Unit 3 – Module 2

Net force and equilibrium activity (Carts and Masses 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

At this point in the course the students should understand the concepts of constant velocity, accelerated motion, and that net force is related to acceleration. The main thrust of this activity is to let the students explore the conditions of equilibrium and non-equilibrium. Before engaging in this activity the students should be well acquainted with force problems where the motion resulting from zero net force and nonzero net force.

The activity is broken into four (4) parts. The first part asks the student for definitions and FBD’s for the three conditions being explored. Since the students should be familiar with these topics this part helps to provide a framework for the hands-on activities that follow.

In Part II the students explore the two possible states of motion, uniform including rest and non-uniform. By using pulleys, string, carts, spring scales and masses the students can investigate directly how changing forces (and thereby the net force) will affect an object’s motion.

Part III focuses on a system not in equilibrium. Most students find this type of force problem the most challenging. By engaging the students in the direct physical experimentation of this situation, they can have a concrete experience to integrate with the theoretical framework the have been developing. A nonzero net force will be applied to a cart and this will cause it to accelerate. (See the set up in the handout.) Students will have to grapple with the relationships between applied forces, net force, and non-equilibrium. The students will be asked to develop a testing procedure and use graphical techniques to analyze the situation.

Part IV, Elaboration and Evaluation, can be assigned individually or as a group. It requires the students to use what they have just learned in a hands-on activity to analyze completely new situations. Internet resources such as “How Stuff Works.com” will be needed as a research tool. The teacher may use it as either a formative or summative assessment. This portion could also be incorporated into future homework or given at a time later on in the unit.

The four parts of this activity could be completed as a whole or broken up to be done at different times. They build in complexity and should be performed in order. After all parts are complete a post activity class discussion is appropriate to go over 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 professional 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).

The students should have the handouts in their hands as you discuss the activity. The entire activity should take 2-4 days complete.

PRIOR KNOWLEDGE AND SKILLS

* knowledge from Units 1, 2 and 3
* ability to calculate the net force on an object
* experience in solving force problems and FBD

CE’s AND PE’s

9. Know that the acceleration of an object is directly proportional to the net forces and inversely proportional to the mass

11. Know that in a free body diagram (FBD) that the object is represented by a point and the forces are represented by arrows

* Only forces acting on the object should be shown

*13. Analyze a free body diagram to find the net force*

* *Multiple applied forces should be shown acting on a point (if applicable)*
* *The net force must be found through proper addition of the force vectors*

1. Know that the forces in a force pair are equal in magnitude and opposite in direction

* In the activities the string will be transferring the force. The spring scales placed in line with the strings should make the concept clearer.

Know the mathematical relationship between force of gravity, mass and g.

* It comes from Fnet = ma in the case where gravity is the only force being considered.
* Emphasize that g changes with the distance from the center of the Earth, or in other words with the distance between the two objects (location).
* Mass does not change with location.

*23. Discuss weight in relationship to gravitational force*

* *Make sure the students understand that the strength of gravity depends on the height above the Earth’s surface (radial distance from the center of the Earth).*
* *Gravity always points to the center of the Earth.*
* *Usually the convention is to assume objects are on the “surface of the Earth” so that the value of g remains constant, even if the object is moving vertically.*

PHYSICS CONVENTIONS

* Objects in this part of the course will be treated as point particles, despite the fact that they are extended objects. Objects will need to be treated as extended objects when discussing rotation, since rotation of a point particle does not make sense.
* The frame of reference may change depending on what object you are exploring
* A FBD consists of a point representing an object and vector arrows indicating the direction of all the forces acting on the object.
* **Choosing the system**
  + 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 (ball) and the surroundings (Earth) is gravity. Gravity is considered an external force on the ball because the Earth is not part of the system.

MISCONCEPTIONS

* If there is no force an object will come to rest
* Gravity, weight and mass are equivalent
* There is never motion when an object is at equilibrium

STUDENT GROUPING

Students should work in groups of 2-4. Groups that are too large will have too much down time while other group members are gathering data.

* Students 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

MATERIALS

Varies – see each part below

FOR EACH STUDENT

* copy of handout
* pencil
* lined paper
* graph paper

TIMELINE (about 2 – 4 days)

10 minutes – Introduction

20 minutes – Part I

30 minutes – Part II

40 minutes – Part III

40 minutes – Part IV

20 minutes – Post activity discussion

* FOUR (4) PARTS
* **Part I**

Materials:

* handout

Summary: Each student should try to answer the prompts on his/her own. The prompts dealing with equilibrium and FBD’s should be recognizable as the students have been solving problems in class.

Intent: To explore the forces acting on objects in hypothetical situations. The concept of net force is critical and should be emphasized by the facilitator.

**Part II**

Materials:

* cart
* masses
* spring scales
* string
* pulleys

Summary: A cart resting on a table is attached via strings and pulleys to two hanging masses, each in the opposite directions. (See the sketch in the handout) The students are to set up the cart as shown in the sketch. By following the prompts the students should be able to explore the two conditions of motion: constant motion (including rest) and accelerated motion. Some help will be required during setup as many students have no experience with pulleys. This is a “qualitative” exercise. The students should “eyeball” the constant velocity and accelerated motion as best they can.

Intent: The intent of this part is to explore and experience situations involving equilibrium and non-equilibrium established with two hanging masses. Explaining the cart’s constant motion (velocity) may be “tricky” as friction complicates the discussion. Establishing accelerated motion can be done by increasing one of the masses incrementally.

**Part III**

Materials:

* cart
* masses
* spring scales
* string, pulleys
* meter sticks
* timers

Summary: The students will develop a procedure to explore the relationship between increasing the hanging mass and the net force (and thereby acceleration). The basic kinematics equation for displacement under constant acceleration can be rearranged to solve for acceleration. This may be a stretch for some students. For a direct measure of acceleration photo gates, force sensors or motion sensors can be used.

Intent: This part will to allow the students to develop a quasi-formal lab write-up independently with a focus on graphing data to see a pattern. The main focus will be on exploring nonzero net force and non-equilibrium conditions.

**Part IV** Elaboration and Evaluation (see below)

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| --- | --- | --- |
| **Stage of activity** | **What the students should do** | **Student mistakes** |
| Activity introduction (teacher lecture) | Recognize activity broken into four parts | 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 | | |
| Part I | Read and answer prompts | - FBD arrow incorrectly drawn  - can’t remember or formulate definitions |
| Possible teacher responses:  - discuss with students the attributes of a FBD  - discuss the concepts surrounding equilibrium, perhaps discuss a similar situation | | |

|  |  |  |
| --- | --- | --- |
| Part II | - set up apparatus  - various trials while changing the masses  - read and answer prompts | - can’t make cart move at constant velocity  - spring scale do not indicate the same values at rest  - can’t assemble apparatus from sketch  - student could drop masses on finger or toes |
| Possible teacher responses:  - friction in the cart bearing may be a problem, try another cart  - scale may need to be “zeroed”  - a sample setup could be built by the teacher prior to the students lab so they could see what the apparatus looks like  - advise the students to be careful when lifting blocks | | |
| Part III | - setup apparatus  - various trials while changing the masses  - read and answer prompts  - write lab report and graph data | - can’t make cart move at constant velocity  - spring scale do not indicate the same values at rest  - can’t assemble apparatus from sketch  - student could drop masses on finger or toes |
| Possible teacher responses:  - friction in the cart bearing may be a problem, try another cart  - scale may need to be “zeroed”  - a sample setup could be built by the teacher prior to the students lab so they could see what the apparatus looks like  - discuss proper graphing techniques | | |
| Elaboration and Evaluation | - search the internet  - 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 | | |

ELABORATION AND EVALUATION

(POST ACTIVITY DISCUSSION AND WRITING PROMPTS)

The following mechanical equipment provides examples of concepts such as force, gravity, friction, equilibrium, net force, acceleration, and so on, which we have been studying. You may not know much about the equipment, but you soon will. You are to research each piece of equipment on the Internet and find out how it works. Next you should make a simplified sketch of each with labels for the main components. Lastly, you are to discuss with your group using the understanding you have gained from the activities in class to explain how and when concepts like force, gravity, equilibrium, friction, net force, acceleration, and so on, are demonstrated when using the equipment. Explain you responses in detail using appropriate physics terminology. Write responses on separate lined paper.

1. The Mount Washington Incline has been in use for many years. It would take a lot of force to lift just one car with a motor and cable. Consider when it accelerates, decelerates, moves at constant velocity and stands still. Address what happens when the one car is full and one is empty.
2. A cable-operated elevator demonstrates forces and the concepts of equilibrium and non-equilibrium while in operation. Consider when it accelerates, decelerates, moves at constant velocity and stands still. When is it in equilibrium?
3. An aircraft carrier catapult system launches planes. Consider when it accelerates, decelerates, moves at constant velocity and stands still. Explain its use with the concepts of net force and equilibrium.
4. An aircraft carrier arrester cable system stops planes when they land. Consider when it accelerates, decelerates, moves at constant velocity and stands still. Explain its use with the concepts of net force and equilibrium.