Lecture (2)

Medical Physics

Fourth Stage
Department of Physics
College of Science
Al-Muthanna University
2018-2019

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Forces action of the body

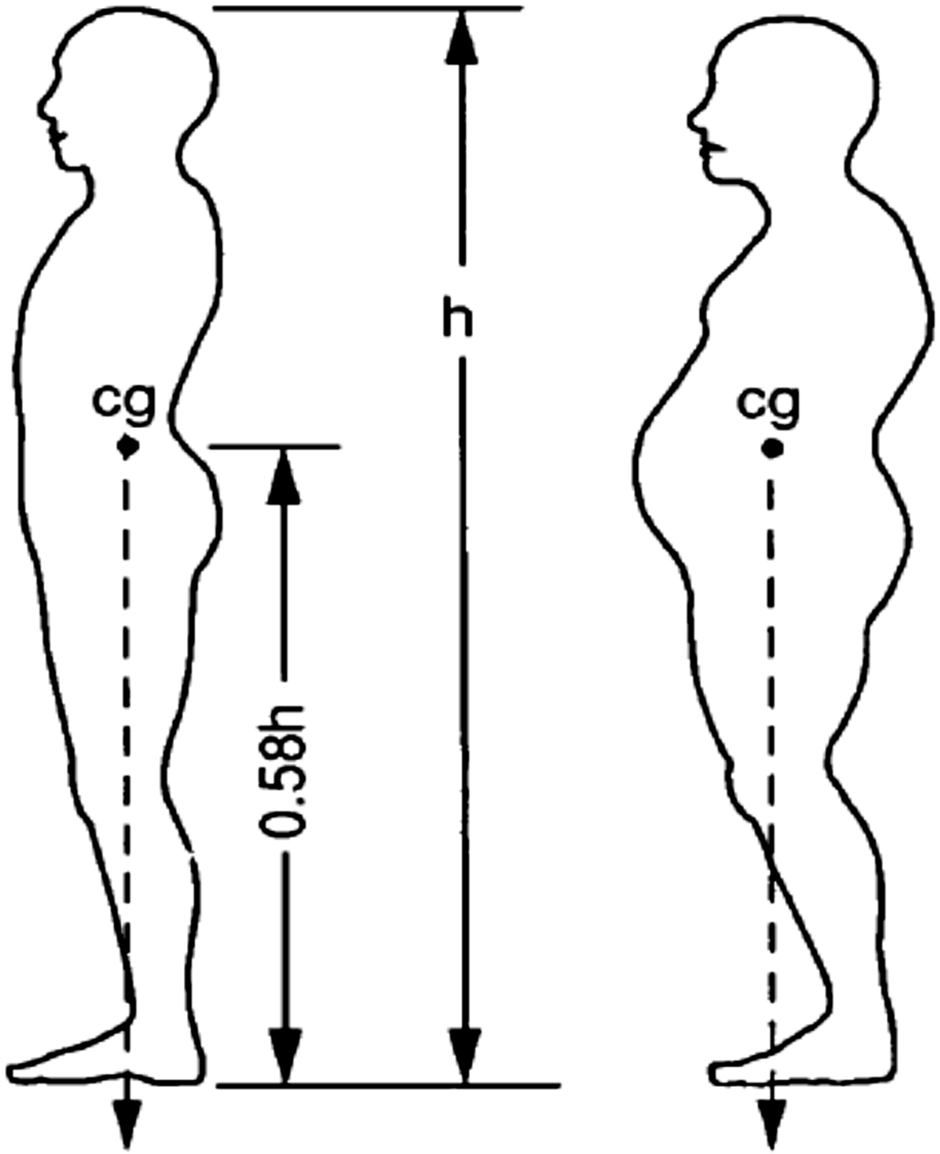
1- Gravitation force: Newton’s gravitation law.

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

Newton's law of universal gravitation states that every particle attracts every other particle in the universe with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.

Medical effects of gravity:

1. Formation of varicose veins in the legs.
2. Healthy bones on earth weightlessness in a satellite. There is loss some bone minerals so you have to bone loss.



In this figure,

(a) The center of gravity of a normal person is located about 58% of the person’s height above the soles of their feet.

(b) An overweight condition can **shift the cg forward** so that the vertical projection of it passes underneath the balls of the feet.

2- Electrical forces: it is more complicated than gravitation force as it involve attractive and repulsive forces between electrical charges as well as magnetic forces produce by current. This is 10^{39} times larger than gravitational force.

- Forces produced by muscle are by electrical charges, control of muscle is electrical.
- Cell has potential difference across cell membrane due to charge gradient inside and outside cell.
- Magnitude less than 0.1 V but produces field of $10^5\ V/cm$, for example Eel, has cell battery occupies 80 % of Eel's body length. It is weightless in water.

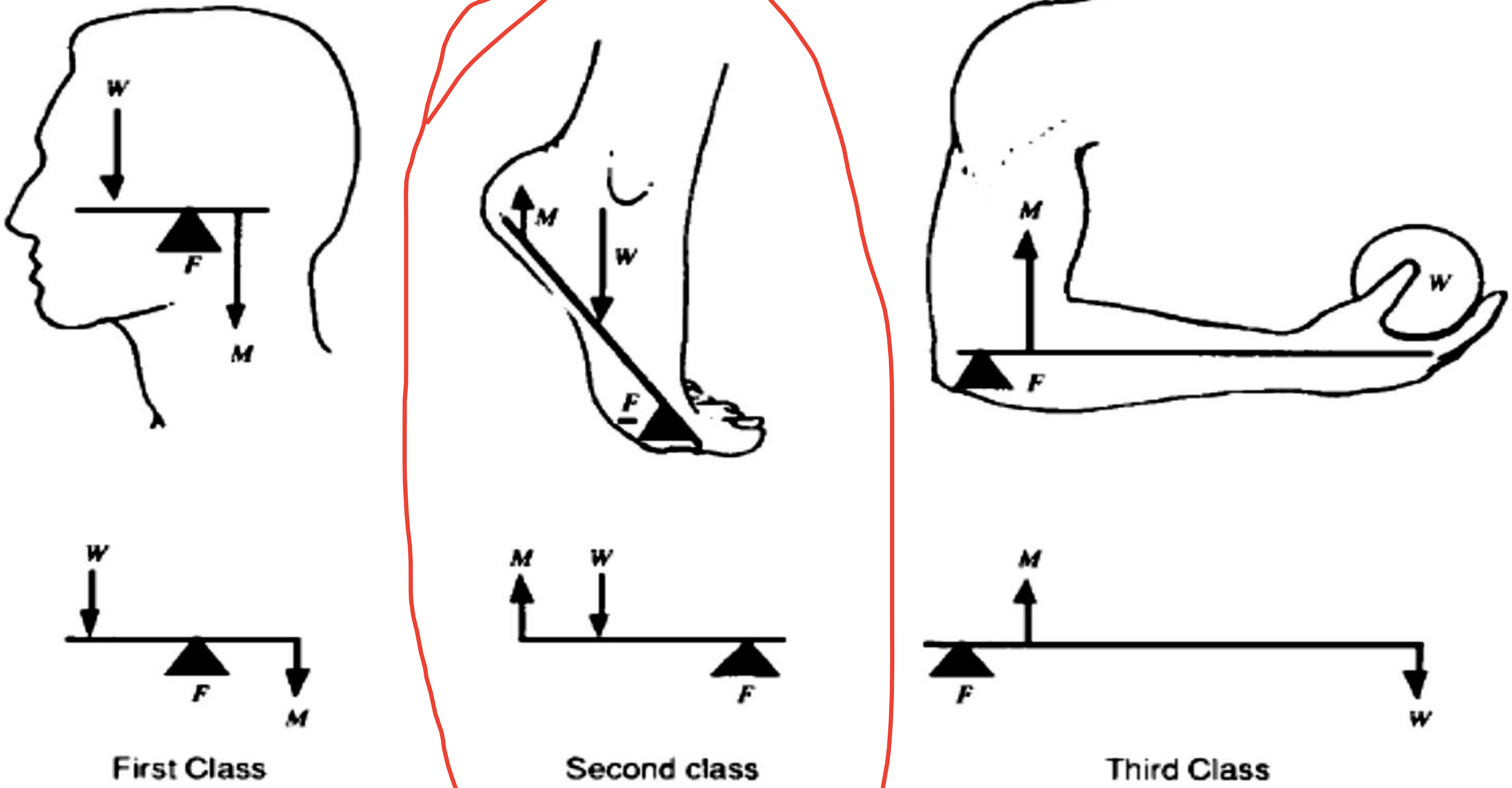
3- Nuclear forces: This force very strong involved in nuclear medicine.

- **In general, there are two types of problems involving forces on the body:**

1. **Static Force**
2. **Dynamic Force**

Static Force:

- When body is in equilibrium state, sum of forces in any direction is zero and the sum of the torques about any axis also equal to zero.
- There are **three classes** of lever in our body as shown in the figure below. Muscles and bones system of body act as a lever.



Three class lever is most common in body where W is the weight, F is the force at fulcrum point and M is the muscle force

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Dynamic Force

Dynamics means body is acceleration. From Newton's second law:

$$F = m\,a \qquad F = m\,\frac{dv}{dt} \qquad F = \frac{\Delta(m\,v)}{\Delta t} = \frac{\Delta p}{\Delta t}$$

- **Acceleration can produce the following effects on the body:**

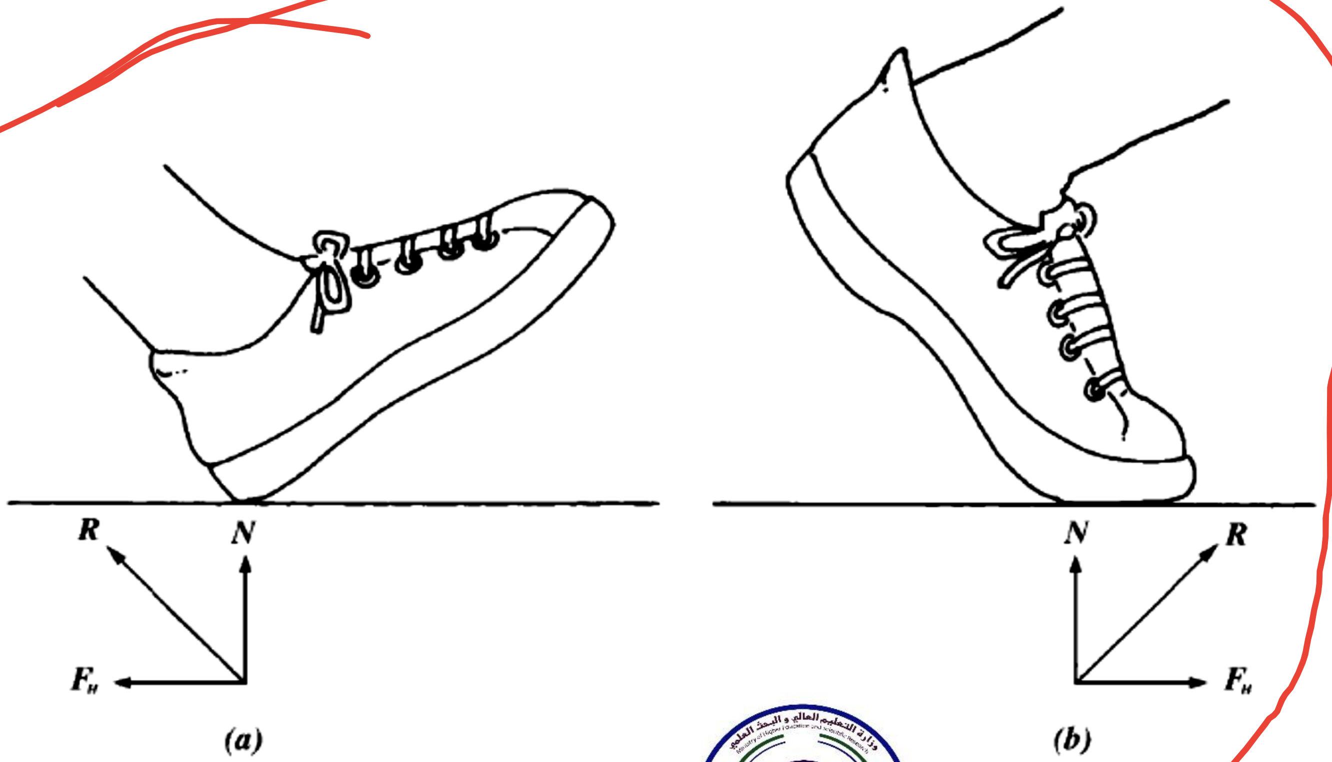
1. Apparent increase or decrease in weight.
2. Change in internal hydrostatic pressure.
3. Distortion of elastic tissue of body.
4. Tendency of solids with different densities suspended in liquid to separate.

Frictional Forces

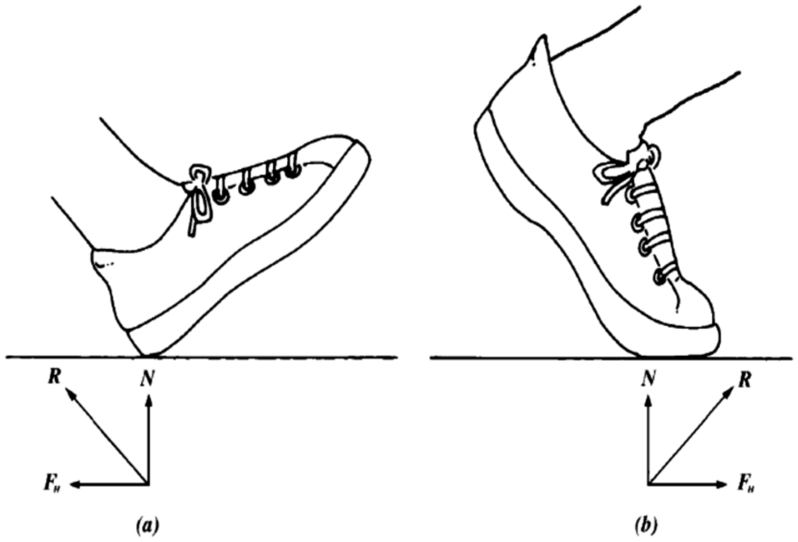
- Friction and energy loss due to friction appear everywhere in our everyday life.
- Friction limits efficiency of most machines such as electrical generators and automobiles. On other hand we make use of friction in devices such as rubber tires and automobile brakes.

<u>Normal walking</u>:

When person walks as heel of foot touches ground force is transmitted from foot to ground.



- Normal walking: When person walks as heel of foot touches ground force is transmitted from foot to ground.
- F → (force) resolved in to vertical and horizontal components.
- N → (normal) vertical force exists on heel.
- frictional force is horizontal force F_v or f.
- friction between heel and surface prevent foot from slipping.



$$\boldsymbol{f = \mu N}$$

- Where N is the normal force and μ is coefficient of friction between the two surfaces. The value of μ depends upon two materials in contact, and independent of the surface area.

- Below table gives values of coefficient of friction **μ** for a number of materials.

Material	**μ**
Steel on steel	0.15
Rubber tire on dry concrete road	1.00
Rubber tire on wet concrete road	0.7
Steel on ice	0.03
Between tendon and sheath	0.03
Lubricated bone joint	0.003

- When a person walks, horizontal force is equal to 0.15 W, where W is the weight of person.
  - If N=W then we can apply frictional force as large as $f = \mu W$.

- For rubber tire on dry concrete road the maximum frictional force can be as large as $= W$.
  - This is much larger than horizontal force component (0.15 W).
  - **So frictional force prevents a person from slipping.**

- When a person on icy or oily surface where $\mu<0.15$ his foot slips.
  - friction must be overcome when joints move, but for normal joints it is very small. If a disease of the joint exists, the friction may become larger. The synovial fluid in the joint is involved in the lubrication.
- The saliva we add when we chew food acts as a lubricant. If you swallow a piece of dry toast you become painfully aware of this lack of lubricant.
- Most of the large organs in the body are in more or less constant motion such as:

- Heart beats
- The lungs move inside the chest with each breath.
- Slow rhythmic motion of intestine.

All of these organs are lubricated by a slippery mucus covering to minimize friction.

Example 1: A 50 kg person walking at 1 m/sec (3.6 km/hr) bumps into wall and stop in a distance 2.5 m in 0.05 sec. what is the force developed on impact?

Sol.

- $\Delta p = m_1 v_1 - m_2 v_2$
- $\Delta p = \Delta(mv) = \left(50\,kg\ \times 1\frac{m}{sec}\right) - (50\,kg\ \times 0)$
- $\Delta p = 50\,kg\,m/sec$
- $Impact = \frac{\Delta(mv)}{\Delta t} = \frac{50\,kg\,m/sec}{0.05\,sec} = 10^3\,kg\,m/sec^2$
- $Impact = 1000\,N$
- The force is 20 times of his weight.

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Example 2: when blood flows then apparent increase of heart beat is say about 60 gm of blood is given velocity 1 m/sec in about 0.1 sec. what is the force applied?

Sol.

- $Upward\ momentum\ of\ mass\ of\ blood = 60\ gm\ \times 1\ m/sec$

$$= 0.06\ kg\ m/sec$$

- $Downward\ reaction\ force = \frac{\Delta p}{\Delta t} = \frac{0.06\ kg\ m/sec}{0.1\ sec}$

$$= 0.6\ N$$

- If a person jumps from height 1m and lands stiff-legged he will get a shock. Under this condition de-acceleration of body takes place through compression of feet.
- The body is traveling at 4.5 m/sec just prior to hitting and if padding collapses by 1cm the body stops in 0.005 sec. The force in the legs is:

$$F = \frac{m\,\Delta v}{\Delta t} = \frac{m\,4.5}{0.005} = 90\,m$$

- Force on legs is 90 times of body weight.
- If person landed on Gym mat the de-acceleration time will be longer. He would land toes first and bend his knees to de-acceleration over a much longer time, thus decreasing landing force.