The University of British Columbia

BIOL/PHYS 438 Assignment # 4: MORE MECHANICS & METABOLISM

Thu. 15 Feb. 2007 — finish by **Thu. 1 Mar.**

Please hand in one assignment per group and list the names & Email addresses of all group members at the top of each sheet. During Reading Break you can gather information from the literature and attempt each problem on your own; then when you return you can pool your information and ideas with the rest of your team and your final solutions should emerge quickly.

As always, *if you think some necessary information is missing, make a reasonable assumption.*
But always *write down* what that assumption is.

Remember to estimate your *uncertainty* in any measured quantity, and don't forget to specify all *units*.

If possible, justify your input. For original comments you may score bonus points!

1. THE ENERGY LOSS OF A HUNT:

(*a*) Search the literature to collect data about a fast hunter such as wild dog, leopard, or lion. Find mass M, top speed U_t, length of leg L, length of step while foot is on the ground S, period $T = \omega/2\pi$ (either from $T = 1/n$ where n is the number of steps per second, or from the distance λ between two imprints of the feet on the ground: $T = \lambda/U_t$, duration τ of the hunt, or the range $R = U_t\tau$. Treat the motion of the rear leg like simple harmonic motion where the position of the foot relative to the vertical is $x = A\sin(\omega t)$, where $A = S/2$ is the amplitude, and $U = \omega A\cos(\omega t)$ is the velocity of the foot. The maximum foot velocity is $U_{\max} = \omega A$, the instantaneous acceleration of the foot is $a = \omega^2 A\sin(\omega t)$, and the maximum foot acceleration is $a_{\max} = \omega^2 A$.

(*b*) Assuming that the maximum acceleration of the foot is equal to the maximum acceleration of the body, find the acceleration time t_1 needed to reach top speed $U_t = at_1$.

(*c*) Determine the speed-up distance s_1 (similar to the free fall distance $s = \frac{1}{2}gt^2$).

(*d*) Calculate the kinetic energy K which the animal attains at top speed.

(*e*) Assuming that K was obtained by the application of an average force F acting during the time t_1 or over the distance s_1, the energy equation reads $K = F \times s_1$, from which F can be found.

(*f*) Find the total energy expense of the hunt, $E_{\text{tot}} = F \times s_1$ and express it in mass of body fat burned, taking into account a reasonable inefficiency of converting the body fat into muscle fuel.

2. LANDING ON YOUR FEET:

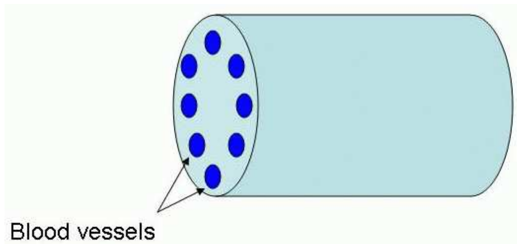
Two young people jump down from a height of $h = 2.0$ m onto the forest floor which has a mud hole and a rocky flat. The boy ($M_b = 70$ kg) lands with stiff legs on the muddy ground, which "gives" so that he depresses the ground by $\Delta y = 5$ cm when being decelerated from the impact velocity U_0 to rest.

(*a*) Determine the impact speed U_0.

(*b*) Calculate the deceleration (negative acceleration) of the the boy's center of mass during landing, and determine the average force on the soles of his shoes during impact.

(*c*) The girl ($M_g = 65$ kg) lands on the rock, but in order to reduce the impact force she lands with soft knees and moves her center of gravity relative to her feet by $\Delta y = 0.5$ m as she lands. What is the average impact force on the soles of her feet during the landing?

3. DIFFUSION AND METABOLIC RATES OF A NUDIBRANCH: A certain nudibranch of mass $M = 0.005$ kg living in 10°C waters off Vancouver Island carries its gills (mass m) outside its body. Assume that (i) the gills are 10% of the total body mass, (ii) the gills are tree-like structures that have branches with an average diameter of $D = 500$ μm, filled with fine capillary vessels of diameter $d = 10$ μm right under the skin of the gills. (See sketch.)



(a) Determine the surface area A of the gills that contributes to the diffusion exchange of oxygen.

(b) Calculate the diffusion flow rate of oxygen $\dot{N}_{0_2}$ [molecules/sec] into the gills. (See Sect. **4.1.3**; assume first that the blood returning from the body into the gills is completely deoxygenated.)

(c) Use the relation between $\dot{N}$ and Γ which is derived in Section **4.3.3** to determine the metabolic rate of the nudibranch.

(d) Assuming that for these animals $\Gamma = aM^{3/4}$, determine the metabolic constant a.

(e) Look into the literature to assess if the assumption is reasonable that the blood returning from the body into the gills is completely deoxygenated. If not, how would this change your answers?