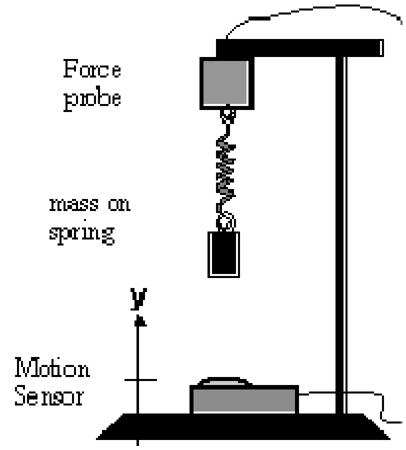
ILD 8: Name: ____________________ Tutorial section _______

Seeking Consistency: Harmonic Oscillation

To describe and understand oscillations, do we need new rules, or are Newton's laws sufficient?

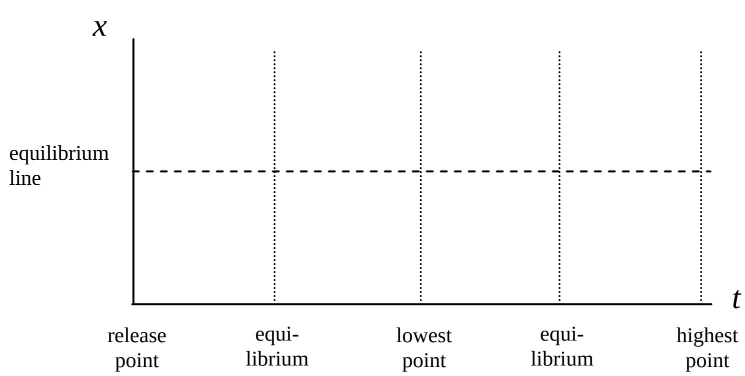
I. Position vs. time

☆ *Experiment & explanation: Equilibrium line.*



A. (*Work together*) Your instructor will demonstrate how the ranger works and what it reads when the mass is at rest in its equilibrium position (that is, the position at which it can remain at rest). When it is in that position, what forces are acting on the mass? What is the net force on the mass? (Hint: A free-body diagram might help decide.)

B. Your instructor will lift the mass hanging up, away from the detector, and release it from rest. On these axes, sketch your prediction of the position vs. time as it goes back and forth once.



☆ *Class discussion. RAD poll. Experiment.*

C. (*Work together*) One equation that might be chosen to describe this motion is: $x = \cos t$.

1. Is there some way to check this equation to see if it needs modification? We're not yet asking you to modify it; we're just asking how you can figure out if such modifications might be needed?

2. When you take the sine or cosine of something, what must be the units of that "something." In other words, can you take the sine of 7 *meters*? Of 7 *seconds*? What units *can* you take the sine of?

3. When you plug “sine of 7 radians” into your calculator, it spits out 0.66. What are the units of that 0.66? Is it 0.66 meters? 0.66 seconds? Just the number 0.66 with no units? How do you know?

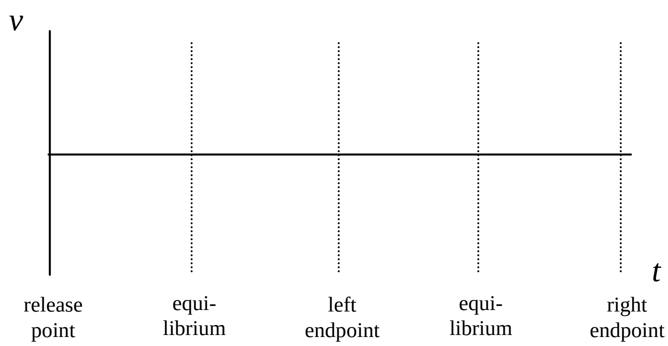
4. What other checks can you make to see if the equation is reasonable?

5. Using your above answers, how must you modify the equation $x = \cos t$ so that everything works out?

✯ *Class discussion.*

II. Velocity vs. time

A. (*Work together*) Your instructor will repeat the experiment of section I, this time measuring velocity instead of position. On these axes, sketch your prediction for the mass’s *velocity vs. time*.



✯ *Class discussion.*

B. Could you have figured this result out without doing the experiment a second time? If so, how. If not, why not?

✯ *Class discussion.*

III. Can Newton's laws deal with oscillatory motion?

A. Consider the oscillating mass at the moment it first passes the equilibrium point, moving down.

1. Does the mass feel a net downward force at that moment? Briefly explain. (Hint: A free-body diagram might help decide.)

2. If you answered "yes," explain what object or objects exert that downward net force. If you answered "no," explain why the mass doesn't just stop when it reaches equilibrium, i.e., explain how the mass can be moving down even though it feels no net downward force.

3. It turns out the oscillating mass feels no net force at equilibrium, even though that's where it's moving fastest. Is this seemingly paradoxical conclusion—*that the force is zero when the velocity is biggest*—explainable in terms of Newton's 2^{nd} law, or do we need new rules? Explain.

✯ *Class discussion.*

B. Consider the oscillating mass at its lowest point.

1. Why might a smart student say the mass has *no* acceleration at that point?

2. Why might a smart student say the mass *does* have an acceleration at that point?

3. Using data already collected in this ILD, can you decide whether the mass has an acceleration at its lowest point? How? According to the data, is the acceleration positive, negative, or zero at that point?

4. Is the intuition that the mass has no acceleration hopelessly wrong, or can it be refined and reconciled with the correct answer? Explain.

✯ *Class discussion.*

C. Does Newton's 2nd law "agree" with your conclusions about the mass's acceleration at the lowest point? In other words, is the mass's positive (away-from-the-detector) acceleration at that moment explainable in terms of Newton's 2nd law, or do we need new rules?

D. Now we'll see if Newton's 2nd law can deal with the mass's motion in general, not just at "special" points. Consider its motion from the moment it was released until the moment it first reaches equilibrium.

1. Intuitively, during that segment of the motion, is the net force on the mass positive (away from the detector) or negative (toward the detector)? Is the magnitude of the force increasing, decreasing, or constant? Why?

2. Check for coherence between your velocity vs. time graph from page 1 and the answers you just gave. Does everything "fit together" in accordance with Newton's 2nd law, or do we need new rules to deal with the mass's complicated motion?

✯ *Class discussion.*