Unit 3 – Module 1

Hands-on exploration of forces (Everyday Forces Activity)

TEACHER NOTE*: It is understood that not all teachers will have the all the supplies or time to perform the following activity in full. Teachers should modify the activity/handouts to best suit his/her needs and supplies. The full activity as presented will take 2 to 3 days.*

RATIONALE

Physics is rife with words that are used in common everyday language but take on very specific unfamiliar meanings. Inertia, force, weight and equilibrium are four such words. For most students it is not enough to simply redefine such words. The words and more importantly the concepts associated with them need to be experienced by the students. This introductory activity is meant to allow the student to investigate his/her own understanding of forces. It is hoped that with the own student’s investigation and teacher facilitation that a new understanding about force is developed clarifying concepts and correcting misconceptions.

One problem teachers often face in a physics class is one of students not having shared relevant experiences. The activities presented here are designed to give shared experiences that can be drawn upon later in the unit and provide a basis for discussion or a reference for another situation that appearing different is just another example of the same phenomena. It is intended to be a two to three day introductory activity.

The idea of this activity is to run the students through a series of preset activity stations at which the students will explore particular phenomenon and develop a sense of how to test and critically evaluate a situation. Each station should take about 5 to 10 minutes to investigate. It does not matter which station they start at just that they get through all stations. They will be asked to make predictions before they perform the task, then discuss with group members and answer written prompts on the handout.

Once the activities have been completed and prompts answered the students are asked to read several sections from the Conceptual Physics Textbook, this should take around 20 to 30 minutes. You may want to assign the reading to be outlined for homework between day 1 and day 2. (Don’t outline in class, it would take well over 20 minutes) It is important that students learn how to “dig into” a technical text and incorporate its meaning into their physics conceptual framework. The active part of this activity is intended to provide a framework that would make the text more relevant and easy to comprehend.

After the reading is completed the groups discuss how they might alter their previous answers. Then with a “green pen” go back and amend their answers where necessary. This allows the individual to gain clarity about the phenomena from the group.

The Elaboration and Evaluation portion can be assigned individually or as a group. It requires the students to use what they have just learned to analyze completely new situations. The teacher may use it as either a formative or summative assessment. This portion could also be incorporated into future homework or given later in the unit.

After the activity is complete a post activity class discussion is appropriate to go over the activity. The students should have the handouts in their hands as you discuss the activity.

The activity handouts provided should be carefully scrutinized by the teacher and modified to suit the level and number of students participating in the activity. Some teachers may decide that there should be more structure for the students to describe their data gathering process, or that the additional questions need to be more complex or subtle. As with all instructional materials, those modifications should be made at the discretion of the teacher based on his or her judgment.

The most effective instruction will probably take place as the teacher circulates amongst the activity groups, asking them to describe what they are doing, why they are doing it and what would it mean if certain things changed. Also, this is an opportunity to give immediate feedback, allowing the teacher to reiterate or explain some of the conventions used when showing work in a physics class. The activity class discussion can also be an effective way to strengthen conceptual relationships and highlight significant ideas present in the activity (the CE and PE items).

PRIOR KNOWLEDGE AND SKILLS

* key concepts from Units 1 and 2 relating to velocity and acceleration

CE’s AND PE’s

1. Describe and recognize situations involving constant velocity

* If an object is accelerating (non constant velocity) then it is not in equilibrium
* Students will be asked to move objects at with acceleration and at constant velocity to experience the feel of these types of motion

3. Define equilibrium

* This concept is essential to understanding what is going on in a force problem. It should be the first question asked by the student dealing with a situation.
* It can be identified by discerning if an object is accelerating or not.
* The concept of net force is needed to explain equilibrium and non-equilibrium scenarios.

*4. Separate a scenario into the system and its surroundings*

* Students need to draw pictures of the scenarios they are considering and indicate on the picture which objects are in the system and which are in the surroundings.

8. Define inertia

* The term “inertia” has always been confusing to me (Stephen Pellathy). I use two ideas to explain the concept, but avoid use of the actual word.
  + Newton’s 1st law: “An object moves in a straight line and at constant speed (including not moving at all) except to the extent that it interacts with other objects.”
  + And the second piece: “If two object have the same velocity (including not moving at all) but one is more massive than the other, it is more difficult to change the heavy object’s speed and/or direction.”

11. Know that in a free body diagram that the object is represented by a point and the forces are represented by a vector arrow.

* The student must first identify the “system” which typically at this stage of the course is a single object
* Students are required to follow the problems solving steps given in this unit.
* Vectors studied Unit 2 are the foundation for this

*12. Translate the sketch of a scenario into a free body diagram*

PHYSICS CONVENTIONS

* The system is chosen by the person analyzing the scenario. Typically the system is chosen as the object under consideration, and the rest of the objects in the universe are labeled the “surroundings” or something similar. The system does not include the forces acting on it because the system is made of an object or of objects. Forces are the interactions between objects. So considering a ball on the Earth’s surface, the ball can be called the system, the Earth is the only relevant object in the surroundings, and the interaction between the system and the surrounding, the ball and the Earth, is gravity. Gravity is considered an external force on the ball because the Earth is not part of the system.
* objects in this class will be treated as point particles, despite the fact that they are in fact extended objects
* the frame of reference may change depending on what object you are exploring

STUDENT GROUPING

Students can work independently, though it is more productive if they work in groups of 2-3. Groups that are too large will have too much down time while other group members are gathering data.

MATERIALS

Varies – see each station setup described below

FOR EACH STUDENT

Copy of handout

Pencil, green pen

TIMELINE (about 2-3 days, and the potential for homework)

5 minutes – outline objectives for the activity

3 minutes – get into groups / go to stations pre arranged

40 minutes – work through each station

20minutes – read from text (could assign as homework)

15 minutes – amend answers with green pen

20 minutes – answer Elaboration and Evaluation section (homework or later date)

20 minutes – post activity discussion

SIX (6) STATIONS

*Teacher note:*

* *students are to follow prompts on handouts as teacher circulates around the room facilitating the activity*
* *depending on the number of students there could be multiple setups of the same station*

The 6 stations are as follows:

* **Station # 1**

Materials:

* sledge hammer
* large ballpin hammer
* small hammer
* several pieces of 2x4 pine wood
* 8 penny common nails
* safety goggles

Summary: Each student should try all 3 hammers

Intent: To explore forces and inertia/mass through the use of hammers of different masses to drive a nail of the same mass. **The relationship between mass and inertia in this course is that the inertia of an object is measured by its mass.** Try to keep velocity of the hammers the same in order to isolate mass.

Student take-aways:

* It may seem boring or unnecessary, but physics talk is very precise as demonstrated by the following bullet point. It is **not true** to just say that the more massive an object is the greater the force it imparts. There need to be some very explicit conditions or assumptions placed on such a statement.
* The more massive object imparts the greater force, but under two crucial assumptions:
  + the three hammers move at the same speed, and
  + then come to rest in the same time interval
* A more massive object (hammer) has more inertia as evidenced by the nail’s ability (or inability) to change the hammer’s motion.

**Station # 2**

Materials:

* three identical shoe boxes, the same at first glance but set up differently:
  + one stuffed with newspaper
  + one with a 3 kg of weights wrapped in newspaper
  + ones stuffed with newspaper with a thin piece of rubber glued to the bottom
* a 1kg pendulum
  + let it go from the same height
  + strike each box identically

Summary: Students from each new group must not touch the boxes before hitting them. Have a place on the lab bench marked so that each group can set it up for the next group. Also make sure pendulum strikes at base of boxes.

Intent: To explore forces and inertia/mass using the different outcomes from hitting the three boxes with the same pendulum. The key is to keep the pendulum swing constant. Since in this case the moving object should always strike with the same impact (discussions of impulse may arise) the focus is on 1) the differences in the boxes’ masses, and 2) friction between the table and the box/rubber.

Student take-aways:

* When comparing the two boxes without the rubber on the bottom, the box that weighs more is moved less by the pendulum. The same force (from the pendulum) causes a different acceleration one each box due to the difference in masses.
* When comparing newspaper only boxes with and without rubber on the bottom, students note that the rubber increases the friction with the table.

**Station # 3**

Materials:

* small paper/plastic cups,
* a heavy block (wood, concrete…)
  + select the weight of block so that it can just barely be supported by 4 cups
* claw hammer

Summary: The students will try to get the block to be supported by the fewest cups. Strike the supported block with hammer to see that the large mass of the block results in such little acceleration from the force of the hammer that the cups continue to hold up the block. And also see what happens when the block is dropped by just a few inches onto the cups.

**Warning:** Use very weak cups so you can use a smaller (less) heavy block to make the point. Keep block under 5 kg.

Intent: To explore how inertia/mass must be taken into consideration while placing the block. When struck by the hammer at rest, the block’s acceleration is quite small because of its large mass. The blow of a hammer would surely crush an individual cup. When the block is dropped, however, even from a very small height, the force it imparts easily crushed the cups.

Student-takeaways:

* The mass of an object determines its acceleration when it experiences a net force. (In this case the hammer imparts a force on a very massive block, so that the block’s acceleration is minimal.)

**Station # 4 (the explanation of this phenomenon is quite sophisticated even though the materials and the actual event could not be more mundane)**

Materials:

* a roll of toilet paper
* a ring stand with a horizontal rod attached which holds the roll of toilet paper

Summary: Students attempt and then describe various ways of tearing off two (2) full sheets of toilet paper.

Intent: To explore what parts force, time, and mass/inertia play in an activity the students do every day. Note: it is often hard to tear a few sheets from a thin roll.

Student-takeaways:

* The analysis of this scenario is quite sophisticated because **time** is a very explicit factor in describing what happens. (In describing events at the other stations, the role of time is implicit or not explicitly highlighted.)
* If students tear the two sheets off very quickly, the roll does not move.
  + The large force applied for a short time (the “tearing”) surpasses the breaking stress of the perforated junction.
  + Since the tear occurs the force of the tearing is not transmitted to the massive roll. The two loose sheet are much less massive than the larger roll and the hand doing the tearing, and therefore are accelerated rapidly.
* If students try to tear the two sheets off very slowly, it is impossible, and the roll unravels.
  + The small force applied over a longer time does not surpass the breaking stress of the perforated junction and the roll unravels

**Station # 5**

Materials:

* 500g mass
* (1) 10-Newton spring scale

Summary: Students hang the 500g mass on a spring scale to find its weight. Next, accelerate the weight upward while noting the reading the reading on the scale. Then accelerate the weight downward while noting the reading.

Intent: To explore the connection between the acceleration due to gravity, mass, and the motion of the scale and mass.

Student-takeaways:

* The weight and the mass of an object are not the same.
* If the scale is acceleration upward with the mass on it, the reading will be greater than 500g. This scenario can be visualized using a free body diagram, which will show the force of gravity acting downward on the mass while the spring (spring force) is acting upward.
* If the scale is in freefall with the mass, there is not force on the spring so it will read zero.

**Station # 6**

Materials:

* masses: 100g, 200g, 300g, 400g, 500g, 600g, 700g, 800g, 900g, 1000g
* (1) 10-Newton spring scale

Summary: Students find out the weight in Newtons of each mass. Plot weight in “Newtons” versus mass in “kilograms”. Find slope of line.

Intent: To provide a concrete experience relating weight and mass through the acceleration due to gravity (which causes weight). Also to relate the slope of line with the acceleration due to gravity. Graphing skills are emphasized.

Student-takeaways:

* The weight and the mass of an object are not the same.
* The acceleration due to gravity, g, on objects near the surface of the Earth is the same and has a nominal value of 9.8 m/s/s.

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| **Stage of activity** | **What the students should do** | **Student mistakes** |
| Activity introduction (teacher lecture) | Recognize activity broken into stations | Expect handout with explicit instructions |
| Possible teacher responses:  - Encourage students to read prompts for each station and decide as a group how to proceed before performing activity  -Reiterate the rationale for the activity as well as the CE’s and PE’s | | |
| Station #1 | All students to try various hammers | - drop sledge hammer on toe or other delicate object  - flying nails  - students may not have much skill at hammer use  - can’t start a nail  -inconsistent hammer swing |
| Possible teacher responses:  -WARN STUDENTS TO WEAR SAFETY GLASSES  - tell students to handle sledge hammer with care  - keep Station #1 away from others and have students wear eye protection  - help students start the nails  - advise students to swing each hammer from similar heights.  - advise students to “feel” the difference the hammer “mass” makes not the force from their arm swing | | |
| Station #2 | - drop pendulum from same height for each box  -not touch the boxes before they use pendulum | - try to reorient boxes (thereby by getting a “feel” for the weight of each)  - not positioning the pendulum correctly  - inconsistent pendulum heights |
| Possible teacher responses:  - remind students not to touch boxes  - make sure to place boxes in starting position for each new group  - question students about why (why not) it is important to be consistent with pendulum drops | | |
| Station #3 | After several attempts the students should be able to get the block to stand and after smash the cups by allowing the block to drop | - student could drop on finger, toes  - cups keep collapsing |
| Possible teacher responses:  - advise the students to be careful and never lift the block higher that 2 cm above the cups.  - ask probing questions about centering the block on the cups and lowering block so that pressure is even. | | |

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| Station #4 | - most students will know what to do intuitively | - use two hands  - pull too slowly and have the paper unroll. |
| Possible teacher responses:  - remind students to use only 1 hand  - discuss how you get paper towels off the roll or how to break a thread from clothes | | |
| Station # 5 | - zero scale  - place mass on spring scale  - experiment scale reading under different circumstances | - don’t know how to “zero” scale  - inconsistent movements |
| Possible teacher responses:  - ask probing questions about how accurate readings can be taken  - discuss how to achieve smooth acceleration | | |
| Station #6 | - weigh the masses  -plot data, best fit line, slope | - improper slope calculation |
| Possible teacher responses:  - discuss rise over run to find slope | | |
| Text reading | - read book (take notes if required) | - confusion about inertia and mass  - confusion about weight vs mass  -not understanding gravity is a force  - not comprehending that normal force is a force |
| Possible teacher responses:  Circulate around students and discuss terms and meanings as required | | |
| Amending Station Prompts | - take information from readings and amend their responses | - confusion about terms and concepts |
| Possible teacher responses:  - circulate around students and discuss terms and meanings as they relate to their station activities | | |
| Elaboration and Evaluation | - apply the physics concepts and terms appropriately to new situations | - confusion about applying terms and concepts |
| Possible teacher responses:  - circulate around students and discuss terms and meanings as they relate to the new situations | | |

POST ACTIVITY DISCUSSION PROMPTS

* A car being hit by a tractor-trailer. How is mass/inertia involved? What force does each experience? What acceleration?
* If gravity is a force give examples of things that are in equilibrium but are under its influence. Describe the forces involved. What are the agents (the objects that cause the forces) of the forces?
* Why is weight given in “Newtons” not “grams” ?
* How would you find the mass of a 10kg mass that on a planet that had a gravitational acceleration 3 times that of Earth? How would you find the weight?
* Two baseball players are arguing. One says the bat should be lighter than the ball so that he can have a quicker swing and thereby hit more pitches. The other player says the bat should be more massive than the ball or the ball will not go far. Discuss the merits of each position.