SPH3U: The Change of Force Principle

Recorder: ____________________
Manager: ____________________
Speaker: ____________________
Reader: ____________________

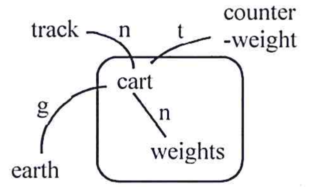
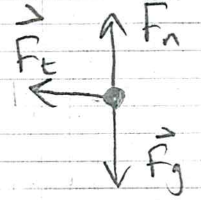
We have made a great discovery with the First Law of Motion (our catalogue of force-motion relationships). Now we need to figure out what happens when forces change.

A: Systems and Interactions

Your teacher has a cart set up on a track with a motion detector. We will create a model for the system of the cart including the extra weights. Our experiment has three events: (1) the cart begins moving, (2) the mass hits the ground, and (3) the cart reaches the end of the track.

Objects outside a system are in the *environment*. When objects outside a system interact with a system object, they produce an *external force*. The First Law of Motion involves **external forces only**. For that reason, we only draw external forces on a force diagram.

1. **Represent.** We will begin by focusing on the system between events 1 and 2. Complete the chart below. Use the interaction diagram to determine the number of force vectors to draw. Use your understanding of the state of motion and force in each direction to determine the size of the force vectors.

Interaction Diagram	Vertical Direction	Horizontal Direction	Force Diagram
	State of motion: none vertical State of force: balanced	State of motion: accelerating State of force: unbalanced	

2. **Interpret.** According to the ID above, what have we assumed about the force of friction?

No friction.

B: Change of State

Let's return to our experiment. We are interested in exploring what happens to the state of motion when forces suddenly change.

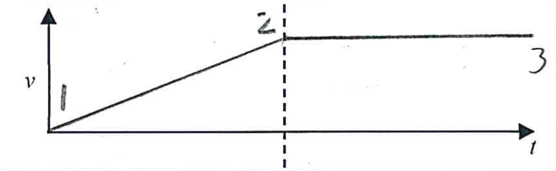
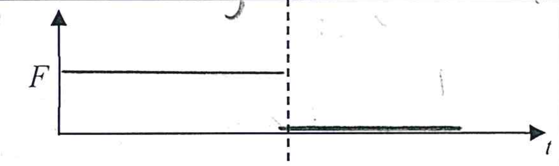
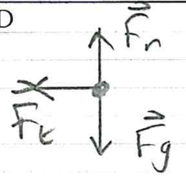
1. **Observe and Interpret.** (*as a class*) Observe the results from the computer. Complete the velocity and tension force graphs. Label the events. Complete the rest of the chart.

2. **Interpret.** During this experiment the state of motion changes and the state of the force change. What do you notice about the timing of these two changes?

They happen at some time

3. **Reason.** Isaac says, "How is it possible in interval 2-3 for the cart to move horizontally with no horizontal force! This doesn't make sense!" Help Isaac understand.

It was travelling horizontally when interval started, and there was no unbalanced force causing it to change speeds.

Interval 1-2	Interval 2-3
	
State of Motion: accelerating	State of Motion: constant vel.
	
State of Force: constant	State of Force: none
FD 	FD 

C: Throw in the Towel

Now we will repeat this experiment with just one change – a piece of paper towel is taped underneath the cart such that it rubs on the track as the cart moves.

1. **Predict**. There are three common hypotheses to explain what happens in this situation.

   Hypothesis A: After the force of tension stops, the cart continues for a while with constant velocity, and then the force of friction starts to slow it down.

   Hypothesis B: When the force of tension stops, the cart *immediately* stops due to the force of friction.

   Hypothesis C: When the force of tension stops, the state of motion changes right away to a new acceleration.

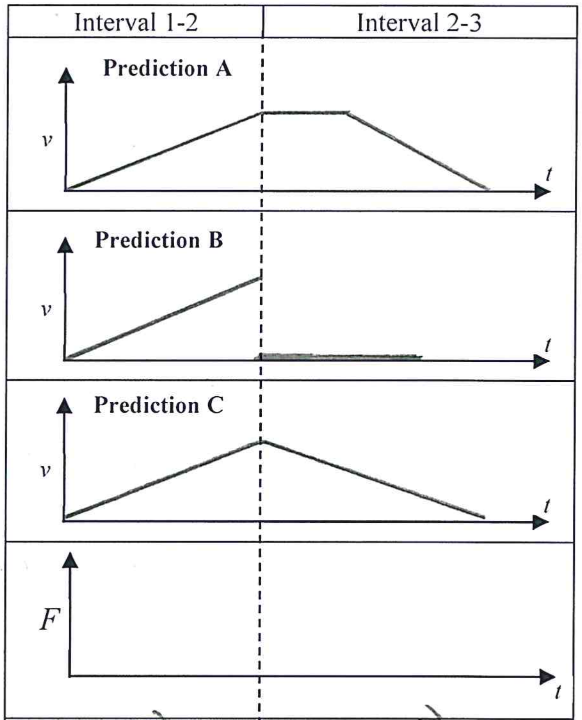
   Use each hypothesis to predict a velocity graph for the cart. Draw each prediction in the chart.

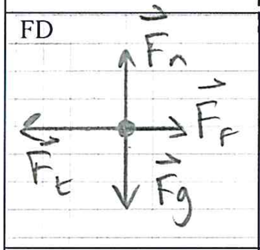
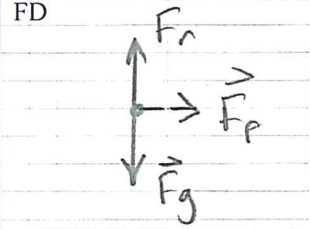
2. **Test and Evaluate.** (*as a class*) Use the computer results to test the predictions. Evaluate which hypothesis is supported and which is refuted.

   Prediction C is closest to observed result

3. **Represent.** Complete the chart. Draw a FD for the cart during each interval. Write an expression for the net force in the x- and y-directions.

Interval 1-2 | Interval 2-3



Interval 1-2	Interval 2-3
FD 	FD 
$F_{net\ x} =$ $\vec{F}_t + \vec{F}_f$	$F_{net\ x} =$ $\vec{F}_f$
$F_{net\ y} =$ 0	$F_{net\ y} =$ 0

Inertia and Mass. All matter has an important property: it takes **time** for the velocity of an object to change when it experiences unbalanced forces. In some cases, the time interval can be very small, but it is **never** zero. We will call this property *inertia*. We can measure the amount of inertia a system has, which is called its *mass*. Inertia is **not** an interaction or force: it is a property of matter.

4. **Reason.** Albert says, "I'm pretty sure that when I push a heavy box along the floor and let go, its state of motion changes suddenly from constant velocity to rest." Do you agree with Albert? Explain why he might have this understanding.

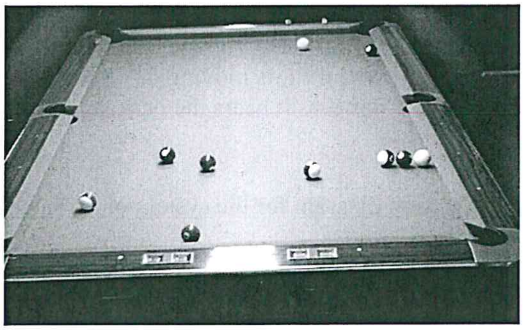
   It appears to stop right away due to the large amount of friction between the box and the floor. In reality it takes a small amount of time for box to slow down.

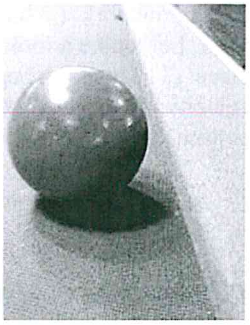
SPH3U Homework: The Force-Change Principle Name:

A: The Billiards Game

In the game of billiards (sometimes known as "pool"), a ball bounces off the cushion at the side of a table. Friction between the ball and the table surface is very small compared with other forces, so make an assumption in your model. We choose five events to help us explore what happens:

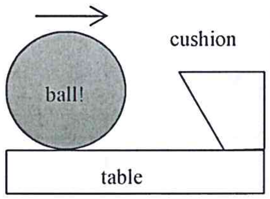
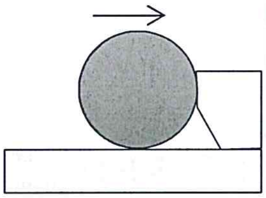
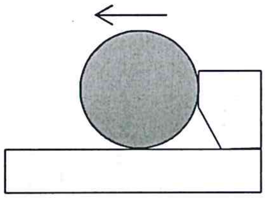
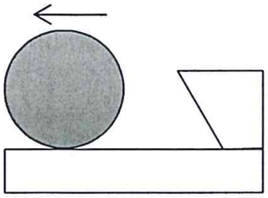
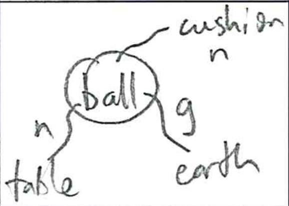
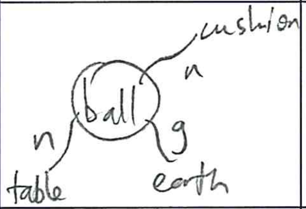
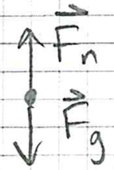
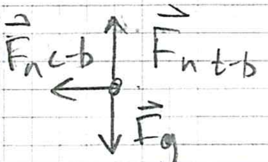
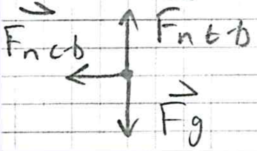
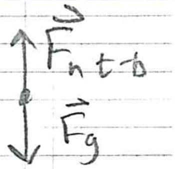
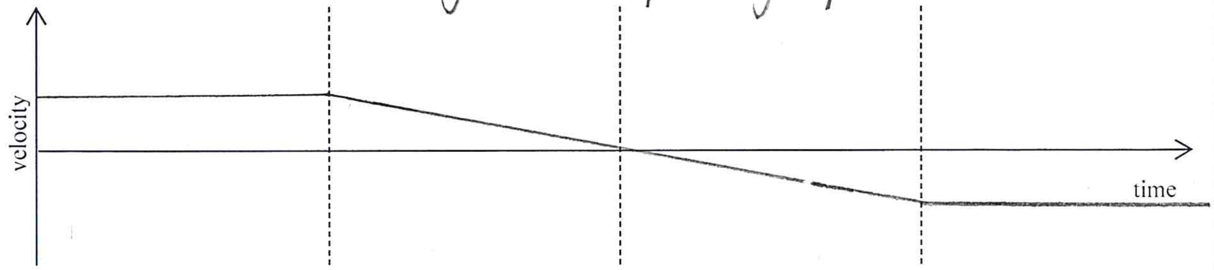
space





(1) The ball is travelling towards the cushion.
(2) The ball makes contact with the cushion.
(3) The cushion is squished and the ball stops.
(4) The ball leaves contact with the cushion.
(5) The ball is travelling away from the cushion.

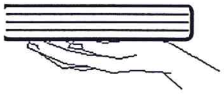
1. **Reason and Represent.** For each interval of time between the pairs of events:
   (a) Draw an interaction diagram and a force diagram. The possible interacting objects are ball, Earth, table and cushion. Label the normal forces $F_{n\ c\text{-}b}$ (normal force of cushion on ball) and $F_{n\ t\text{-}b}$ (normal force of table on ball)
   (b) Describe the state of forces, the state of motion, and what is happening to the speed.
   (c) Sketch a velocity time graph and label the events (the graph is divided up according to the time intervals).

Interval	1-2	2-3	3-4	4-5
Description	Ball rolls towards cushion	Cushion becomes squished (compressed)	Cushion expands	Ball rolls away from cushion
Sketch				
Interaction Diagram				
Force Diagram				
State of Force	balanced	unbalanced	unbalanced	balanced
State of Motion	constant v	acceleration (−)	acceleration (−)	constant v
Speeding Up or Slowing Down?	neither	slowing down	speeding up	neither
Velocity Graph				

SPH3U: Normal Forces Homework

Name:

You grab your physics textbook off a shelf and lower it down on to your desk in preparation for doing your homework. (What a good student you are!) As the book moves, it lies flat on the palm of your hand. Let's take a look at the physics of this **daily** routine. There are four important events that take place: (1) The book begins to speed up as it starts moving downwards, (2) the book reaches a constant velocity, (3) the book begins to slow down as it nears the desk, and (4) the book comes to rest at the bottom.



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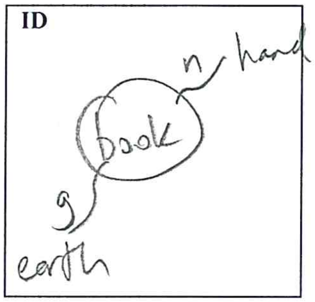


1. **Represent.** Draw an interaction diagram for the system of the book during this sequence of events.

2. **Represent.** Complete the chart below for each of the three intervals in the book's downwards motion.

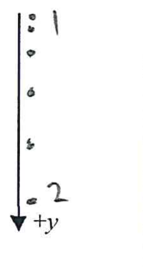
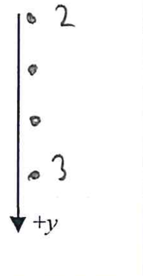
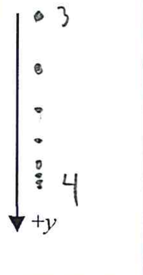
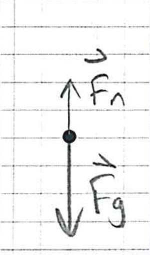
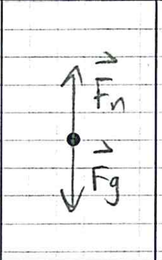
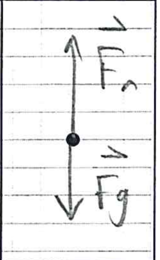
3. **Explain.** Which force changes during this sequence of events? How does that affect the book's motion?

sp

Normal force is small, so downward acceleration

Then $\vec{F}_n = \vec{F}_g$, so constant velocity

Then $\vec{F}_n > \vec{F}_g$, so slows down

Interval	1-2	2-3	3-4
Motion Diagram			
Force Diagram			
Net Force	$= \vec{F}_g + \vec{F}_n$	$= 0$	$= \vec{F}_g + \vec{F}_n$

negative result

positive result since

4. **Calculate.** The mass of the book is 1.3 kg. What is the size of the force exerted by your hand between events 2 and 3?

$$F_n = F_g = mg$$
$$= (1.3\ \text{kg})(10\ \text{N/kg}) = 13\ \text{N}$$

5. **Test and Describe.** Try this. Find a heavy book and place it on the palm of your hand just like in the picture. Lower the book just as we have described above. Try to connect how it feels in your hand when you do this with your understanding of the forces. Describe what you notice.

Feels lighter when accelerating

Feels heavier when constant vel.

Feels heaviest when slowing down

5. **Reason.** Your friend places the same book on a table. She then leans on top of it, pushing down with 7 N of force. Draw a FD for book with and without the downwards push. Compare the size of all the forces in the two diagrams.

No push: $F_g = F_n$

with push: $F_n = F_g + 7\ \text{N}$

FD – no push	FD –push