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 **make a 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).

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

Short-term learning goals
Make explicit connections between physics principles and biological fact through model building activities: - Identify relevant physics principles - Show explicitly how physics principles explain facts - Use diagrams or pictures to aid explanation - Reflect on simplification of models that one develops

Long-term learning goals
Make connections between physics principles and real life in general
Develop competence with more sophisticated model building
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 model based on the previous exercise to explain explicitly the shape of the glove when filled with water

Human Blood Pressure Measurement (Students should be able to…)
- Develop a 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 prediction made by developed models and the observation

Final Model Building (Students should be able to…)
- Refine or revise their initial model by drawing on various modeling they have done

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. *<u>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</u>* in this example. Please keep this in mind throughout the lab – *the focus is on the process rather than on the product*.

WHAT DOES a TA DO in THIS LAB?

Introduction (5 min)

What you do:

- Describe the general structure of the lab
- Write and describe on the board the short term learning goals and how the lab will be graded (see discussion of suggested grading procedure at the end of this guide).

Model Building Practice Session (30 - 40 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 poles? Why is it unbalanced without the poles?" (~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).
- With the whole 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
- With the whole class discuss the simplifications made in constructing the models. In particular,
    - Whether those simplifications are reasonable
    - 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 (to be found in the worksheets) when necessary.

Giraffe's Skin (20 min)

What you do:

- Tell students that from here on they are working individually in their small groups as usual.
- Pass out a note card to every student. Each student should come up with a possible explanation of the giraffe fact and a physics principle that is relevant to their explanation **on their own**.
- 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.
- **Visit the groups and be sure that each model is complete**, e.g. they identify relevant physics principles, have an explanation of how the identified principle(s) helps explain the fact, have a diagram aiding the explanation and have a discussion of the simplifications made in constructing the model.
- Many students skimp on the explanation here – they don't make the connection to the physics principle explicit.

Pressure Thought Experiment (5-10 min)

What you do:

- TA should go around the room, helping students with their misconceptions and misunderstandings of the diagram/setup.
    - Students often believe that pressure is constant throughout a water-filled tube

- Students often have not differentiated concepts of force and pressure
- Students often invoke free-body-diagram by default in their explanations even when they are irrelevant like when the problem is about pressure not forces on a single particle.

Latex Glove Activity (20-30 min)

What you do:

- Be sure students hold the glove by the tied (knotted) end, with the tied off fingers pointing down.
- If a glove breaks, fill up another by first tying off the fingers, then fill the glove with water until it begins to noticeably sag. Then tie off the end of the glove (this is actually easier with more water)
- Students tend to easily get distracted trying to include the elasticity of the glove or include individual forces on the glove. Try to guide them to use the ideas of pressure from the previous activity.

Blood Pressure Measurement (40-50 min)

What you do:

- See technical notes about the operation of the blood pressure machine.
- If students do not use pressure variation with height as a physics principle when building their model (part (d)), they will have a very difficult time coming up with a prediction. Help them by pointing out this direction.
- Some students may feel that the model building exercise (part (d)) is repetitive at this point. While the physics principles are similar to previous exercises, be sure to emphasize that it is how the physics principle explains the fact that is important. Of course, that the same physics principles apply in all these different contexts is an example of how physics applies to the real world.
- Make sure that the diagrams in the model building exercise are sophisticated and actually help explain the fact.
- The model is best tested by comparing the ΔP from standing and laying (because it maximizes the change in height), but some students are uncomfortable with laying down. Tell the students that they may substitute sitting for laying.
- Part (f): Students always have a problem with conversions – be sure they're converting to mmHg correctly!
- Part (f): Note that the estimated error in the measurements comes from the equipment error.
- Part (f): Amazingly, some students merely estimate the height difference between the points where they measure the blood pressure. Remind the students that we have meter sticks for this purpose.
- Part (h): Be sure students state whether the prediction agrees or disagrees with their measurement, and that they include a discussion of why they think this.
- Part (h): Students will have trouble coming up with a criteria to judge whether the simplifications they made are valid. They tend to go with their "gut" feeling. The only criteria they have at their disposal currently is whether the model agrees with the measurements – if it does, then the simplifications seem reasonable and valid. Of course, these are not the only criteria scientists use to judge the validity of assumptions, but they are the only ones available to the students at this stage. The TA should engage the students in a discussion of the criteria if possible – the goal of this activity is for students to devote thought to judging simplifications and their model, not to get a "right" answer.

Final Model (10-15 min)

What you do:

- If students constructed a complete model using pressure at the beginning of the lab, they may feel this as repetitive. If that's the case, they should use this opportunity as a chance to articulate their explanation, diagram, and discussion of the simplifications they have made.
- Go around the room to ask each group whether they have components specified in the guideline for model building: Does it identify relevant physics principles? Does it have explicit descriptions of how it explains the fact that needs to be explained? Does it have a diagram that aids the explanation? Do they reflect on simplifications their model makes?

<u>Suggested Grading Procedure</u>

Ideally, a student's lab grade should reflect how well they have met the goals of the lab. With this in mind, we have developed a grading scheme, which attempts to measure students' achievement of the primary goals of the lab.

Below are a set of "rubrics" – grading schemes for 4 chosen "checkpoints", which are parts of the lab that, when graded, give a reasonably accurate indication of how well students met the primary learning goals. The rubrics have been carefully designed – they were designed by analyzing in detail the responses from 30 (randomly chosen) students from a previous implementation of the lab. Distinctions between different scoring levels correspond to different levels of achievement of the goals. For each rubric, a simple "at a glance" criteria for a scoring level is given in **bold** as a way to quickly determine the scoring; just below this is a more detailed explanation of how to score this. The number of students who obtained a given score is given in the last row of each rubric (with the exception of Checkpoint 3, which is special in that the grading is more qualitative and data here is not available).

The proposed grading procedure is for each TA to collect one worksheet from each group (each member of the group will then get the same grade). The worksheets are graded according to the rubrics, with the point assignments:

Checkpoint #	Maximum # of Points
1	4
2	4
3	3
4	4
<u>Total:</u>	15

Rubric

Checkpoint 1: Pg 3, part b)

In your group, use at least one of the notecards you're given (or an idea of your own, if you can't do anything with the cards you have) to create a model explaining the fact above. A good model explains the fact based on some physics principles, with the aid of a diagram. It is typically helpful to also explicitly list the assumptions you have made in developing your model.

Goals of this Checkpoint**:**

- For students to include all of the aspects of a successful model.
- Students should ground their explanation on a specific physics principle
- Students should make an honest effort to connect principles and the fact. Just explaining the principle is not enough.
- Some discussion of simplifications involved, with no judgment about whether these simplifications are relevant or important, since the focus is on generating ideas, not necessarily "correct" ideas.

Four components necessary for a successful model

1. A picture or diagram
2. An underlying physics principle
3. A written explanation of how the principle explains the fact
4. A discussion of simplifications

0	**1**	**2**	**3**	**4**
No Answer	**Answer lacks 2 or more components from above**	**Answer lacks an explanation of how the principle explains the fact**	**Answer only lacks a discussion of simplifications**	**Answer has all major components from above**
Nothing is written, or essentially nothing is written	The model is severely deficient and highly underdeveloped. Little effort was involved in its creation	A physics principle was mentioned, but an explicit connection to the fact was not made (or is not very clear)	The model contains a decent explanation of how the physics principle explains the fact, but did not consider simplifications	The model is well developed and has all of the major components above.
Number of students who scored this: 0	4	16	3	7

<u>Rubric</u>

Checkpoint 2: pg 6, part c)

Based on the relevant physics principles that you identified, develop a model that explains the **shape**? In other words, explain why the glove is **shaped** this particular way. A good model explains the fact based on some physics principles, with the aid of a diagram. It is typically helpful to also explicitly list the assumptions you have made in developing your model.

<u>Goals/expected responses for this Checkpoint</u>:

- A picture or diagram
- Must identify that pressure increases with depth as a central physics principle.
- Must make <u>explicit and valid</u> connection between the physics principles and the fact (explanation must make sense to an independent reader).
- Must identify relevant limitations and/or assumptions

0	**1**	**2**	**3**	**4**
No Answer	**Answer does not identify "pressure increases with depth" as relevant.**	**Answer lacks an adequate explanation of how pressure explains the shape of the glove**	**Answer <u>only</u> lacks a discussion of limitations or assumptions**	**Answer has all major components from above**
Nothing is written, or essentially nothing is written	Something has been written for the model, but it does not identify the variation of pressure with depth as a central component.	The explanation does identify pressure as relevant to the explanation, but does not make the connection to explaining the fact as being relevant.	The model makes an explicit connection between the variation of pressure with depth and the shape of the glove. A discussion of Limitations or Assumptions is either lacking or not relevant, however.	The model makes an explicit connection between the variation of pressure with depth and the shape of the glove, and contains a discussion of relevant Limitations and Assumptions.
Number of students who scored this: 0	12	11	1	6

Rubric

Checkpoint 3**:** pg 12, part g)

Compare the adequacy and limitations of the model by comparing your measured difference in pressure to the difference in pressure predicted by your model. Are the differences completely explained by error?

g) Do your measured ΔP agree with your predicted ΔP for both standing and sitting/laying down? In your answer, take into account your estimated errors from the previous page.

1 pt

Standing	Sitting/Laying Down
Model answer: The difference between the measured ΔP and predicted ΔP is approximately 2 mmHg for standing. This is within the estimated error of 5 mmHg.	Model answer: The difference between the measured ΔP and predicted ΔP is approximately 10 mmHg for standing. This is **not** within the estimated error of 5 mmHg.

h) What are the simplifications you made in developing this model?

1 pt

Model answer: Some of the simplifications in this model are that real blood is not static; that the blood pressure cuff measures bp in the arteries, not the veins (which is where most of the blood is); and that the veins are not simply elastic tubes.

Are they valid or acceptable for standing or sitting down/laying? Explain why or why not.

1 pt

Standing	Sitting/Laying Down
Model Answer: The simplifications seem fairly valid for standing because the predicted values agree very well with the observed values.	Model Answer: The simplifications do **not** seem valid for laying down because the predicted values **do not** agree very well with the observed values. Some of the simplifications, such as static blood, may no longer be valid here.

Rubric

Checkpoint 4**:** pg 12

By drawing on the examples from this lab, construct a model that explains the fact about the giraffe's skin.

Goals for Students for this Checkpoint:

- To be explicit in the connection of the principle of the variation of water pressure to explain the giraffe fact.
- To construct a picture which meaningfully connects the idea of the variation of water pressure with depth to the giraffe fact.

0	**1**	**2**	**3**	**4**
No Answer	**Explanation does not involve pressure at all.**	**Model involves pressure, but explanation *not* explicit**	**Picture is not meaningful. Model involves pressure and explanation is explicit**	**Model has an explicit explanation of how pressure explains the fact. The model contains a meaningful picture.**
No answer is written – the section is not completed	The student's explanation does not involve the concept of pressure variation with depth at all. This is a primary point of the lab, so if they do not use this concept the student is not rated very highly.	The student's explanation involves pressure, but does not make the connection of this concept to the fact explicit, but rather makes jumps in their reasoning. Since a desire for students to be explicit is one of the stated goals of the lab, students not meeting these criteria are not rated highly.	The student's explanation involves pressure and is explicit in their connection to the fact. However, the picture, which accompanies the explanation is not "meaningful", in that it does not clearly represent the physics concepts explained in the explanation. Since an explicit connection is a primary goal of the lab, students are rated highly.	Same as (3), but now the picture is meaningful. This meets all of the goals for this activity, so students are rated highly.
Number of students who scored this: 0	5	15	4	6

Common problems for why students' explanation is not explicit:

- Stated that "pressure is high" in leg, but not explained why, or what "high" pressure is relative to.
- Stated that "pressure is greater in leg, thus skin must be tighter". This is not complete – why must the skin be tighter?
- Did not recognize why the skin must be tighter in the leg, e.g. should note that all of the blood rushing to the legs is a bad thing physiologically.