

## Solutions to Assignment 2; PHYS 185

1. (20 points) You're in a spaceship traveling to a nearby star, in deep space far from large gravitational influences.

- (a) Is there any way you can tell the difference between moving at an extremely high constant speed toward your destination, and idling at rest going nowhere, *without receiving information from outside the spaceship*? Explain why.

**Answer:** There is no way. Since force is proportional to acceleration, all forces inside the spaceship will look exactly the same if the acceleration is the same. And in both cases  $\vec{a} = 0$  since  $\vec{v}$  is not changing.

- (b) Say you're close to your destination, and slowing down at a constant acceleration. You need to slow down from  $1.00 \times 10^7$  m/s (about 3% of light speed) to 0 in 10.0 days. Your mass is 60.0 kg. As you stand on a surface perpendicular to the direction of your acceleration vector, what is magnitude of the normal force you will feel? Compare this to the normal force you would feel standing on the ground back on Earth. Is it safe?

**Answer:** The acceleration involved is

$$a = \frac{\Delta v}{\Delta t} = \frac{10^7 \text{ m/s}}{60 \times 60 \times 24 \times 10 \text{ s}} = 11.6 \text{ m/s}^2$$

This will be provided by the normal force, since there will be no other forces involved. Therefore  $n = ma = 696$  N, compared to  $n = mg = 588$  N on Earth. This is 18% higher; uncomfortable but bearable for ten days.

2. (40 points) Say you're down in the introductory physics lab, and you have all the equipment you have used so far available to you: low-friction track, motion detector, masses and mass hangers, string, rulers, tape, scissors, card stock, boxes, photogates, electronic scales, stopwatches, small pulley wheels, etc. etc.

Now say I also give you a wooden block about the same size and shape as a typical textbook. The block also has a couple of hooks on it in case you want to attach anything. And now I tell you that your job is to measure  $\mu_s$ , the coefficient of static friction between the block and the stone surface of the lab table.

Design an experiment that will allow you to obtain  $\mu_s$ . Be sure to include:

- A clear description of your setup and procedure.
- A list of the equipment you need.

- A clearly labeled diagram of your setup, with arrows indicating the relevant forces.
- If you are going to obtain  $\mu_s$  by using an equation, a derivation of the equation and a clear indication of how you measure the various quantities that go into it. (Standard values such as  $g$ , you can just look up.)
- If you're going to use a graph rather than an equation, a drawing of an example graph, and a description of how you would use that graph to obtain  $\mu_s$ .

*Hint:* Keep it simple! There are lots of ways you can measure  $\mu_s$ , but some of the best ways are also reasonably simple. So don't trip yourself up trying to be overly elaborate.

**Answer:** There are many ways to do this. The most straightforward is probably to tie a string to the block and let it go over a pulley, with masses attached to the end. You add hanging masses until you reach  $m_h$ , when the book just starts sliding across the table. In that case, the balance of forces means  $m_h g = \mu_s n = \mu_s m_b g$ , where  $m_b$  is the mass of the block. Your equation would then be  $\mu_s = m_h / m_b$ .

In that case,  $m_b$  would be obtained by the electronic scale, and  $m_h$  by adding up the hanging masses.

**3. (40 points)** In Lab 3, "Acceleration due to Gravity," you made a number of simplifying assumptions. In the list below, describe how neglecting each effect made you slightly underestimate or overestimate  $g$  as calculated from your data. (I include the answer for the first as an example.) Also draw and label arrows for *every* force you know of on the diagram, including those that you neglected as being too small to worry about, and including forces on the string and pulley.

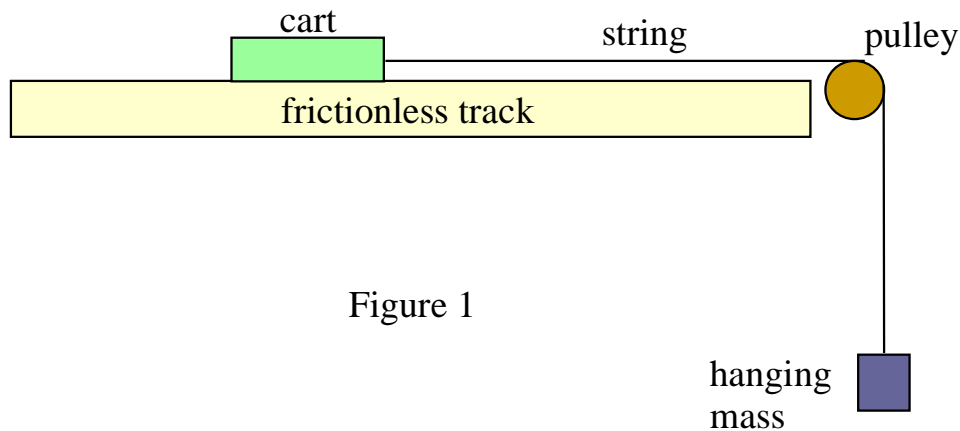


Figure 1

- (a) **Track not frictionless:** A small extra kinetic friction force on the cart toward the left slows the cart down, increasing the measured  $\Delta t$ . The equation for  $g$  was

$$g = \frac{2(m_{\text{hanging}} + m_{\text{cart}})\Delta x}{m_{\text{hanging}}(\Delta t)^2}$$

With increased  $\Delta t$ , friction will cause us to underestimate  $g$ .

- (b) **Drag on the cart:** Though not constant, drag, like friction, opposes the motion. Its effect will be same, leading to an underestimate of  $g$ .
- (c) **Track not exactly level; cart goes slightly downhill:** A downhill tilt will add a component of the weight in the forward direction, making the cart go faster and reducing the measured  $\Delta t$ . So the effect is the opposite of friction: it will lead to an overestimate of  $g$ .
- (d) **Drag on hanging mass:** This drag will be in the same direction as the tension in the string, therefore reducing the tension opposing the weight of the hanging mass. The same tension pulls the cart, which will now be smaller. This increases  $\Delta t$  and leads to an underestimate of  $g$ .
- (e) **Initial speed of cart into first photogate not quite zero:** Being faster will reduce  $\Delta t$  and lead to an overestimate of  $g$ .
- (f) **Pulley not frictionless:** Friction in the pulley will also increase  $\Delta t$  and lead to an underestimate of  $g$ .
- (g) **Pulley not massless:** This means that a force is needed to accelerate the rotation of the pulley. Imagine what would happen if the pulley mass was really large: everything would slow down to a crawl. Therefore, a massive pulley increases  $\Delta t$  and leads to an underestimate of  $g$ .