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6.894 Legged Locomotion in Robots and Animals

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Problem Set 1

Problem 1

1.1 Pearson states that swing time is relatively constant while support time is determined by the animal's velocity. Why do you think this is so?

1.2 Pearson's paper states:

> There are numerous examples in nature where evolutionarily unrelated animals rely on similar mechanisms for the same task... The similarity of the walking systems in the cat and the cockroach suggests that the number of ways of optimally constructing a walking system is quite limited.

Do you agree or disagree? Explain.

Problem 2

This problem deals with negative work. The metabolic efficiency for negative work is -1.20. This means that if the body is to absorb 1.2 Joules of mechanical energy, then it must burn 1.0 Joules in doing so. As Margaria shows, when walking down an incline, this metabolic efficiency limit is reached.

2.1 Jack is about to walk down a trail to the bottom of the Grand Canyon. He is going to walk smoothly, without slipping, sliding, or jumping. With equipment Jack weighs $100kg$ and the end of the trail is $1000m$ lower than the top.

a) How much mechanical work (in Joules) is done in transferring Jack's body down the trail?

b) Given that metabolic efficiency of doing negative work is -1.2, how much metabolic energy (in Joules) must Jack's muscles provide? How many calories is this? Given that a Snickers contains 280 Kcal, how many extra Snickers will Jack need to eat to make up for this exercise?

c) All of the mechanical energy of part a) goes into the form of heat (what else?). How many calories of heat are created? Suppose Jack's body is 37^oC, how many grams of water must heat to boiling temperature 100^oC, and evaporate to take this extra heat away from

Jack's body? The specific heat of water is $1.0\frac{cal}{^oCg}$ and the heat of evaporation is $540\frac{cal}{g}$. How many liters should Jack drink to restore this water?

d) Jack is told by the park rangers to carry 2.0 liters of water and 10 Snickers bars. What accounts for the discrepency between this and your calculations? i.e. what else do you need food and water for besides generating and dissipating mechanical work.

e) Jack is upset that he has to drink so much water, eat so many Snickers, and exert so much effort to go *down* a trail. What sort of devices could Jack make to decrease the amount of metabolic work his body must do? Hint: What passive devices or mechanisms are good at doing negative work?

2.2 (Extra) Do Problem 2.1 for going back up the trail.

Useful Formulas and Constants:

Potential Energy E_{pot} of a mass m at height h in a gravitational field of constant g:

$$E_{pot} = mgh \tag{1}$$

Metabolic Energy $E_{metabolic}$ spent in doing E_{mec} negative work:

$$E_{metabolic} = \frac{-E_{mec}}{-1.2} \tag{2}$$

Specific heat c:

$$c = \frac{Q}{m\Delta T} \tag{3}$$

Conversions:

$$1.0cal = 4.187J$$

Constants

$$g = 9.81\frac{m}{s^2}$$

Constants for water:

$$c = 1.0\frac{cal}{^oCg}$$

$$Q_{evap} = 540.0\frac{cal}{g}$$

Problem 3 (Extra)

3.1 What percent of human-kind's time, money, space, effort is devoted to transportation? How about nature?