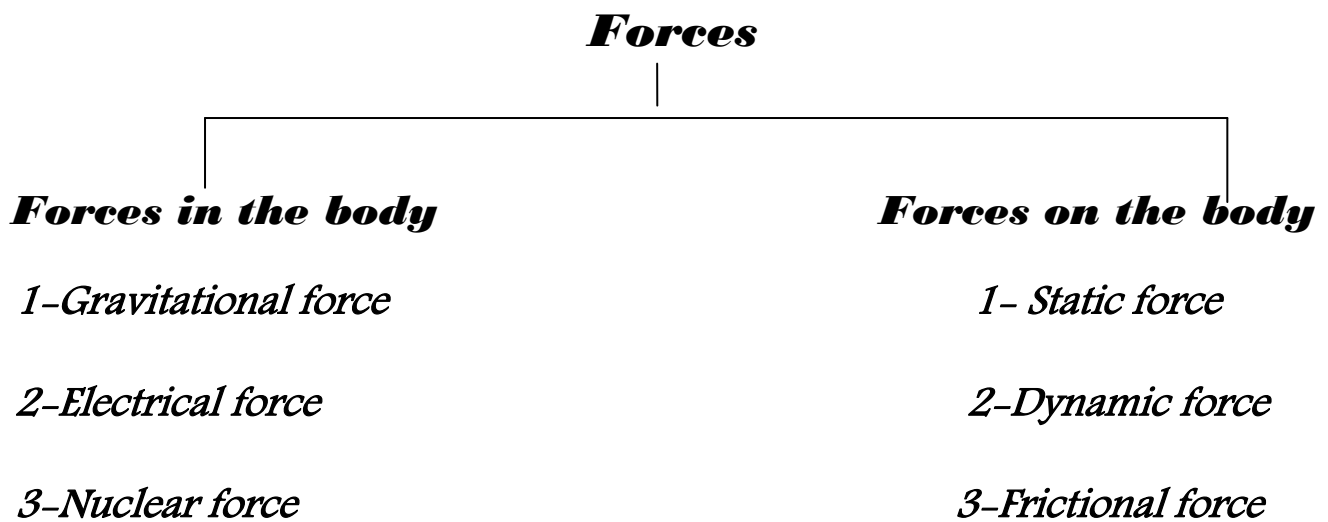


FORCE ON AND IN THE BODY

Force controls all motion in the world; we are usually unaware of important forces in the body, for example, the muscular forces that cause the blood to circulate and the lungs to take in air.



Forces in the body

1-Gravitational forces:

Newton formulated the law of universal gravitation. This law states that there is a force of attraction between any two objects; our weight is due to the attraction between the earth and our bodies. The gravitational force is much smaller on the moon.

$$(F=mg)$$

Where: g = acceleration due to gravity (cm/sec^2 or m/sec^2),

m = the mass (g , kg),

F = the force (N , dyne)

Medical effects of gravitational force

- ✚ The formation of **varicose veins** in the legs as the venous blood travels against the force of gravity on its way to the heart.



Figure 1. varicose veins

✚ Medical effects of gravitational force on the skeleton (**On the bones**), in some way contributes to "healthy bones". If a person becomes "weightless" such as in an orbiting satellite, he may lose some bone mineral, and this may be a serious problem on very long space journeys. Long-term bed rest removes much of the force of the body weight from the bones and can lead to serious bone loss.

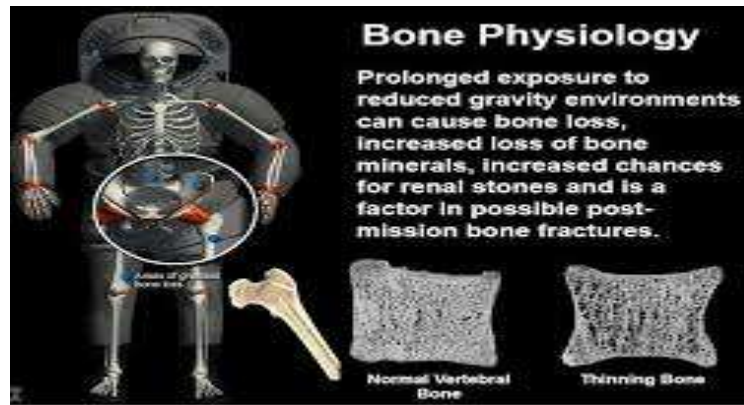
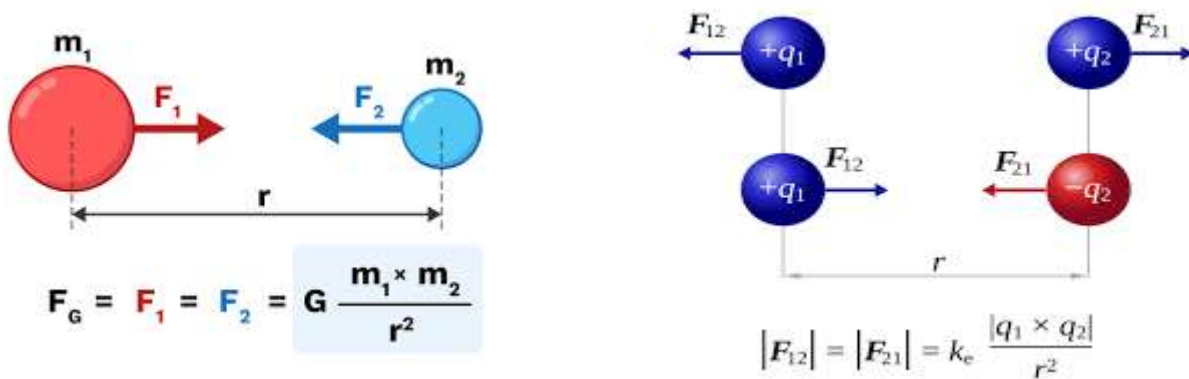


Figure2: effects of gravitational force on the skeleton

2-Electrical forces:

This force more complicated than gravity since it involves attractive and repulsive forces between static electrical charges as well as magnetic force produced by moving electrical charges (electrical current).Electrical forces are immense compared to gravitational force. For example, the electrical force between an electron and a proton in a hydrogen atom is **about 10³⁹ times** greater than the gravitational force between them.



Which Force Is Stronger—Electrical or Gravitational?

Let's peek into the hydrogen atom and compare the gravitational force on the electron due to interaction of its mass with that of the proton to the electrical force between the two particles as a result of their charges. In order to do the calculation, you'll need to use some well-known values:

$$\text{Electron: } m_e = 9.1 \times 10^{-31} \text{ Kg} \quad q_e = -1.6 \times 10^{-19} \text{ C}$$

$$\text{Proton: } m_p = 1.7 \times 10^{-27} \text{ Kg} \quad q_p = +1.6 \times 10^{-19} \text{ C}$$

$$\text{Distance between the electron and proton: } r = 1.0 \times 10^{-10} \text{ m}$$

Our bodies are basically electrical machines. This forces produced by the muscles are caused by electrical charges attracting or repelling other electrical charges.

Control of the muscles is primary **electrical**. Each of the billions of living cells in the body has in electrical potential difference across the cell membrane because of the differences in charge between the inside and outside of the cell. This amount to less than 0.1V, but because of the very thin cell wall it may produce a field as large as 10^5 V/cm.

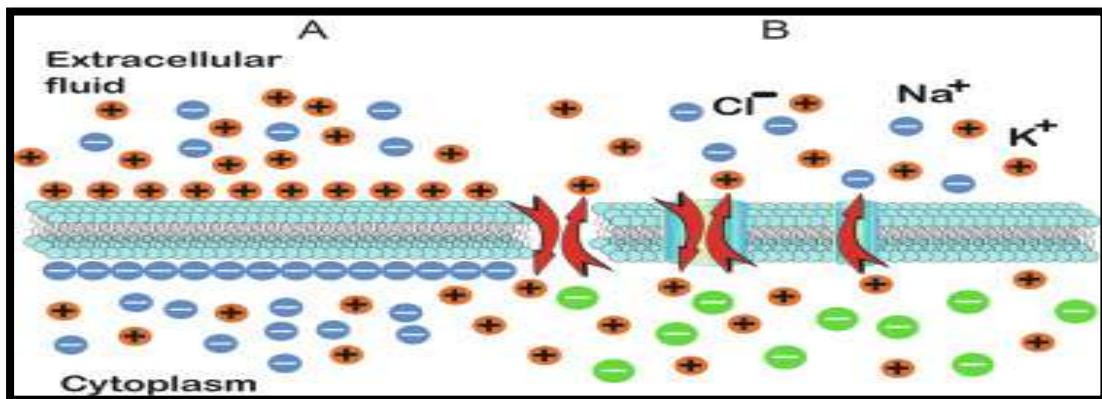


Figure3. electrical potential difference of the cell membrane

3-Nuclear forces.

Nuclear force keep the positive charges "proton" together inside the nucleus .we have two types of nuclear forces:

- ✚ Strong nuclear force: it is very larger than the other type. it is act as "glue" to hold the nucleus against the repulsive forces that produce by the protons on each other
- ✚ Weaker nuclear force: it is involved with electron decay from the nucleus. It may be related to the electrical force.

Forces on the body

1-**Statics** : When objects are stationary (static) they are in a state of equilibrium. The sum of the forces in any direction is equal to zero, and the sum of the torques about any axis also zero.

Many of the muscle and bone systems act as levers which are classified to:

a-**First class levers**: They are least common in the body. The fulcrum point (F) is between the muscle forces (M) and the weight (W), for example the head.

b-**Second class levers**: They are found more than first class levers. Weight (W) is between the fulcrum point (F) and muscle forces (M), for example standing on the toes.

c- **Third class levers**: They are most common in the body. Muscle forces (M) is between fulcrum point (F) and weight (W).For example, the arm in the elbow joint.

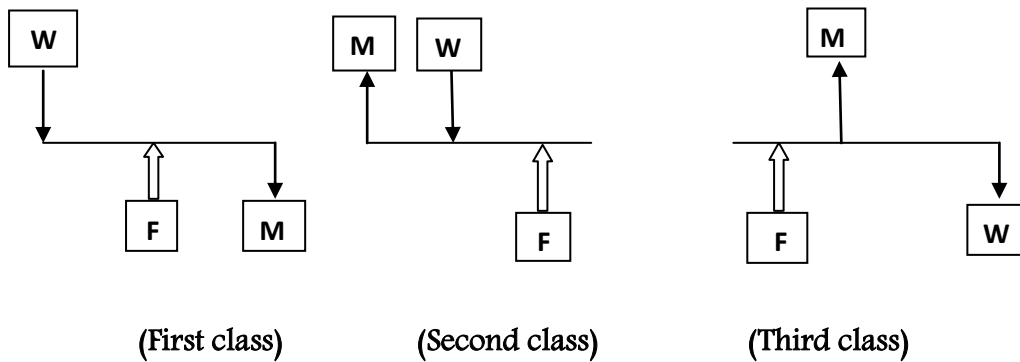
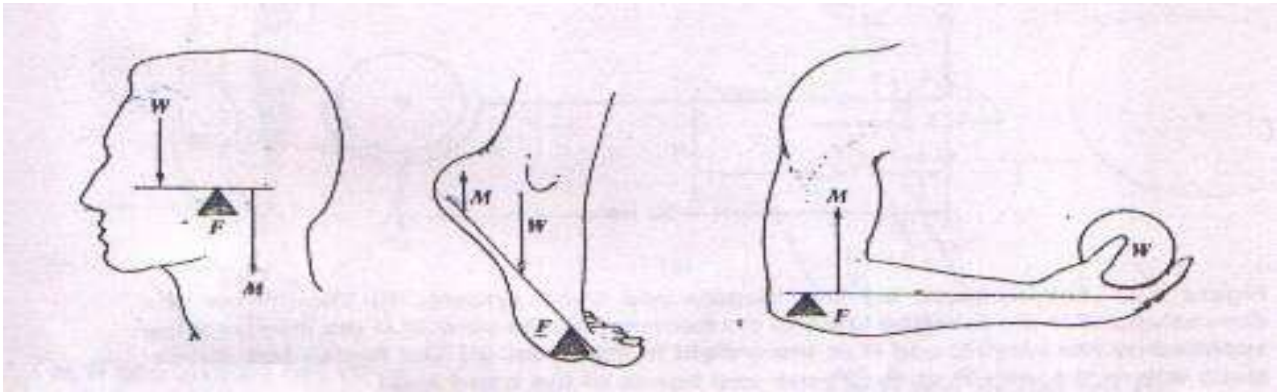


Figure4. The three levers classes and schematic example of each in the body. W is a force that could be the weight, F is a force at the fulcrum point and M is the muscle force.

The sum of force in any direction is (zero) $\sum F = 0$

The sum of the torques about any axis is (zero) $\sum \tau = 0$

$$\tau = F \cdot L$$

Where τ : The torque (N.m), F : The force (N), and L : The vertical distance from the fulcrum (pivot) point to the line action of the force (m, cm).

$\tau_{cw} = \tau_{ccw}$ sum of clock wise torque = sum of counter clock wise torque

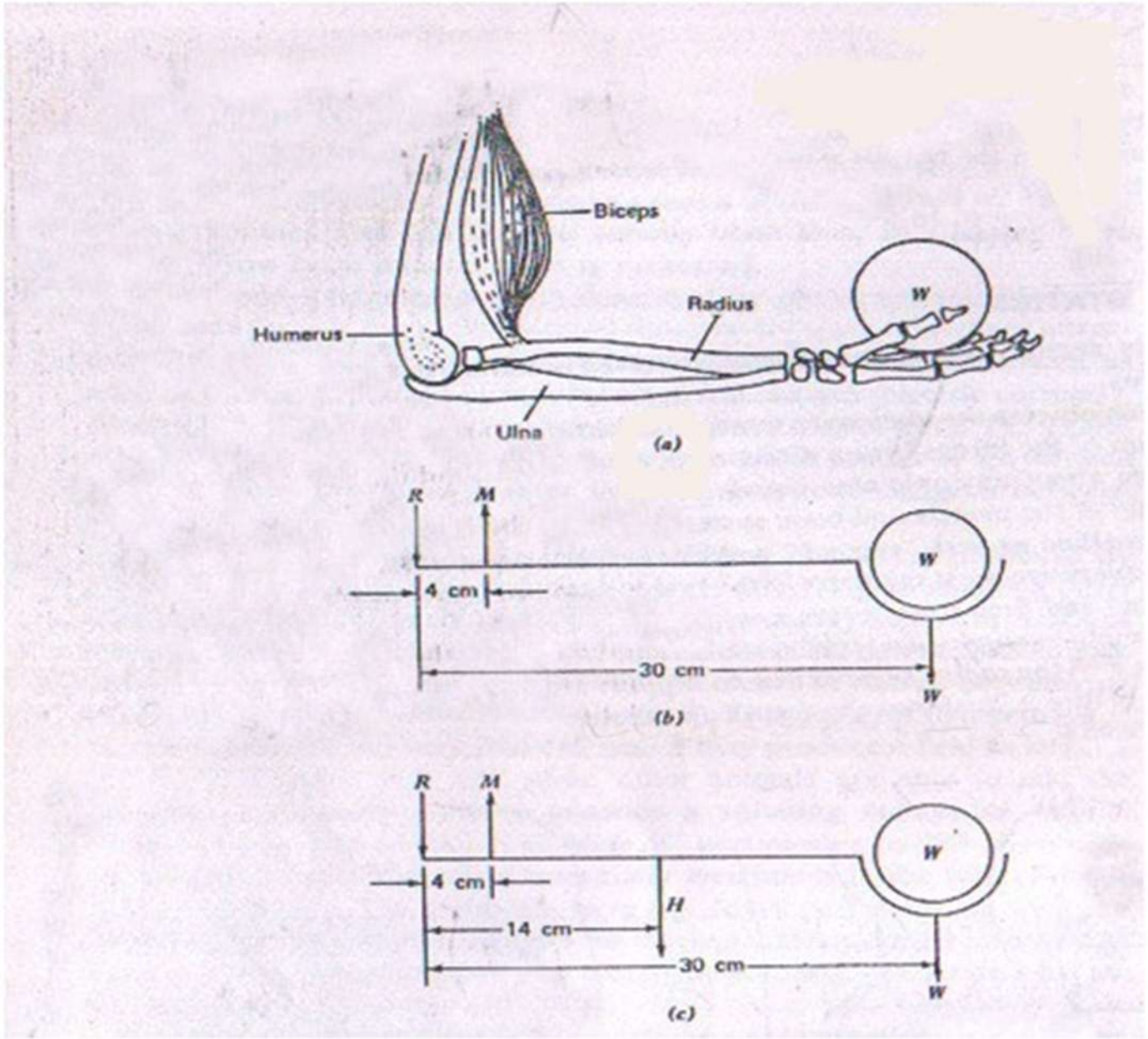
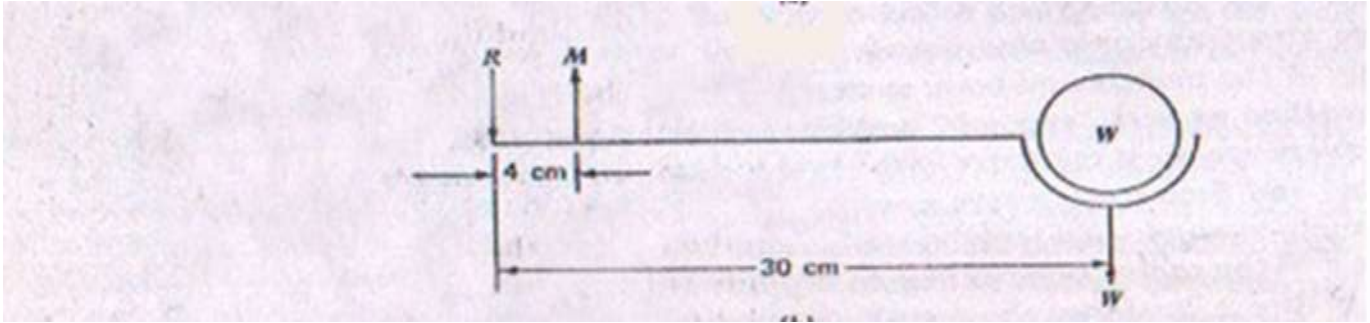


Figure 5. The forearm (a) the muscle and bone system. (b) the forces and dimensions, R is the reaction force of the humerus on the ulna. M is the muscle force supplied by the biceps, and W is the weight in the hand. (c) the forces and dimensions where the weight of the tissue and bones of the hand and arm H is included and located at their center of gravity

A simple example of a lever system in the body is the case of the biceps muscle and the radius bone acting to support a weight W in the hand (Figure 5a).

Figure 5b show the forces and dimension of a typical arm. We can find the force supplied by the biceps if we sum the torques about the pivot point at the joint. There are **only two torques**: that due to the weight W , which is equal to $30W$ acting clockwise,

and that produce by the muscle force M which counterclockwise and of magnitude $4M$. With the arm in equilibrium we find that:



$$\tau_1 = F_1 \cdot L_1$$

$$\tau_2 = F_2 \cdot L_2$$

$$\tau_1 = M \cdot 4$$

$$\tau_2 = W \cdot 30$$

$$\tau_1 = (+ 4 M)$$

$$\tau_2 = (- 30W)$$

$$\Sigma \tau = 0$$

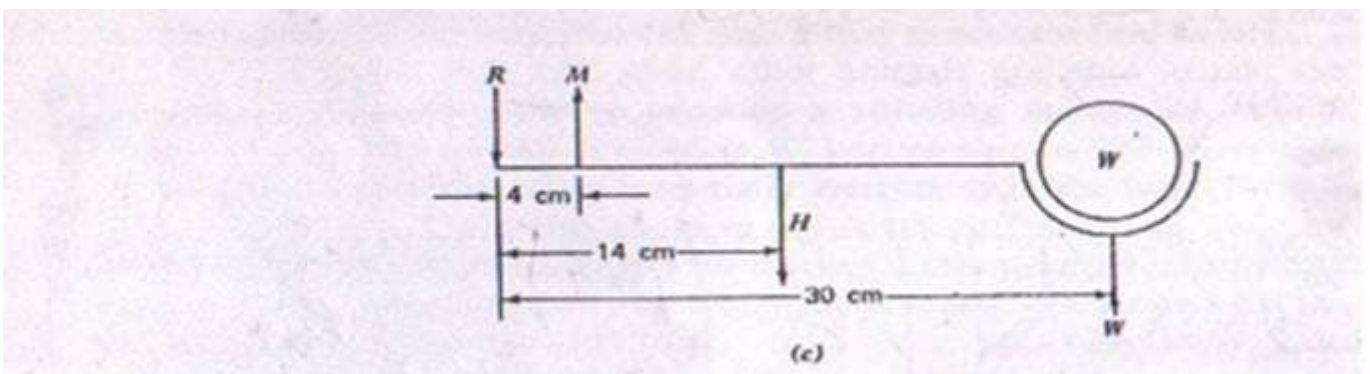
$$- 30 W + 4M = 0$$

$$4M = 30W$$

$$M = 7.5W$$

Or that a muscle force 7.5 times the weight is needed (we neglected the weight of the forearm and hand).

Figure 5c show a more corrects representation of the problem with weight of the forearm and hand H included.



$$\tau_1 = F_1 \cdot L_1$$

$$\tau_2 = F_2 \cdot L_2$$

$$\tau_3 = F_3 \cdot L_3$$

$$\tau_1 = M \cdot 4$$

$$\tau_2 = H \cdot 14$$

$$\tau_3 = W \cdot 30$$

$$\tau_1 = (+ 4 M)$$

$$\tau_2 = (- 14H)$$

$$\tau_3 = (- 30W)$$

$$\Sigma\tau = 0$$

$$- 30W + (- 14H) + 4M = 0$$

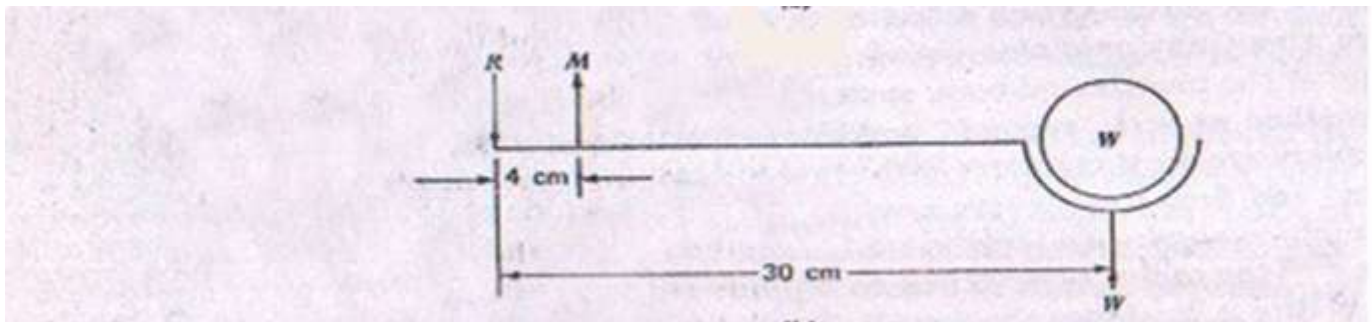
$$4M = 30W + 14H$$

$$\div 4$$

By summing the torques about the joint we obtain

$$M = 3.5 H + 7.5 W$$

Example 1:- The lever system in the body is the case of the biceps muscle and the radius bone acting to support a weight in the hand. R:- The reaction force of the humerus on the ulna. M:- The Muscle force supplies by the biceps. W:- the weight in the hand and equal (100 N). Find muscle force? (Neglected the weight of the forearm and hand).



$$\tau_1 = F \cdot L$$

$$\tau_2 = F \cdot L$$

$$\tau_1 = M \times 4 \times 10^{-2}$$

$$\tau_2 = 100 \times 30 \times 10^{-2}$$

$$\Sigma\tau = 0$$

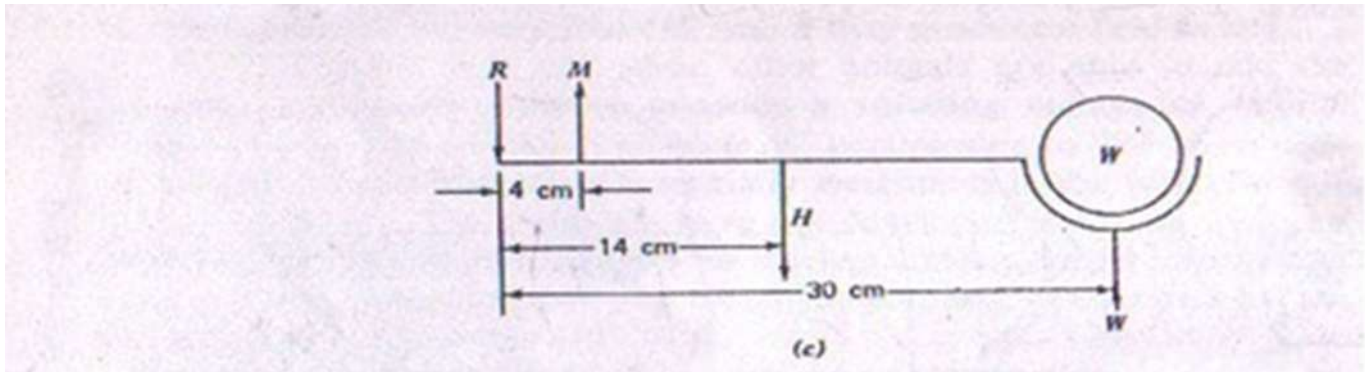
$$(M \times 4 \times 10^{-2}) + \{- (100 \times 30 \times 10^{-2})\} = 0$$

$$(M \times 4 \times 10^{-2}) = (100 \times 30 \times 10^{-2})$$

$$M = 750 \text{ N}$$

Example2: The lever system in the body is the case of the biceps muscle and the radius bone acting to support a weight in the hand, **M**:- The Muscle force supplies by the biceps. **W**:- the weight in the hand and equal (5 N).

The force and dimension where the weight of the tissue and bones of the hand and arm (**H**) at their center of gravity. (**H=15N**) Find muscle force (**M**)



$$\tau_1 = F_1 \cdot L_1$$

$$\tau_2 = F_2 \cdot L_2$$

$$\tau_3 = F_3 \cdot L_3$$

$$\tau_1 = M \cdot L_1$$

$$\tau_2 = H \cdot L_2$$

$$\tau_3 = W \cdot L_3$$

$$\tau_1 = M \times 4 \times 10^{-2}$$

$$\tau_2 = 15 \times 14 \times 10^{-2}$$

$$\tau_3 = 5 \times 30 \times 10^{-2}$$

$$\sum \tau = 0$$

$$M \times 4 \times 10^{-2} + (-\{15 \times 14 \times 10^{-2}\}) + (-\{5 \times 30 \times 10^{-2}\}) =$$

$$M \times 4 \times 10^{-2} = \{15 \times 14 \times 10^{-2}\} + \{5 \times 30 \times 10^{-2}\}$$

$$M \times 4 \times 10^{-2} = (2.1 + 1.5)$$

$$M \times 4 \times 10^{-2} = 3.6 \longrightarrow \mathbf{M=90N}$$