Laboratory 5: Introduction to Forces – Prelab

1 Newton's first law

Tom and Jerry are pulling in opposite directions on ropes that are attached to a cart, as in Fig. 1. The cart remains at rest, and there is no friction between the cart and the ground. Answer the following questions.

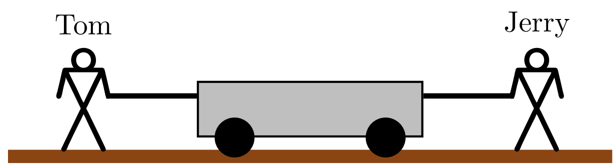

Figure 1: Tom, Jerry and a cart

i) If there were no friction between Tom and the ground, what would happen to Tom when he pulled on the rope?

ii) Assuming there is friction between Tom's shoes and the ground, draw a free body diagram for Tom. Identify what is exerting each of the forces on Tom in your free body diagram.

iii) Draw a free body diagram for the cart. Identify what is exerting each of the forces on the cart in your free body diagram.

iv) Suppose that the cart moves to the right with *constant speed*. Is the force exerted on the cart by the rope that Tom pulls smaller than, larger than or the same as that exerted by the rope that Jerry pulls? Explain your answer.

Laboratory 5: Introduction to Forces – Activity

The notion of force, which lies at the heart of Newtonian mechanics, is used to describe interactions between pairs of objects. Unlike the colloquial usage of the word, force in Newtonian mechanics entails precise mathematical descriptions of interactions and their effects on the motion of objects. The purpose of these exercises is to familiarize you with the precise language of force as it is used in Newtonian mechanics and to examine the relationship between force and motion in simple examples.

1 Identifying and specifying forces

a) A cart is on a horizontal surface and there is no friction between the cart and the surface. Andrew pushes on the cart from the left as illustrated in Fig. 2. For each force acting on the cart, name the two interacting objects and describe the force using the following language with appropriate details provided for the underlined words:
"<u>*Object*</u> **exerts a** <u>*type of*</u> **force on** <u>*object*</u>."

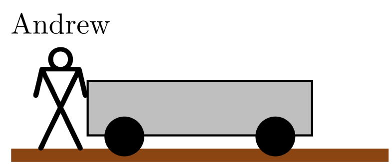

Figure 2: Person and cart

Draw a free body diagram for the cart.

b) A tug-of-war team pulls on a cart as illustrated in Fig. 3. There is no friction between the cart and surface. A black rope connects Denise and the cart while a gray rope connects Cindy and Denise. A red rope connects Cindy to a machine that pulls this rope to the right. All ropes are taut and there is no friction.

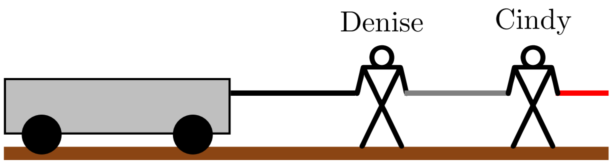

Figure 3: Tug-of-war team and cart

i) Using the format of the previous question, list the forces acting on the cart.

ii) List the forces acting on Denise.

iii) List the forces acting on Cindy.

iv) For each of the cart, Denise, and Cindy, draw a free body diagram.

c) Two carts are on a horizontal surface and there is no friction between either and the surface. Carla pushes cart A from the left. While this happens cart A is in contact with cart B. Draw a free body diagram for cart A.

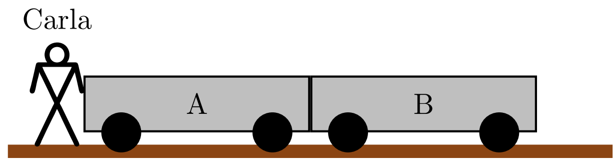

Figure 4: Pushing two carts

Draw a free body diagram for cart B.

d) Two books are stacked on a table and are at rest. *Hitchhiker's Guide to the Galaxy* lies on top of *War and Peace* which sits on the table. *War and Peace* is much heavier than *Hitchhiker's Guide to the Galaxy.*

i) Draw a free body diagram for each book.

ii) The author Tolstoy claims: "The weight of *Hitchhiker's Guide to the Galaxy* is a force that acts on *War and Peace.*" Is this the correct way to use the language of such forces? Explain your answer.

iii) The author Douglas Adams states that there is only one force acting on *Hitchhiker's Guide to the Galaxy* and the *only reason* that it does not move is because *War and Peace* is in the way. Is this correct? Explain your answer.

2 Forces and motion: vertical motion

a) A phone is suspended from a rope and is held at rest. Draw a free body diagram for the phone.

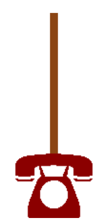

Figure 5: Suspended phone

b) How is the tension in the rope, T, related to the weight, W, of the phone (i.e. gravitational force on the phone) while it is at rest? Explain your answer.

c) The rope and phone are raised at a constant speed. While this happens, will the tension differ from what it was when the phone was at rest? Explain your answer, describing what differences, if any, occur. *(Note that a free body diagram and Newton's laws could be useful for explaining this.)*

d) The rope and phone are lowered at a constant speed. While this happens, will the tension differ from what it was when the phone was at rest? Explain your answer, describing what differences, if any, occur.

e) You will be given a spring balance, a piece of thread and a mass that can be suspended from the thread. The spring balance measures the tension in the thread.

   i) Suspend the mass from the spring balance and determine the tension while the mass is at rest.

   ii) Raise and lower the mass at a constant speed. Observe and record the tension while the mass moves with constant speed in each case. *(Note that if the mass is initially at rest and it later moves up with constant speed, then there will be a period when it is not moving with constant speed. Ignore this period.)*

   iii) Do your observations agree with your predictions that you made about the tension in these cases? If not, explain how you could use Newton's laws to modify your predictions so that they agree with your observations.

f) If the phone is raised or lowered with a constant speed, will the tension in the rope depend on the speed with which it is raised or lowered? Explain your answer.

g) Now consider the tension in the rope while the phone ascends.

   i) Describe how the phone might move for the tension to be larger than the weight of the phone to be possible (e.g. constant speed, increasing speed,. . .).

   ii) Could the tension in the rope be smaller than the weight of the phone while the phone ascends? Describe how the phone might move for this to be possible (e.g. constant speed, increasing speed,. . .).

   iii) Demonstrate these cases with the equipment that you were given.

h) Repeat all of part (g) while the phone descends.

3 Forces and motion: inclined plane

a) A brick is on a frictionless inclined surface as illustrated. The brick is held at rest by a rope. Draw a free body diagram for the brick *as accurately as possible.* Use your free body diagram to determine the net force vector by graphical *(not components)* means. Describe whether your result is consistent with Newton's second law.

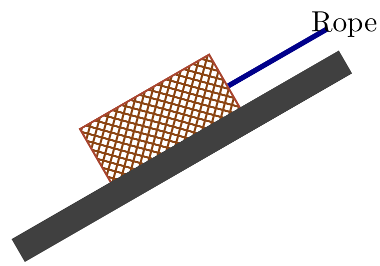

Figure 6: Brick on a ramp

b) The same brick is on the same inclined surface and is lowered, moving down the surface with a constant speed.

i) Draw a free body diagram for the brick *as accurately as possible.*

ii) How does the tension exerted by the rope in this situation compare to that of part (a)? The same, different? Explain your answer.

iii) King Zog states: "The brick can only slide down the slope if there is a non-zero net force acting on the brick." Is this correct? Explain your answer.

iv) If time permits, carry out the following demonstration of the above exercise.

- Mount a force sensor to a cart. Place the cart on the track.
- Mount a motion sensor to one end of a track and a pulley to the other end. Lift the pulley end of the track by a few centimeters. The motion sensor must be adjusted to record the cart's position.
- Connect the cart to a mass suspended mass by a string that hangs over the pulley. Suspend some masspieces from the string and adjust these and the slope of the ramp so that the suspended mass counterbalances the cart, keeping it at rest in near to the top of the track.
- Use CapStone to graph the force exerted by the force sensor and the velocity recorded by the motion sensor.
- Observe the force when the cart is at rest.
- Give the cart a brief push down the ramp and observe the force while the cart moves with constant velocity. How does the force compare while the cart is moving with constant velocity to that while it is at rest?