36 Power and the Human Body ♡

Formulae:

work done (J) $=$ force (N) $\times$ distance moved parallel to direction of force (m)

$$E = Fs$$

$$\text{power (W)} = \text{energy (J)}/\text{time (s)}$$

$$P = \frac{E}{t}$$

36.1 A weight-lifter lifts a mass of 20 kg through 1.5 m ten times in one minute.

(a) What is the weight of the 20 kg mass?

(b) Calculate the total work done in lifting the weights.

(c) Calculate the weight-lifter's average power in watts.

36.2 A 70 kg bricklayer needs to put 100 bricks (2.0 kg each) on the first floor of some scaffolding. The first floor of the scaffolding is 3.0 m above the ground floor.

(a) Calculate the potential energy change when the bricks are lifted to the first floor.

(b) Assuming that they move five bricks at a time, calculate the energy needed for the bricklayer to climb the ladder enough times to lift 100 bricks to the first floor.

(c) If the bricklayer's maximum power is 800 W, how much time would they spend going up the ladder while doing the jobs in parts (a) and (b) combined?

36.3 The power needed to keep a human being alive is called the basal metabolic rate (BMR). For adults this is about 6.0 MJ/day.

(a) Calculate the BMR in watts (J/s).

(b) Calculate the BMR in joules per hour (J/h).

36.4 A cyclist on an exercise bike has a basal metabolic rate of 100 W. Her muscles are 30% efficient. This means that for every 100 J of energy given to the muscles in the form of food, only 30 J are converted into work done on the bike. The power reading on the exercise bike is 150 W. Calculate the total power needed by her body to produce this output.

36.5 Sometimes energies are given in kilocalories (kcal). One kilocalorie (sometimes called a Calorie) is equal to $4\,200$ J.

(a) Express the amount of energy needed to keep a person alive (6.0 MJ/day) in kcal/day.

(b) How much energy (in kcal) is needed per hour to stay alive?

36.6 Someone swimming has a total metabolic rate of 600 W.

(a) How much energy would they need for an hour of swimming? Give your answer in kilojoules (kJ).

(b) How much energy (in kcal) is needed for an hour of swimming?

36.7 The chemical processes in your body generate thermal energy, which keeps you warm. If you lose 30 J of thermal energy each second to your surroundings, your body needs to convert another 30 J into thermal energy each second to maintain body temperature. If this doesn't happen, your body temperature will fall, and you may become ill.
Fred's body has a surface area of 2.0 m^2. He loses 80 J of thermal energy each second to his surroundings.

(a) What basal metabolic rate is needed (in J/s) for Fred to keep his body temperature constant?

(b) How much thermal energy does Fred lose per second through each square metre of body surface?

(c) Fred's baby sister has a surface area of 0.20 m^2. How much thermal energy do you expect her to lose each second?

(d) Who finds it easier to stay warm - Fred or his baby sister? Why?