PHYS 121: Homework #10

April 22, 2024

Physics 121: Spring 2024: Week 12 Reading assignment:

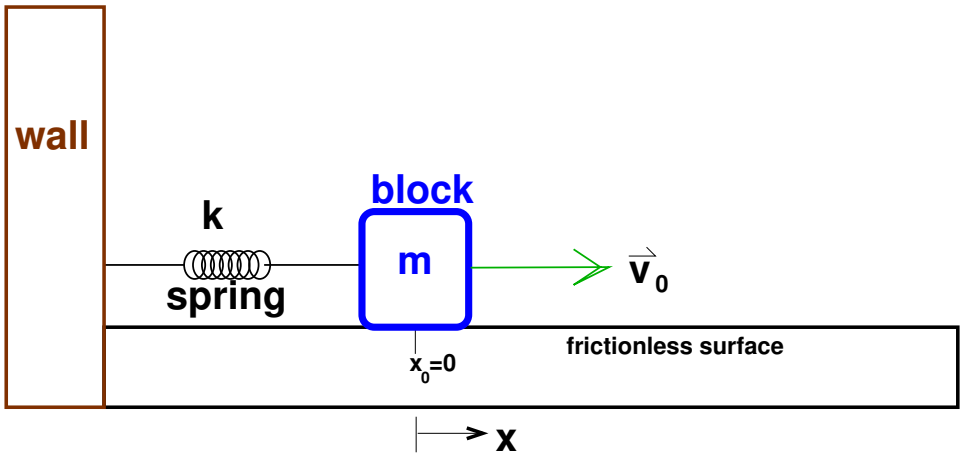
REQUIRED: ***Physics 121 Online Class Notes*** **Cycle 3, Chapter 15++, posted on the Canvas Website, as follows:**

- **Read Carefully *Chapter 15*++: Here we get a first look at the concept of waves.**

Homework continues next page....

Problem 1: Simple Harmonic Motion

Suppose a block of given mass m is attached to a spring of given spring constant k and released on a frictionless surface with an initial horizontal velocity given as v_0 at time $t = 0$. At time $t = 0$ the block is located at the equilibrium position corresponding to $x = 0$ as shown:



We showed in class that the Equation of Motion for a Simple Harmonic Oscillator is this:

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0$$

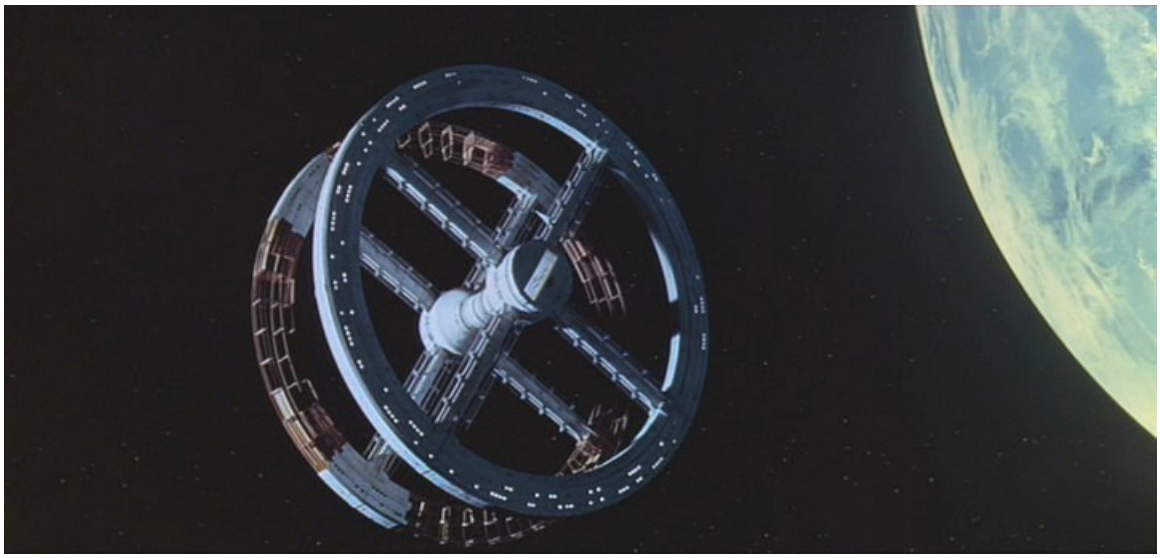
We also showed that the *general solution* for the Equation of Motion of a Simple Harmonic Oscillator is given by this equation:

$$x(t) = B\cos(\omega t) + C\sin(\omega t)$$

Determine the particular values of ω, B, and C that correspond to this particular system. Give your answer in terms of the given parameters: m, k, and v_0. Explain how you know this. Hint: Consider the value of x at time $t = 0$. Now consider the value of $v = \frac{dx}{dt}$ at time $t = 0$.

Problem 2: Space Station.

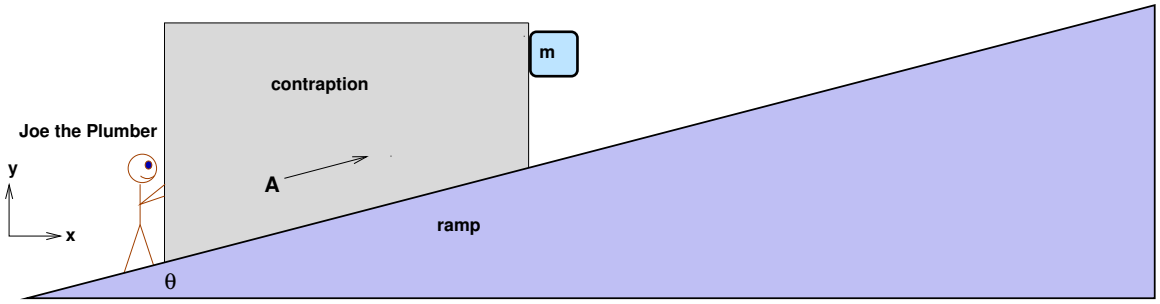
Suppose a space-station is designed in s shape of a torus such as this one depicted in Stanley Kubrick's "2001: A space Odyssey" below:



Suppose the space station has a diameter of 175 meters. At what rotational rate should the station be spun so that occupants standing on the inside surface of the outer wall (maximum distance from the center) experience earth-normal artificial gravity? Give your answer in terms of rotations per minute.

Suppose that inside the space station there is a transport cart for transport around the rim that can reach a maximum speed of 25.0 meters per second. Using such a cart, how could you tell which way the space station from spinning from inside without looking out any windows? Be quite specific about what you experience when you drive around with the cart in one direction or the other.

Problem 3: Joe the Plumber (from prior year's final exam):

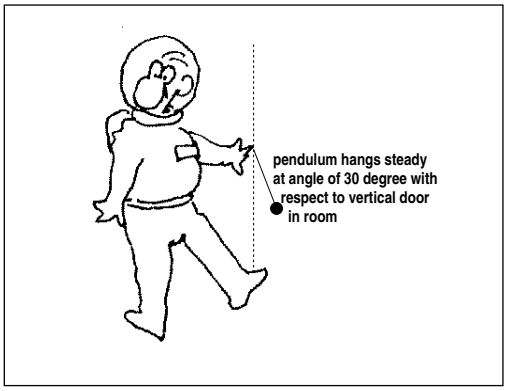


Joe the plumber pushes a contraption up a ramp at a given small angle θ as shown at a given constant acceleration $\vec{A}$. A small box of mass m is in contact with the vertical surface of the contraption as shown.

a) Assume that there is *static friction* between the small box and the contraption. The coefficient of static friction between the box and the contraption is μ. Calculate the direction and the magnitude of *all forces* on the small box in terms of the given parameters. Explain your work.

b) Suppose the small box contains a mini-aquarium with water and fish. Assuming that the system is in equilibrium, with what angle will the surface of the water inside the aquarium make with respect to the horizontal? Explain how you know this.

Problem 4:



After a disorienting and ill-advised episode involving mind-altering substances, Ringo inexplicably finds himself in a locked room with no windows. The room appears normal in every respect except that the whole room appears to be tilted at an angle of 30 degrees relative to level. Ringo determines this tilt by holding up a small pendulum relative to the door-frame that is aligned with the room and measuring with his protractor that the pendulum hangs steady at 30 degrees relative to the door frame. There is a loud vibrating fan in the room that makes it impossible for Ringo to get any noise or vibration from outside the room. Ringo concludes that *either* he is in in a tilted room, *or else* he is in a room that is moving in a special way to give the illusion that the room is tilting.

Part (a): Ringo is trying to guess what is going on. First, he assumes that the room is not moving at all but is simply tilted. Draw a simple sketch indicating how the room looks from the outside (just draw a box and indicate the tilt angle).

Part (b): Now Ringo is wondering if his observations can be explained as a result of the motion of the room rather than a tilt. Suppose we assume that the room is not really tilted but is actually moving horizontally with constant velocity. Can Ringo's observations be explained under this assumption? Explain your answer.

Part (c): Now assume that the room is not really tilted but is actually accelerating with constant acceleration in the horizontal direction. Can Ringo's observations be explained under this assumption? If so, what is the magnitude of this acceleration? Hint: work this problem in the inertial frame where you can use Newton's second law. Consider the forces and acceleration on Ringo's pendulum. Draw a sketch that shows the room and the pendulum as it would appear to an outside observer.

Part (d): Suppose in fact that Ringo is not on the surface of the Earth but has been kidnapped by space aliens so that the whole room is really on an accelerating space ship in deep space. Draw a sketch to indicate the direction that space ship is accelerating relative to the room. What the is magnitude of the acceleration?

Part (e): Is there any physics experiment or any other test that Ringo can do to verify that he is in an accelerating spaceship in deep space vs. sitting in a room on Earth? If not, why not?

Homework Problem 5.

This problem is entirely optional!

A bear travels 100 miles due south (precisely). Then he travels 100 miles due east. Then he travels 100 miles due north, to arrive at the exact same location from where he started. ***What color is the bear?***

(This problem is demonstrates the effects of "curved space" on geometric objects, such as triangles). Based on this example, describe how – in principle – a space traveler might be able to measure the ***curvature of space due to gravity*** by traveling and very carefully measuring distances and angles. Here, imagine that somehow the practical constraints on traveling and communicating over great cosmological distances could be easily overcome.