On-line activities for complex systems dynamics and 2-D dynamics labs

Below is the list of experiments (real, video based and data-based) that students can perform as labs for the second week of learning dynamics. For each experiment we provide goals, equipment and rubrics for self-assessment. Rubrics can be found at https://sites.google.com/site/scientificabilities/rubrics

1. Observational experiment: pulling a block part 1

Goals: a) To determine the direction and magnitude of the force that the surface exerts on the object being pulled across it.

b) To use force diagrams to explain the results of the experiment.

Equipment: (if available) a block or another similar object and a spring scale.

Rubrics for self-assessment Ability to collect and analyze experimental data G4 and G5; Ability to Represent information in multiple ways A5 (Force diagram)

a. Perform the experiments described below or watch the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-experiment-video-7] and analyze the experiments using force diagrams. The system is the block. Describe the patterns that you find.

Observational experiments	**Force diagram for the block** Remember that each object interacting with the block exerts *one* force on it
A block is at rest on the horizontal surface of a desk.	
A spring scale pulls lightly on the block that is at rest on a horizontal surface; the block does not move.	
The spring scale pulls harder on the block at rest on the horizontal surface; the block still does not move.	

The spring scale pulls even harder on the block at rest on the horizontal surface, right at the instant it starts to move.	
The spring scale pulls the block at a slow constant velocity across the horizontal surface.	
Patterns	

b. What is the direction and magnitude of the force that the desk exerts on the block in the experiments described above? Does the force have a constant magnitude? Constant direction?

c. Resolve the force that the desk exerts on the block into two components: one perpendicular to the interacting surfaces and one parallel. The perpendicular vector component is called the **normal force** (normal is the term for "perpendicular" in mathematics) and the parallel vector component is called the **friction force**.

2. Observational experiment: pulling a block part 2

Goals: a) To determine what factors affect or do not affect the maximum static friction force.

b) To use force diagrams to explain the results of the experiment.

Equipment: (if available) a block or another similar object, material to cover the surface and a spring scale.

Rubrics for self-assessment Ability to design and conduct an observational experiment B7;

Ability to Represent information in multiple ways A5 (Force diagram)

a. Perform the experiments similar to those in the video or just watch the experiments in the video [https://youtu.be/5zOxH7CMlIg] to investigate what physical quantities or other factors affect (or do not affect) the maximum static friction force component of the force that the surface exerts on the object pulled across it.

b. What patterns did you find? Make a list.

3. Application experiment

Goals: a) To apply the knowledge of friction to solve a practical problem.

b) to evaluate uncertainty in the result.

Equipment: video experiment 2

Rubrics for self-assessment Ability to conduct an application experiment D7 and D8.

Use the video Experiment 2 to estimate the coefficient of static friction in each of the experiments. The mass of the wooden block is 154 g (do not forget to convert to kg).

4. Application experiment

a. Watch the video of an object on a platform scale [https://youtu.be/R8lXd5Un8dA]. Note the reading, then record the reading when the scale is tilted 10° or so and the object does not slide. Explain the change in the reading by drawing two force diagrams for the object on the scale: One for the case when the scale is level, and one for the case when the scale is tilted.

b. How are the different forces (or their components) exerted on the object related to each other when the scale is tilted but the object is not accelerating? What coordinate system might you want to choose to best show the key relationships?

5. Application experiment

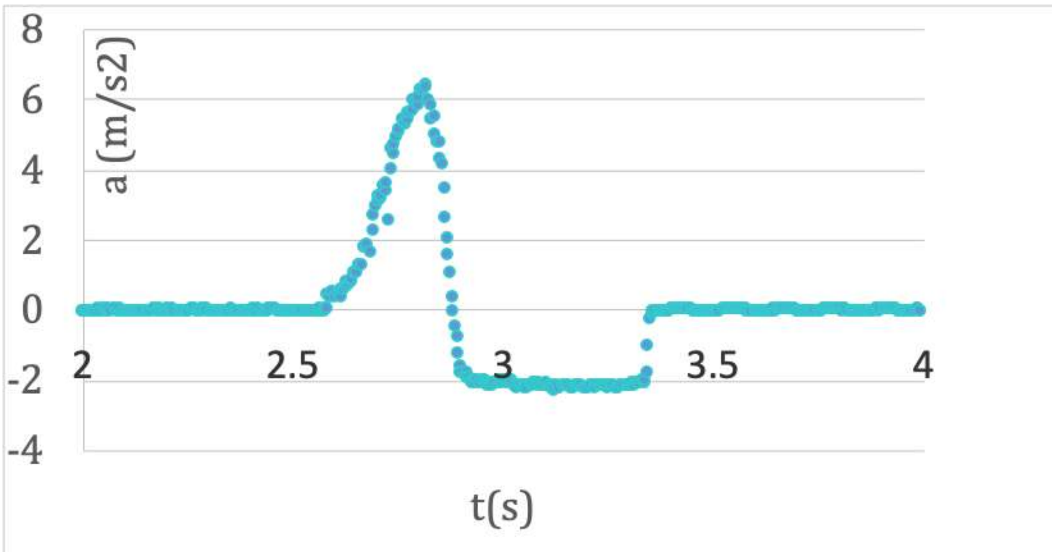
Goal: to use Newton's laws to explain the outcome of the experiment quantitatively.

Equipment: a textbook with a glossy cover, the Phyphox app on your phone.

a. Fix your phone on top of a textbook and turn on the Phyphox application "acceleration without *g*". Push the book across the table, let it slide and come to a stop. Record the acceleration-vs time graph that the Phyphox application created.

b. Write down everything you can determine from the graph. Where on the graph is the time when you released the book?

c. Use the graph that we collected from a similar experiment (we just pushed the phone - it was not on top of a textbook) to determine (1) the time when the hand stopped pushing the phone, (2) the largest speed of the phone, (3) how far the phone went while slowing down, and (4) the coefficient of kinetic friction between the phone and the desk.



6. Application experiment

Goals: 1) Use Newton's laws to make a prediction about a real-life situation;

2) Evaluate uncertainties in the result, 3) Evaluate assumptions used to make the prediction.

Equipment: video

Rubrics for self-assessment: Ability to collect and represent data G 1 and G2; Ability to conduct an application experiment D7, D8 and D9.

The video [https://youtu.be/sUQPlAGbyMo] shows the following experiment:

a. The object on the left has a mass of 112 g and the object on the right, 101 g. The experimenter holds the left object on a table; the right one is about 1 meter above the table. Use your knowledge of Newton's laws and kinematics to predict how far the object on the left will move in the first second after letting go of the object on the table. Do not forget about experimental uncertainties.

b. After you have made that prediction, watch the video and use the frame count to determine the time. The video is digitized at 30 frames per second. Did the outcome match that prediction? Consider the assumptions that you made about the motion of the objects, the pulley, and the uncertainties in the data.

7. Application experiment: shoe and coefficient of friction

Goals: 1) Use Newton's laws to determine a physical quantity.

2) Evaluate uncertainties in the result, 3) Evaluate assumptions used to make the prediction.

Equipment: video

Rubrics for self-assessment: Ability to collect and represent data G 1 and G2; Ability to conduct an application experiment D7, D8, D9, and D5.

Watch the videos to determine the coefficient of static friction between the shoe and the board [https://youtu.be/772zpP3cGkc].

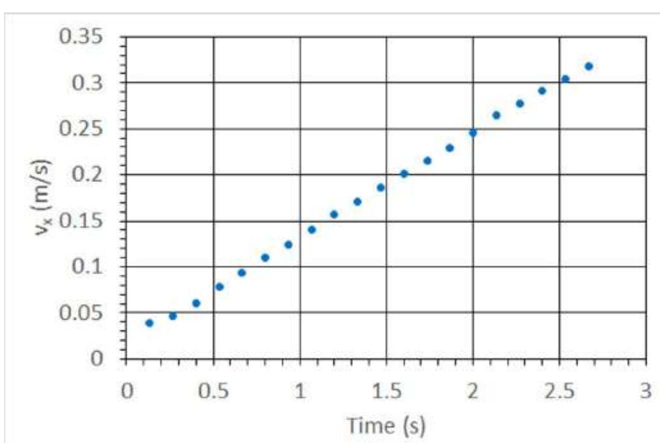
a. Take your measurements, devise a mathematical procedure to determine the coefficient of static friction, record your results, and estimate the uncertainty in your determined value of μ_s for each method.

c. Compare the outcome of the two methods. Do your two measurements agree within expected uncertainties? Explain. Discuss what assumptions you made to implement each mathematical method and how these assumptions might impact the results you found.

8. Application Experiment: battle of fan carts

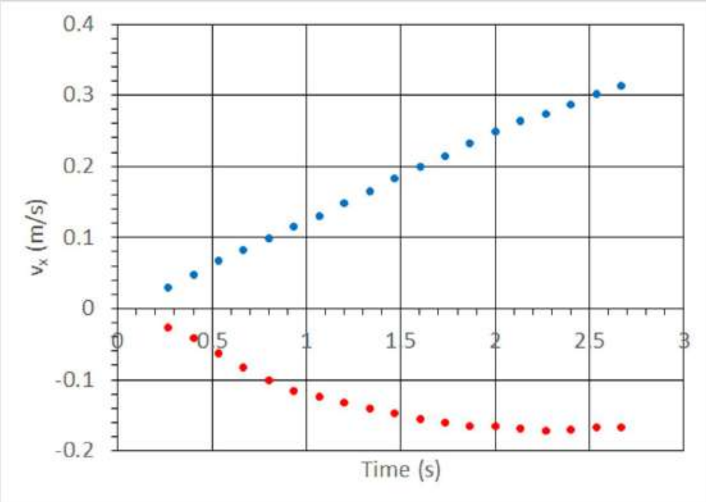
Imagine that you have two low friction carts to carry out the following three experiments. You fix a vertical board on cart A and a battery-operated fan on cart B. As the fan blades on cart B rotate, they exert a constant force on the air.

Experiment 1: You put cart B on the track and switch on the fan. While the cart is moving to the right, you record the following video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-4-4-16a]. Analyze the video frame by frame and produce the velocity-versus-time graph of the cart's motion (alternatively use the graph of the motion of cart B shown below; the *x*-axis points to the right.).



Experiment 2: You put both carts on the track, connect cart A and cart B together (using Velcro) and switch on the fan (see the figure below). The air pushed by the fan on cart B is blowing toward the vertical board on cart A, but both carts remain at rest.

Experiment 3: You repeat Experiment 2 but this time you separate the carts so they can move independently. While the carts are moving, you record the following video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-4-4-16b]. Analyze the video frame by frame and produce the velocity-versus-time graph of the carts' motions (alternatively, use the graphs of the motions of cart A (in red) and cart B (in blue) below).



a. Explain the outcome of each experiment using Newton's laws. Show how the outcomes of the first two experiments help you explain the outcome of the third experiment.

b. Draw qualitative force-versus-time curves that show the time dependence of the sum of the forces exerted on each cart (draw both curves on the same graph).

c. Eugenia says: "The outcome of Experiment 3 violates Newton's third law." What might have led Eugenia to this conclusion? Do you agree or disagree with her? If you disagree, what would you say to Eugenia to convince her that Newton's third law is not violated in this experiment?

9. Observational experiment: catching a ball while running

Goal: Explain the motion of a projectile.

Equipment: a ball or any object that you can safely throw and catch

[https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-4-5-1]

If you have a ball (or any object you can throw up and catch) at home, try to do this experiment yourself first . The goal of the experiment is for you to run at constant speed and throw the ball up while running so that the ball lands in your hands when it comes back down. If you have a friend at home, they can take a video of the experiment (as soon as you do it successfully.) Then, carefully analyze the motion of the ball. How did you throw it and why did it land in your hands? If you do not have a ball or room to run, use the video above.

a. Observe the motion of the ball and the person, and describe what you observe in simple words.

b. Observe the motion of the person with respect to the floor. Draw a motion diagram representing the motion of the person. Describe the motion of the person relative to the floor.

c. Observe the motion of the ball with respect to the person. (It is helpful if you can view your video frame by frame.) Draw a motion diagram representing the motion of the ball with respect to the person. Describe the motion of the ball relative to the person.

d. Observe the motion of the ball with respect to the floor. What pattern do you see? What can you say about the motion of the ball and the person with respect to each other that is always true? Draw a motion diagram representing the motion of the ball relative to the floor.

e. How is the motion diagram you constructed in part d. related to the motion diagrams in parts b. and c.? Is there a relationship? What is it? Come up with an explanation for the direction of the throw that lets the ball land successfully in the runner's hands.

10. Testing experiment: how does the ball move?

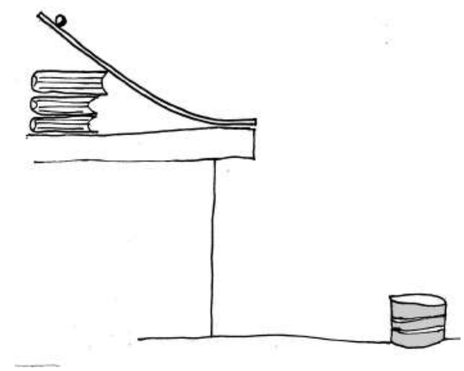
a. Design an experiment to test the explanation for the direction of the throw that lets the ball land successfully in the runner's hands. Describe the experiment in words and with a sketch.

b. Use available equipment to conduct the experiment. Record the outcome.

c. What is your judgment about the explanation you were testing?

11. Application experiment: catching a marble

Equipment: a marble, an incline (a board will suffice), a tape measure or a meter stick, and a container with some cloth inside to prevent the marble from bouncing.



a. Think of how you can predict where the marble will land on the floor if you let it go from the top of the incline plane and let it roll off the table as shown in the figure on the right

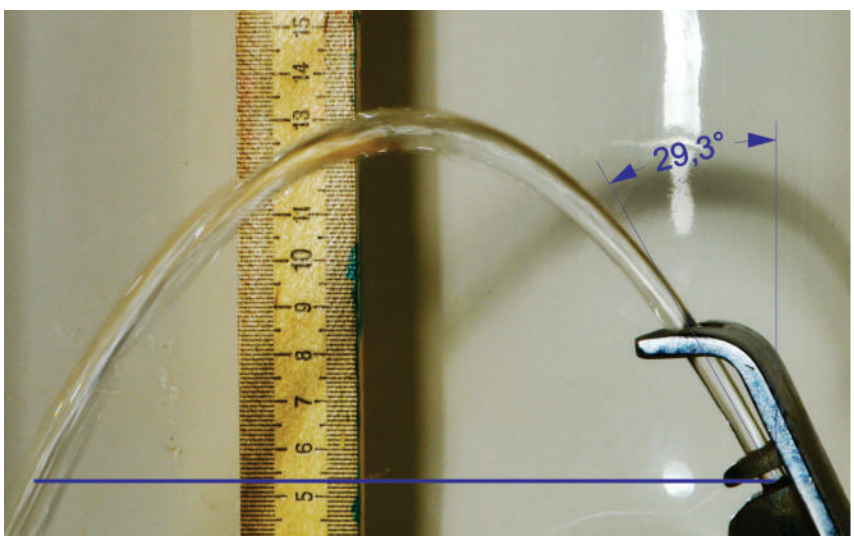
b. Take the necessary measurements to do the calculation, predict the distance, and place your container at that location. Do not forget to take into account the uncertainty!

c. Run the experiment. Did the marble land in the bucket? If not, reexamine your procedure and assumptions.

12. Application experiment: how fast is the water moving (1)?

Equipment: a meterstick, a protractor, a water fountain.

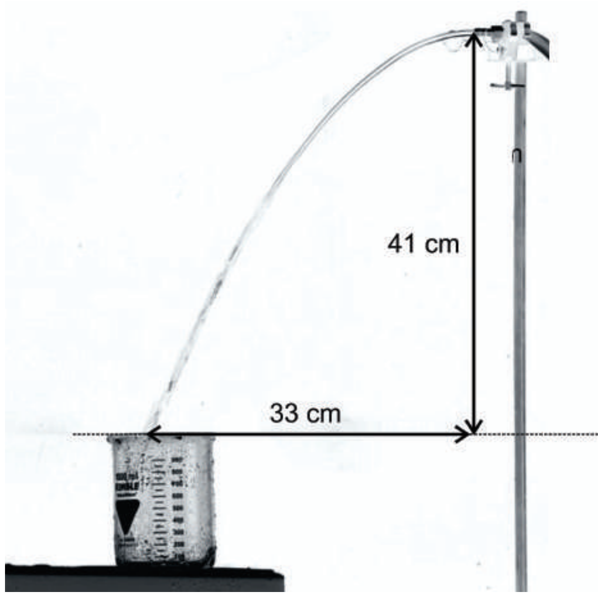
Obtain a photo of a steady jet stream from a water fountain or use the photo below. Estimate the speed of the water. Indicate any assumptions that you made and evaluate the result.



Units on the meter stick are centimeters.

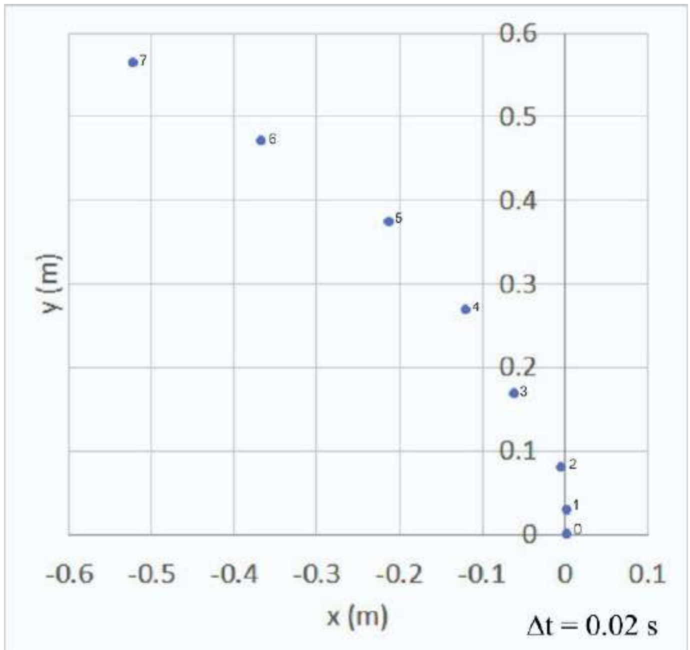
13. Application experiment: how fast is the water moving (2)?

The photo below shows a steady water jet coming from a 5.5-mm diameter nozzle. The water from the jet fills a 900-mL beaker in 35 seconds. Estimate the speed of the water at the nozzle. Indicate any assumptions that you made.



14. Application experiment: Trebushet

A small version of a trebuchet (see the photo on the right) was used to launch a ball (view the slow motion video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-4-5-9]). The figure below shows a two-dimensional motion diagram of the ball during the launch (the data were obtained from the video). The coordinate system is shown in the photo. The time interval between two successive points is 0.020 s.



a. Based on the motion diagram, estimate the what time when the trebuchet arm stopped exerting a force on the ball (at $t = 0$, the ball was at the 0 mark). Include uncertainty in your answer. Explain how you made the estimate.

b. Estimate the launch speed of the ball (the speed of the ball when it loses contact with the arm) and the angle above the horizontal at which the ball was launched.

c. Estimate the distance from the trebuchet at which the ball landed on the ground. Indicate any assumptions that you made.

d. Your friend says that the trebuchet arm exerts a constant force on the ball during the launch. Can you reject his hypotheses based on the data provided above? Explain.