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Anesthesia Techniques Department
First stage /medical physics
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Lecture 2:

Energy, work and power of Body

In the physics of the body, energy is of primary importance .All activities of the body including thinking, involve energy changes.

The conversion of energy into work such as lifting a weight or riding a bicycle represent only a small fraction of the total energy conversions of the body.

Under resting (basal) conditions about;

25% of the body's energy is being used by the skeletal muscles and the heart.

19% is being used by the brain.

10% is being used by the kidneys.

27% is being used by the liver and spleen.

The body's basic energy (fuel) source is food. We can consider the body to be an

Energy converter that is subject to the law of conservation of energy.

The body uses the food energy to operate its various organs, maintain a constant body temperature, and do external work.

The energy used to operate the organs eventually appears as body heat .Some of this heat is useful in maintaining the body at its normal temperature. Any energy that is left over is stored as body heat.

The conservation of energy in the body can be written as;

$\Delta U = Q - W$

ΔU; change in stored energy.

Q; the heat lost or gained.

W; the work done by the body in some interval of time.

-Basal Metabolic Rate (BMR):

BMR: the lowest rate of energy consumption at rest, it is the amount of energy needed to perform minimal body function such as breathing and pumping the blood through the arteries.

The BMR depends on the mass of the body and temperature.

The BMR depends primarily upon thyroid function. A person with an overactive thyroid has a higher BMR than a person with normal thyroid function.

-WORK AND POWER:

Chemical energy stored in the body is converted into external mechanical work as well as into life- preserving function.

The external work (ΔW), defined as a force (F) moved through a distance (ΔX).

$\Delta W = F.\ \Delta X$

The force and the motion through (ΔX) must be in **the same direction**.

The rate of the doing work is (power) P.

$$P = \frac{\Delta W\ (J)}{\Delta t\ (Sec)}$$

$$= \frac{F.\Delta X}{\Delta t}$$

$$= F.V$$

Where $\frac{\Delta x}{\Delta t}$ = velocity (V)

The muscles are doing internal work which appears as heat in muscle, and causes a rise in its temperature. This additional heat in muscle is removed by blood flowing through the muscle, by conduction to the skin, and by sweating.

The **efficiency** of the human body as a machine:

$$E = \frac{work\ done}{energy\ consumed}$$

-The temperature depends on:

1- The temperature of the environment.

2- Time of the day.

3- A mount of clothing.

4- Amount of recent physical activity.

5- Health of the individual.

Example 1:

3000 J of heat is added to a system and 2500 J of work is done by the system. What is the change in internal energy of the system?

We have:

Heat (Q) = +3000 Joule

Work (W) = +2500 Joule

Solution:

$\Delta U = Q - W$

Note that:

Q is positive if the heat added to the system

W is positive if work is done by the system

Q is negative if heat leaves the system

W is negative if work is done on the system

The change in internal energy of the system

Solution:

$\Delta U = 3000 - 2500$

$\Delta U = 500$ Joule

Internal energy increases by 500 Joule.

Example 2

How much work is required to lift a 40Kg crate 20M high?

Solution:

W= mgΔh

W= (40Kg) (9.8M/s^2) (20M)

=7840J

Example 3:

How far must a 5N force pull a 50g toy car if 30J of energy are transferred?

Solution:

WD = F x d

Rearrange to get:

d= $\frac{\mathrm{WD}}{\mathrm{F}}$ =

=$\frac{30}{5}$

So d = 6m

Example 4:

A man exerts a force of 200 N on a boulder but fails to move it.

Calculate the work done.

Solution:

By Using:

WD = F x d

Note that: d = 0 because the boulder doesn’t move

= 2000 x 0

So WD = 0

*If an object does not move when the force is applied then no work is done. Work is only done if the object moves.

Example 5:

A person of mass 70kg runs up a flight of stairs with a vertical height of 5m. If the trip takes 7s to complete, calculate the person’s power.

Solution:

WD = mgh

= 70 x 10 x 5

= 3500 J

Power = $\frac{\text{work done}}{\text{time}}$

$= \frac{3500}{7}$

So Power = 500 W