Lab T-1: What Can Physics Tell Us About Physiology? (TA GUIDE)

WHAT IS THE POINT OF THIS LAB?

The over all aim of this lab for students is to **understand the connection between physics and biology** by investigating how the principle of pressure is relevant to understanding various physiological facts about different organisms (giraffes and humans in this lab), particularly blood circulation in the absence and presence of gravity.

What students should be able to do after this lab can be summarized as follows:

Short-term learning goals	Long-term learning goals
Develop a clear visual and verbal representation of pressure	Make connections between physics principles and real life
Make connections between physics concepts and biological examples with a diagram and a written explanation	Develop competence in model building
Discuss limitations of the models that you develop	Appreciate the usefulness of physics in understanding nature

The lab is made up of several relatively disjointed exercises, each of which has a precise set of goals, which lead the student towards achieving the overall learning goals. All goals are expressed in terms of **what students should be able to do at the completion of each exercise.**

Pre-lab (Students should be able to…)
- See that this lab is about modeling nature using physics principles

Model Building Practice Session (Students should be able to…)
- State what model building entails in general
- State clearly **what** they are expected to learn in this lab

Giraffe's Skin Exercise (Students should be able to…)
- Understand that applying physics to another discipline is possible
- Recognize the creative aspect of model building
- Begin thinking about factual observations of nature in terms of physics principles

Pressure Thought Experiment (Students should be able to…)
- Understand how pressure varies with depth visually and overcome misconceptions

Latex Glove Activity (Students should be able to…)
- Develop a qualitative model based on the previous exercise to explain the shape of the glove when filled with water
- Connect this model to the giraffe fact

Human Blood Pressure Measurement (Students should be able to…)
- Develop a quantitative model of how blood pressure varies with depth in humans based on the concepts of previous activities
- Begin to understand the complexity of model building by comparing the developed model to real life

TA Note: This lab has been developed with an eye towards experimental verification of the models developed, but the please be aware that the model developed at the end of the lab is only one of several possible explanations. *The point of this lab is to teach the connection of physics to other disciplines and how to go about that process, not what the exact mechanism is* in this example. Please keep this in mind throughout the lab – *the focus is on the process, not the product.*

WHAT DOES a TA DO in THIS LAB? (A guideline) (Total Time: 2 hrs 20 min)

Introduction (5 min)

- Discussion of the lab; explicit discussion of the learning goals, how the lab will be graded through the boxed sections throughout the worksheet.

Model Building Practice Session (20-25 min)

What you do:

- Show demonstration of tightrope clown, with and without balancing arms.
- Ask students, in their lab groups, to model the tightrope clown so that they can answer the question, "Why does the tightrope clown stay balanced with the pole? Why is it unbalanced without the pole?" (~10 min)
- Have each group put the models up on the board. The TA should also have a model developed that he/she puts up on the board (it could be a pre-made model that every TA uses, for example something they made during the previous week's TA meeting).
- As a class, discuss the features of the models they came up with. In particular, discuss
    - The visual diagram they created
    - What aspects of the situation they chose to ignore
    - What physics principles were relevant
    - How they used these physics principles to answer the question
- As a class discuss the limitations of the models. In particular,
    - The assumptions made,
    - Whether these assumptions are valid, and
    - Possible improvements such as more explicit discussion of the physics principles and how they apply.
- Draw out and summarize the important aspects of model-building, referring to the guidelines for model building when necessary.

Giraffe's Skin (15 min)

What you do:

- Students are given the observation that "The skins of giraffes are tighter in their legs than the upper part of their body."
- Pass out a note card to every student. Each student should come up with a possible explanation of the fact and a physics principle that is relevant to their explanation **on their own**. (~5 min)
- Collect the note cards, and redistribute the cards throughout the class randomly.
- Every group should pick one idea out of the note cards they are given to develop further into a model. If they don't like any of the ideas on the note cards they can use one of their own ideas.
- **Each model should be complete**, e.g. have a diagram, an explanation of the diagram and how it helps explain the fact, and a discussion of the assumptions and limitations of the models.

Pressure Thought Experiment (5-10 min)

What you do:

- Students are presented with the diagram of a tube with springs attached.
- Students are asked to draw the diagram when water is poured into the tube, and asked to justify their answers with explanations and correctly identifying the relevant physics principle (pressure increases with depth).
- TA should go around the room, helping students with their misconceptions and misunderstandings of the diagram/setup.

Latex Glove Activity (20-30 min)

What you do:

- Students hold latex glove filled with water in the air and observe the shape.
- This is a visual representation of the pressure varying with the height. Students directly see that the pressure varies with depth, and apply the visual model/representation of how pressure varies with depth that they developed in the Thought Experiment.
- Students are asked to come up with a simplified model describing why the latex glove looks the way it is.
- Students are asked to apply this model to the giraffe.

Blood Pressure Measurement (40-50 min)

What you do:

- Students first must make a *qualitative* prediction about whether they think the blood pressure will be larger or smaller in their legs.
- Students then take a preliminary measurement to check their qualitative prediction.
- Students identify the fact that *blood pressure in the legs is higher than in the arms*.
- Students are then asked to develop a quantitative model of this fact. This model should be based on the fact that pressure varies with depth, as in the previous exercises.
- Students are asked to develop their own measurement plan. The reason for this is a tradeoff: we want students to emulate the model building process as much as possible, but coming up with an appropriate test is difficult and requires practice. We don't expect the students to do this correct the first time, but we want to give them practice with it. In the next step, they are told what measurements to make so that they can test the model appropriately.
- Students are told to take a set of measurements of blood pressure on the arm and leg on both the right and left side, as well as standing and lying down. *Anticipate that this measurement can take around 30-40 minutes, so ensure the groups stay focused*. Students should also come up with the quantitative prediction from their model.
- Students are asked to compare the adequacy of their model when compared to actual observations and to brainstorm ways to modify the model to improve it. Students are prone to blaming any difference between the model and measurement on "error", but in many cases differences will still exist even after taking into account errors. **These differences should be interpreted as inadequacies of the model**. Some possible limitations are: blood pressure measures the pressure of the arteries (where blood rushes through quickly), not the veins (where most of the blood sits). Also, the model should really only apply for a stationary liquid, which is certainly not the case here! Modifications could include taking into account of the motion of the blood through Bernoulli's equation.
- Students are asked to make a prediction, based on their quantitative model, for the blood pressure difference in a giraffe. Using this, as well as knowledge from previous activities, students are asked to come up with a model which explains the giraffe fact.

Conclusion (5 min)