Lab T-1
What Can Physics Tell Us About Physiology? – Prelab

Name:________________________
Section #:________________________

Introduction

Physics aims at discovering the most general underlying order behind natural phenomena at the most fundamental level. The discovered laws of physics can be used to understand a wide range of natural phenomena from planetary motion to the forces that hold atoms and molecules together.

In order to understand and appreciate the connection of physics and the real world of birds, lions, and flowers, we need to *understand* the specific ways in which certain physics principles apply to some biological facts through *concrete examples.*

In order to study the connection between physics and biology most directly, in this lab, we will engage in 'model building activity' of various natural phenomena. We will develop several 'models' to explain various natural facts in biology, mostly interesting physiological facts about various organisms. But, we first need to clarify what we mean by 'models' and 'model building activity'.

What is a 'Model' and 'Model Building Activity'?

A 'Model' is a hypothetical, simplified representation of Nature that encapsulates and helps us understand the essence of phenomena. Because it is simplified, the model is limited (not exactly like how it really is) but allows us to ignore some insignificant details that are not relevant to the question that we want to answer. Whether you have noticed or not, you have encountered many 'models' of nature in this class already.

Guidelines for Model Building

- A 'model' represents a natural phenomenon in terms of simpler, easy-to-understand terms (often employing pictures).
- The simplification involved in 'modeling' is primarily guided by the question one is trying to answer. So, simplification is a decision that must be made by the questioner.
- 'Models' are hypothetical; they do not represent nature as it "really is". This means that in model building some simplifications and assumptions are necessary. These are the limitations of your model.
- 'Model-building' does not have rules to use that always work when building a model. It is almost an art – building good models relies on experience, creative thinking and insight.

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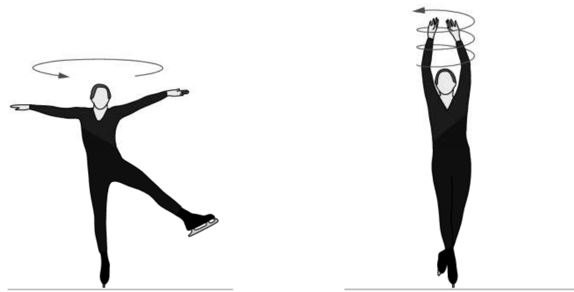
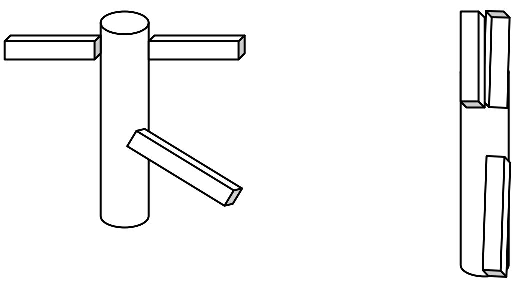
Example 1: Why does a figure skater rotate faster when he or she folds his or her arms?

Before After



What we write

Before After



We will draw the skater as a bunch of blocks as above. Since the moment of inertia decreases after the rectangular bars (arms) are folded in, the angular speed must increase to keep the angular momentum constant. The increased angular speed of the "*model*" figure skater explains why the *real* figure skater rotates faster.

We assumed angular momentum is constant, which is only true in the absence of an external torque. But air resistance will only cause a *small* external torque.

What we're thinking

When we consider this situation, we are concerned with rotational motion. In this case, representing the skater as a point particle would be oversimplifying the situation. For a point particle, we cannot define an axis of rotation, so this representation would not help us answer the question. Instead, we can represent the figure skater as a combination of basic shapes; the solid cylinder can represent the body and one of the legs of the skater, and the rectangular bars can represent the limbs of the skater.

This representation ignores the details of the skater, such as his body shape, hairstyle, or the kind of skates he is wearing. However, this simplified representation allows us to estimate the moment of inertia of the skater.

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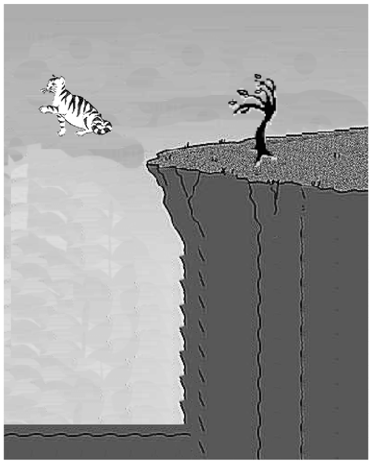
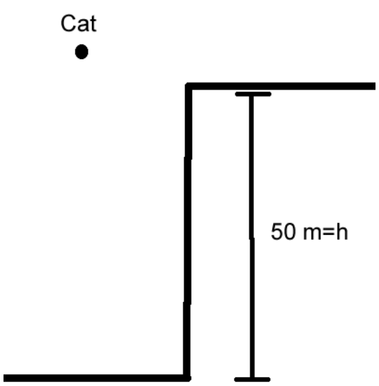


Example 2: **Even when solving a problem, you build a model of the situation, as in this example**. A cat of 10 kg is dropped from rest from a cliff of 50m. At what speed does it strike the ground?

What we write

Ignore details of the cliff; treat cat as point particle (ignoring air resistance!), because it is dense and may not have a lot of drag.



Use Conservation of Energy:

$$\frac{1}{2}m_{cat}v_{bottom}^2 = m_{cat}gh$$

$$\Rightarrow v_{bottom} = \sqrt{2gh}$$

Including air resistance will decrease v_{bottom}

What we're thinking

We usually start by drawing a picture of the situation. The standard picture we draw does not include irrelevant details like the tree or bumps on the cliff, and we draw the cat as a point particle. This is making an approximation, ignoring things like air resistance, rotational motion, etc…We are justified in making such a simplification because we are only interested in linear motion of the cat.

We next identify the relevant physics principles (conservation of energy).

We then perform a quantitative analysis.

The model is limited, because we ignored things like air friction.
The result is trustable only if our assumptions and simplifications are valid! For a cat, they probably are not too bad. For a piece of paper our experience tells us that these assumptions are not valid, and we need to take air resistance into account.
If this were an experiment, we would then make a measurement and compare to our model. If there is a large discrepancy, the first thing we doubt are our simplifying assumptions.

In the preceding examples, we can draw out some general points about 'model' and 'model-building activity'.

- A 'model' represents a natural phenomenon in terms of simpler, easy-to-understand terms (often employing pictures).
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- 'Models' are hypothetical; they do not represent nature as it "really is". This means that in model building some simplifications and assumptions are necessary. These are the limitations of your model.
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The Aims of this Lab

The overall aim of this lab is to understand the connection between physics and biology. Rather than merely reading or hearing your instructor talk about this connection, you will investigate the connection directly through model-building activities. In particular, you will investigate **how the principle of pressure is relevant to understanding various physiological facts about different organisms, particularly blood circulation in the absence and presence of gravity**. After the completion of this lab, you should be able to…

1. Develop a clear visual and verbal representation of pressure.
2. Make connections between physics concepts and biological examples with a diagram and a written explanation.
3. Discuss limitations of the models that you develop

The long-term learning goals of this lab are to learn aspects of thinking like a physicist, in particular:

1. Make connections between physics principles and real life.
2. Develop compentence in model building
3. Appreciate the usefulness of physics in understanding nature

At the end of the lab, **you will be asked to reflect on your evolving understanding of how physics is relevant to biology**. Final question at the end of the lab are:

1. Compared to before you started the lab, what changed in the way you see the connection between physics and the real world?
2. To what extent do you think physics is useful in understanding the natural world?

Keep these questions in mind as you work through the lab.

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Pre-lab Exercises

To be done **BEFORE** lab

The reason you are doing these exercises before the lab is to:

- Start learning about what 'model-building' is like
- Get comfortable with the concept of pressure
- Develop skills in carrying out simple calculations involving pressure
- Be ready to do some calculations based on some rough estimates

- Based on your reading of the section above "What is a 'Model' and 'Model Building Activity'?" come up with a 'model' for the following situation:

  A kid on a sled slides down a snow-covered hill starting from rest. You are interested in the speed of the kid and sled at the bottom of the hill.

- A glass is filled with water and sits on a table. Circle the figure below that best represents the pressure exerted by the water on the sides of the glass. Longer arrows represent greater pressure.