Physics 131 Some extra problems for those that want them! You're welcome! Dr. AP

Kinematics (Gr. *kinesis* motion) is the description of motion; dynamics (Gr. *dynamikos* powerful) is an attempt to understand the *cause* of motion – i.e., forces!

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1. Gravity is a "downward" force in our daily lives. For most biologists (with the exception of xenobiologists!), it is not worth noting that the full form of Newton's gravity is $\propto mM/R^2$; that is, the force of attraction is proportional to the two masses considered and inversely proportional to the square of the distance between them (it's crucial to understanding gravity between planets and moons and such on the large scale). Life on Earth is pretty much confined to the surface and the atmosphere, a thin layer like a shell that's pretty much the same distance from the center of the Earth whether at the bottom of the Mariana Trench 6 km down from mean sea level in the Pacific Ocean or the thinner regions of the stratosphere 20 km up from mean sea level. The radius of the Earth is about 6400 km for comparison! So we can get away with treating the M/R^2 as constant (specifically, since $F = GmM/R^2$, we can lump the stuff that's essentially constant into one constant "g": $F = mg$; $g = GM/R^2$. For all objects in your daily life from planes in the sky to submarines in the ocean, from a grapefruit to an apple, gravity on that object is just proportional to the mass of that object with proportionality constant "g".
    a. What is the ratio of the force of gravity from the Earth on an apple vs. a grapefruit?
    b. If we were holding an apple in the left hand and a grapefruit in the right and let go of them at the same time, why do they accelerate the same if the force of gravity is different for both?
    c. If I drop a feather, it tends to accelerate briefly but then fall at a constant speed. As it's falling, why will the magnitude of the force of air friction on the feather never be more than the magnitude of the force of gravity? Why does the feather keep falling if the two forces are equal in magnitude?

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2. Aristotelian physics says that an object's natural state of motion is at rest. Why did it take so long for people (Galileo, Newton and so forth) to figure out this is wrong? Start with speculation on why Aristotle's ideas are backed up by evidence.

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3. A pedestrian example, all puns intended…
   You walk to class every day (well, some of you), so how do you get there?
    a. Approximate your pace as a "constant" speed of 2 m/s. In that case, what is the average horizontal force on you and from what source/sources?
    b. You don't actually move at a constant speed of course. Describe your motion in more detail and draw a free body diagram (FBD) for the "start" of one step and another free body diagram for the "end" of that step; identify all the forces on you in each case (treat your body as a simple "point mass"). Be sure to indicate on your FBD which way is forward.
    c. On an icy day, you "skate" on both your shoes (i.e., neither one leaves the ground) on the way to class. Draw the same two diagrams that you drew in part c. but now for the "beginning" and the "end" of a single skating step. Even though you should still treat your entire body as a point mass, identify the forces on you from the ground by which shoe is receiving that force: the "back" foot or the "front" foot. Comment on why ice skaters align their skates one way to push to speed up, but another way to glide.
    d. Comment on "static" friction: does it always oppose motion?

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4. You push a cart of mass 45 kg (100 lb) with wheels across a horizontal floor with no sliding friction (and ignore the sliding friction in the wheels' bearings/axle, etc.) starting from rest and get it up to a speed of 2 m/s in 5 seconds.
    a. What's the average acceleration of the cart?
    b. Assuming that the average acceleration is also the *actual* acceleration in that time period, what is the position of the cart after those 5 seconds?
    c. How hard was your average push against the cart in that time period?
    d. If you stopped pushing right at that 5 second mark, what does the cart do?

e. Starting at that 5 seconds, how hard would you have to pull (on average) to get the cart to stop in 1 second?
f. Does your answer to part e. change if you waited to start pulling until the 6^{th} second?
g. Based on the setup given and e., graph the cart's acceleration, velocity and position, the force of you pushing on the cart and the force of the cart pushing on you in a "stack" of five graphs such that the tick marks on the time axes match up vertically. Time should run from t = 0 when you started pushing the cart from rest until t = 6 when the cart came to rest.
