# Semester I lab quiz Study Guide (Mechanics)
# Physics 135/163

In this guide, lab titles/topics are listed alphabetically, with a page break in between each one.

You are allowed to refer to your handwritten lab notebook during quizzes, and to the pre-lab exercises, but not to the printed lab manual.

Students work alone on lab quizzes.

Questions and tasks on the lab quizzes are based directly on what you have learned and done in lab activities. Therefore you should expect to turn in a perfect quiz if your lab notebook is complete, detailed, well-written and explains completely how you carried out activities and interpreted them. Patience and extreme care will be rewarded, but careless mistakes will be costly.

**TIPS:**
Read the descriptions and sample questions, discuss them with your lab partners, and please come in with any questions.

Be familiar with the experiments, calculations and concepts.

Check your work and pay attention to details; verify and include units, label graph axes, read and use your calculator carefully.

Keep a neat lab notebook with diagrams and details, and answer all questions with full sentences in your lab notebook.

# Acceleration in Freefall: Tape Timer

Given a strip of tape with marks on it, supposedly recorded on another planet in a free-fall tape-timer experiment, deduce what the acceleration due to gravity is on the alien planet. The time interval between markings may differ from 1/40 sec.

SAMPLE

You are performing a tape timer and freefall experiment on Planet X. Four spots from your tape (actual size) are shown below, separated in time by 0.04 second. Call them points 0, 1, 2, and 3.

(Use 3 or 4 significant digits in this problem, and show all work.)

a. Find the instantaneous speed of the object at t1 and t2. Include units.

b. Using the previous results, find the acceleration due to gravity on Planet X, which you may assume is constant. Include units.

# Atwood’s Machine

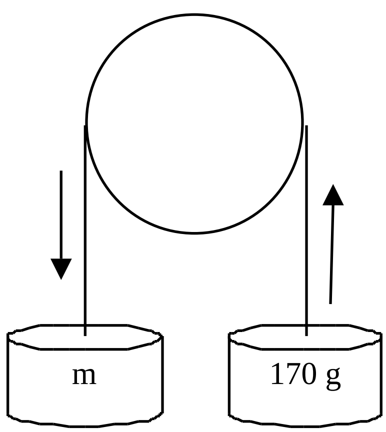
Given an Atwood’s machine situation and the value of both masses, use the computer and/or theoretical calculation to measure/determine the acceleration of the system, or one of the masses. Or, given the value of one of the two masses and the magnitude of the system’s acceleration, deduce the unknown mass.

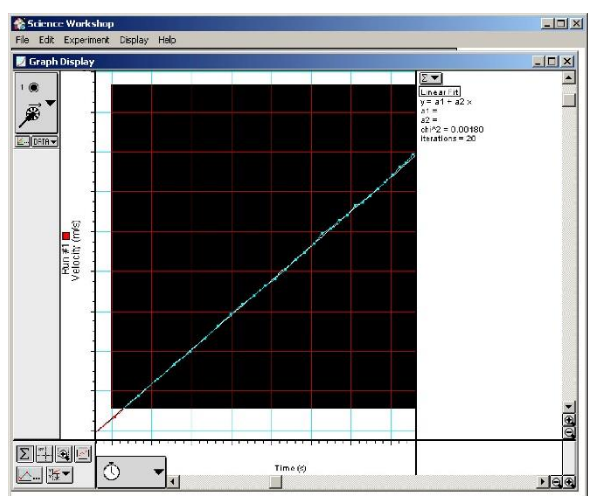
SAMPLE

A string runs over a frictionless, massless pulley. Two blocks hang from the string. When the system is released from rest, the system begins to accelerate as shown. The velocity vs. time points shown are collected on the computer, using the Smart Pulley sensor.

The curve fit to the data is given by y = 2.105+3.459*x

You have measured one of the masses, as shown in the figure. Calculate the mass m of the other block. Include units.



# Collisions in 1-D: Linear Momentum and KE

Be able to describe the types of collisions (elastic and inelastic) and whether or not momentum and/or kinetic energy is conserved for each of these.

Given the masses and lengths of 2 carts on an ideal frictionless airtrack, and the time it takes each of them to pass through photogates, calculate the system momentum and kinetic energy, or the individual momentum (with sign) and KE of a cart.

Given the system's momentum or kinetic energy before the collision, predict that the system's momentum and KE should be the same after an elastic collision. However, if the carts stick together, the momentum should be the same though the KE must go down.

Suppose you were given complete data for the carts before the collision, and partial data for the carts after the collision (or vice versa). Be able to use the conservation of momentum principle to solve for unknowns such as the velocity (speed and direction) of either cart, or the time a cart takes to pass through a photogate, or the mass of either cart.

EXAMPLE 1: Two air carts have total masses m1=320 grams and m2=195 grams. Assume that there are absolutely, positively, undoubtedly, unequivocally <u>no</u> frictional or other external, horizontally directed forces acting on the system of the two air carts.

Initially, cart #1 is moving to the right and cart #2 is moving to the left. Cart #1, which has a mounted flag 12.1 cm long, takes 0.374 seconds to go through its photogate, and Cart #2, with an identical flag on top, takes 0.158 seconds to go through its photogate, and then the two carts collide and stick together.


a. Your lab partner hit "Stop" too soon and you lost all the data after the collision. Oops! Using your knowledge of physics, determine the expected *momentum* of the system AFTER the collision. Make sure you designate which direction is positive. Remember units!
b. What is the total kinetic energy <u>before</u> the collision? Again, remember your units!
c. Consider the KE <u>after</u> the collision. In this ideal experiment, do you expect it to go down, go up, or remain the same? Why?

EXAMPLE 2: Suppose you were not given one of the masses, but told, for example, the final velocity of the 2 carts. You could be asked to solve for the unknown mass, and/or the system's momentum before or after the collision, and/or the system's KE before or after the collision.

# <u>Conservation of Angular Momentum</u>

Given data on two disks, such as masses and inner/outer diameters/radii, and the initial angular velocities of the 2 disks, use the conservation of angular momentum principle to calculate the common angular velocity after the two disks are allowed to contact each other and spin together.

Or, given the common final angular velocity, solve for unknowns such as the initial angular velocity of one of the disks.

Or, given data on the starting and final angular velocities and some data on the disks, solve for unknowns such as moments of inertia, masses or diameters/radii.

EXAMPLE

Two metal disks have masses m1=3.45 kg and m2=UNKNOWN kg, and each has a radius of 8.31 cm. (You may ignore the inner hole for both disks - assume that it is very small.) They spin on cushions of air in a standard rotational dynamics apparatus. Initially, disk #1 is spinning counterclockwise at 6.02 rad/s and disk #2 is spinning clockwise at 2.5 rad/s. A pin is removed that drops disk #1 onto disk #2. After a short time they are seen to spin at the same angular speed of 2.33 rad/s, counterclockwise. Assume that there are <u>no</u> outside frictional forces acting on the system of the two disks.

a. Calculate the moment of inertia of the first disk. Include units.

b. Calculate the mass of the second disk in this ideal situation. Include units.

# Introduction to the Computer Interface and DataStudio

Be able to physically set up the computer interface and use the software to record motion data, and to plot position, velocity, or acceleration vs. time. Be able to use the software to measure and interpret the slopes of lines.

Be able to make and justify kinematics calculations similar to those that you performed in the virtual labs (skee ball and cannon ball labs, if applicable). Tip: write the kinematics equations you used in these virtual labs in your lab notebook.

Given a graph of x vs. t, or v vs. t, describe in words what you would have to do to replicate the graph. Make sure that you clearly indicate directions (e.g., "moving away from the sensor" or "moving toward the sensor"), speeds (e.g., "slowly," "quickly") and accelerations (e.g., "constant velocity," "speeding up" or "slowing down").

a. OR, draw a graph (either x-t or v-t) from a description such as "run away from the force sensor, speeding up as you go, then stop for 3 seconds. Turn around and come back, quickly at first and then slowing down. Finally, walk away slowly at constant speed".
b. Make sure you can do this for both x-t and v-t graphs.

## EXAMPLE

(You will need a ruler and graph paper for this question.)

You are using the ultrasonic motion sensor.

Your lab partner is 2.0 meters away from the sensor (point A) and moves away from the sensor while gradually slowing down: that is, very quickly at first, then continually slowing down. After 3.5 seconds, she stops at a distance of 6.0 meters from the sensor (point B on your graph), and then immediately moves back toward the sensor at a constant speed of 1.5 m/s. Finally, when she reaches her original position (point C on your graph), she reverses direction and moves away from the sensor at constant speed of 0.4 m/s, finally stopping when she is 5.0 meters from the sensor (point D on your graph).

Draw a scaled graph of position vs. time as measured by the Science Workshop motion sensor. Label your axes, and clearly indicate the positions and times on your graph for points A, B, C and D.

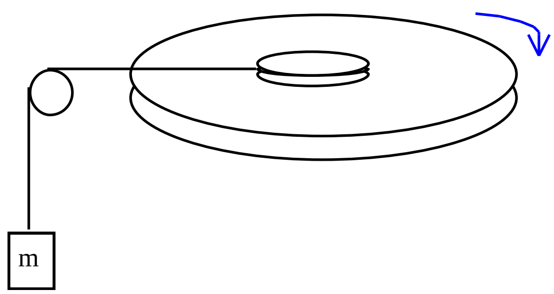
# Moment of Inertia of a Disk

Be able to use the rotational dynamics apparatus to measure the moment of inertia of an unknown disk. Or, given data on a disk such as its mass or diameter/radius, and the radius/diameter of a torque pulley, and a table of data (e.g., hanging mass and corresponding angular acceleration, or hanging mass and corresponding linear acceleration), determine the moment of inertia of the disk.

Be able to find the moment of inertia of a disk or annular disk from parameters that you measure (such as mass, inner radius and outer radius).

SAMPLE

A disk of overall diameter 12.6 cm spins on an air cushion, and is connected by a cord to a hanging mass that descends as the disk experiences an angular acceleration. The cord pulls on the disk by unwrapping from a torque pulley of diameter 4.0 cm. The following values are obtained for the hanging mass and the acceleration.




| Trial | **Total** mass hanging from cord | Linear Acceleration of falling mass |
|---|---|---|
| 1 | 6.0 grams | 0.148 m / sec$^2$ |
| 2 | 8.5 grams | 0.224 m / sec$^2$ |
| 3 | 13.0 grams | 0.320 m / sec$^2$ |
| 4 | 18.0 grams | 0.426 m / sec$^2$ |

For each of the four trials, calculate the torque exerted on the disk. (Be sure to show your work.) Carefully construct a (**large**) graph of torque vs. angular acceleration, and *from the slope* determine the moment of inertia of the disk. Include units!

# Projectile Motion:

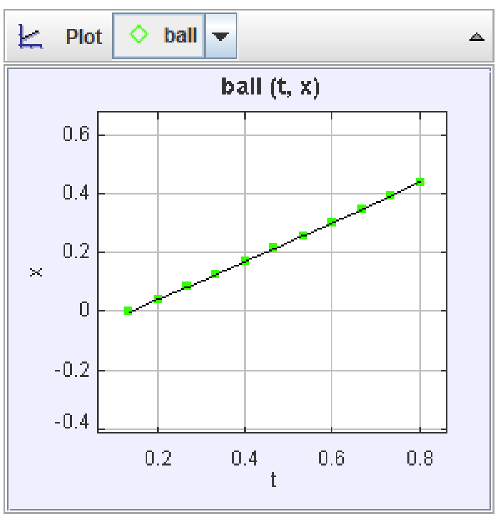
Be able to make graphs of the motion of a projectile, including horizontal and vertical position and velocity graphs. The origin of the axes may be located at the beginning or end of the motion.

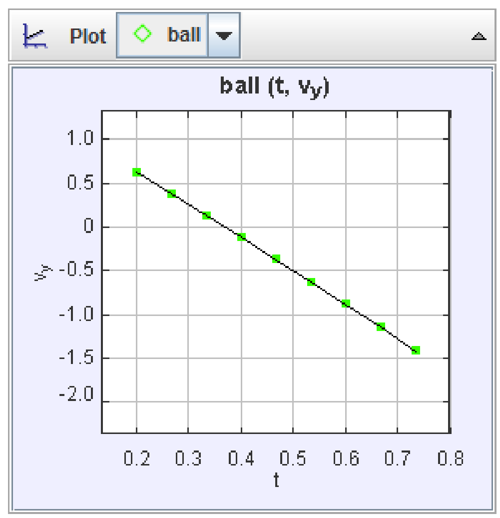
Given graphs of position versus time and/or velocity versus time for a projectile and the fit equations for each, be able to determine the initial position(s)/velocities and accelerations throughout the motion.

SAMPLE

Two graphs of horizontal position-versus-time and vertical velocity-versus-time for a ball in projectile motion are shown below. Also given is the "Fit Equation" for these lines.

Note: The values given below are in SI-units: distances are in meters and time in seconds.




Fit Equation
$x = (0.66)t + (-0.09)$

Fit Equation
$vy = (-3.826)t + 1.412$

- What is the initial speed of the ball, i.e, how fast is the ball moving?
- What is the vertical acceleration of the ball?
  What is the horizontal acceleration of the ball?
  *[Careful: The ball is not on Earth.]*

## Significant Figures

Be able to do arithmetic using the rules of significant figures.

SAMPLE

Perform the following calculations and round off the answers to the correct number of significant digits. Please report the answer in scientific notation.

$1.73 + (0.000533)(92.3)$

$3.141592654 \times 3.2 + 0.6$

$3.141592654 \times (2.0)^5$

$(200.9)(69.3)$

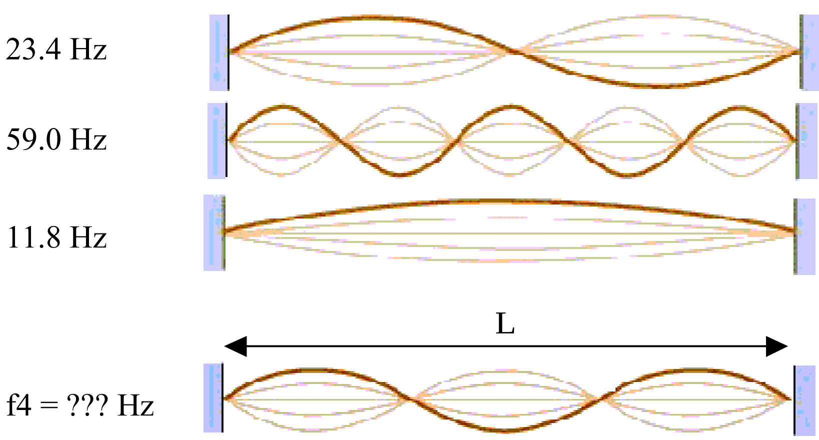
# Standing Waves: Waves on a String

Given the total string length L, pictures of a few standing wave patterns, and the frequencies at which they are observed, deduce some quantities, given sufficient information. You should be able to graph wavelength vs. period data to find quantities such as the mass per unit length of the string, the tension in the string, or the mass hanging from the end. All graphs that are used to determine a slope must be sufficiently large (at least 1/2 page).

EXAMPLE

A string is stretched horizontally, and one end is connected to the tip of a mechanical oscillator. The other end extends over a pulley and supports a total hanging mass of 300 grams. The string is L = 1.74 meters long, from the point of attachment to the oscillator to the point of contact with the pulley. The patterns shown in the figure (NOT ACTUAL SIZE) are observed at the frequencies indicated.

a. Make a (large) graph of wavelength vs. period. Include units on your axes.
b. Using your graph, determine the wave speed on this stretched string? Include units.
c. Estimate the mass per unit length of the string, and please include units!
d. What is the frequency f4 of the pattern shown?




EXAMPLE 2

Suppose you were told the mass per unit length of the string, and its total length, but not the amount of hanging mass. Using the same diagrams as above, you should know how to find the mass, and the tension in the string.

EXAMPLE 3

A string is under a tension of 120.0 N. A 1.6 m length of the string has a mass of 5.7 grams.
a. What is the speed of a transverse wave of wavelength 0.60 m in this string?
b. What is the frequency of the wave?

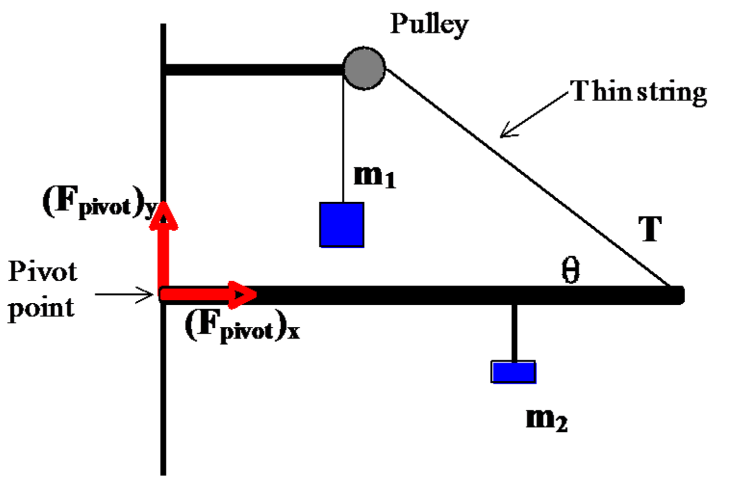
# Static Equilibrium

Perform calculations similar to those you performed in lab.

SAMPLE

A horizontal bar of mass 1.90 kg and length 1.50 meters is suspended by a cord at one end, and by contact with a support at the other end. In the diagram provided, $\theta = 29°$. Also, a mass $m_2$ = 230 grams hangs from the bar, 1.20 meters from the pivot (i.e., 0.30 m from the tip).

THIS DIAGRAM MAY NOT BE DRAWN TO SCALE




Determine the mass $m_1$ (which supplies the tension in the cord). Include units.

Determine the components of the force at the pivot, i.e., $F_{pivot,x}$ and $F_{pivot,y}$. Include units!

## **Vector Addition/Force Table**

Given a force table problem with 2-3 masses hung at various angles, be able to use the force table, and/or the graphical method, and/or the components method to combine force vectors and deduce any of the following:

a. the *resultant* (i.e., net or total or sum) force

b. the *equilibrant* force (this is NOT the same as net force. Know the difference.)

c. thee value and angular location of the *mass* that must be hung to balance the system.

SAMPLE

A 150 gram mass (150 g includes the hanger's mass) is hung on a vector force table at an angle of 105°, measured counterclockwise from the zero-degree mark. A second mass of 235 grams (also including the hanger) is hung on the same table at an angle of 180°.

Using **the graphical method** of adding forces, determine the magnitude (include units!) and direction of the *resultant force*.

SAMPLE

A 150 gram mass (150 g includes the hanger's mass) is hung on a vector force table at an angle of 115°, measured counterclockwise from the zero-degree mark. A second mass of 200 grams (also including the hanger) is hung on the same table at an angle of 220°.

Using **the components method** of adding forces, determine the amount of *mass* (include units) and its angular location that will balance the center ring.