**University of Maryland**
**Department of Physics**

**Physics 121**
**Fall 2007**

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## Exam 1 (Make up) Solution

**1. (35 points)** *In the picture at the right (taken from a video), a juggler is shown in the process of juggling three tennis balls.*


*At the instant shown,*

- *The ball at the right (labeled "A") is traveling upwards; he released it a few frames ealier.*
- *The middle ball (labeled "B") is traveling downwards; he is about to catch it.*

*Both balls are traveling approximately vertically only; they have negligible horizontal motion.*

*For the vector quantities specified in parts (a)-(e) below, specify whether they point up (↑), down (↓), left (←), right (→), or are zero (0) by inserting the appropriate symbol in the space provided.*

*For this problem, assume that air resistance can be ignored.*

*Parts (a)-(c) refer to the instant of time shown.*

__↓___ *(a) The net force on ball A.*
__↓___ *(b) The net force on ball B.*
__↓___ *(c) The acceleration of ball A.*
__↓___ *(d) The acceleration of ball B.*

*Parts (e)-(g) refer to the instant of time when ball A is at the TOP (the highest point) of its trajectory.*

__↓___ *(e) The acceleration of ball A.*
__↓___ *(f) The net force acting on ball A.*
__**0**___ *(g) The velocity of ball A.*

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The answers are written in the blanks. Here's how we get them. If we do a free body-diagram for a ball in the air and ignore air resistance, the only force acting on it is its weight, *mg*. This points down. Since the acceleration is determined by the net force through $a = F^{net}/m$, and since the net force equals the weight, the net force on the ball and its acceleration is always down until it is touched again. At the top, since the velocity is changing from positive to negative, it must be 0.

(Grading: Each item is worth 5 pts. There is no partial credit for any other answers, but two points are deducted for inconsistency between net force and acceleration. That is, if the force or acceleration at a given instant is given correctly but the other of the pair is not, those answers are worth 3 pts, not 5.)

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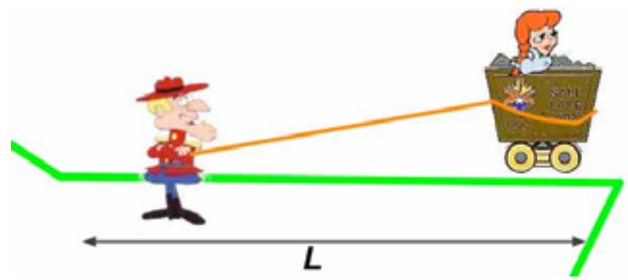
**2. (15 points)** *Little Nell is in trouble. Boris Badenov has tied her up and put her in an ore cart at an abandoned mine. The cart was is on a track at the top of a hill. The track runs down the hill, onto a flat stretch, and then over a cliff. Boris pushes the cart down the hill, but Dudley Doright is there and lassos the cart just as it comes off the hill. By digging in his heels and being dragged along the ground, he is able to exert a constant force of 1000 N on the cart and bring it to a stop in 5 s – just before it is about to go over the cliff! The cart (including Nell) has a mass of 250 kg.*




*(a) How fast was the cart going at the start of the long flat stretch? (Although the mine is long abandoned, Boris has been keeping the wheels of the cart oiled for just such an opportunity and friction can be ignored.) (8 pts)*

*(b) How long was the long flat stretch? (7 pts)*

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A major part of what is being tested here is whether you can extract a simple physics problem from a mass of verbiage. Reading it carefully, it basically says: A mass of 250 kg going with a velocity (call it $v$) is pulled back by a constant force of 1000 N for 5 s until it stops after traveling a distance (call it $L$). Find $v$ and $L$. To simplify our calculation, we'll assume the force is exerted directly opposite to the velocity so as to me most effective in slowing the cart. (Dudley may be a twit, but he's not a total doofus.)

(a) To find *v*, we'll use two equations: Newton's second law and the definition of acceleration.

$$a = \frac{F^{net}}{m} \qquad \langle a \rangle = \frac{\Delta v}{\Delta t}$$

The first tells us at what rate the cart slows. Putting in numbers we get

$$a = \frac{F^{net}}{m} = \frac{1000 \text{ N}}{250 \text{ kg}} = 4\,\frac{\text{m}}{\text{s}^2}.$$

Putting this into the definition for acceleration gives us the change in velocity. Since we know the final velocity is 0, the change is equal to the initial velocity.

$$\langle a \rangle = a = 4\,\frac{\text{m}}{\text{s}^2} = \frac{\Delta v}{\Delta t} = \frac{v-0}{5 \text{ s}}$$

$$4\,\frac{\text{m}}{\text{s}^2} = \frac{v}{5 \text{ s}} \qquad .$$

$$v = 20\,\frac{\text{m}}{\text{s}^2}\text{s} = 20\,\frac{\text{m}}{\text{s}}$$

(b) To find *L*, we can use the equation for the definition of velocity:

$$\langle v \rangle = \frac{\Delta x}{\Delta t}$$

Knowing that the average velocity is $(v_i+v_f)/2$ when the rate of change is uniform (acceleration is constant), plugging in to this gives

$$\langle v \rangle = \frac{v_i + v_f}{2} = \frac{v_i}{2} = \frac{\Delta x}{\Delta t} = \frac{L-0}{5 \text{ s}}$$

$$\frac{v_i}{2} = 10\,\frac{\text{m}}{\text{s}} = \frac{L}{5 \text{ s}}$$

$$L = 50\,\frac{\text{m}}{\text{s}}\text{s} = 50 \text{ m}$$

(Grading: (a) 2 for each of the two main equations, 2 for calculating the acceleration, 2 for calculating the velocity. (b) 2 for the velocity equation, 2 for knowing how to deal with the average velocity, 1 for knowing how to deal with position difference, and 2 for calculating the distance.)

**3. *(15 points)*** *Estimate how fast your hair grows in km/hr. Express your answer in scientific (powers of 10) notation. Be sure to clearly state your assumptions and how you came to the numbers you estimated, since grading on this problem will be mostly based on your reasoning, not on your answer.*

I get my hair cut about every 6 months, whether I need it or not. To get it back to what it was at the last haircut, I tell the barber to take off about 3 inches. So my hair grows at about ½ inch per month. To get this into km/hr I have to convert. I know 1 inch = 2.54 cm, so ½ inch is about 1 cm. (Really 1.27, but 1 is close enough for this kind of estimation.) Here's my conversion:

$$1\frac{\text{cm}}{\text{month}} = \left(1\frac{\text{cm}}{\text{month}}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)\left(\frac{1 \text{ km}}{10^3 \text{ m}}\right)\left(\frac{1 \text{ month}}{30 \text{ days}}\right)\left(\frac{1 \text{ day}}{24 \text{ hrs}}\right)$$

$$= \left(1\frac{\text{cm}}{\text{month}}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)\left(\frac{1 \text{ km}}{10^3 \text{ m}}\right)\left(\frac{3 \text{ month}}{10^2 \text{ days}}\right)\left(\frac{4 \text{ day}}{10^2 \text{ hrs}}\right)$$

$$= 12 \times 10^{-9} \text{ km/hr}$$

or about $10^{-8}$ km/hr.

(Grading: 4 points for the estimation, with enough words to make it plausible. Only 2 if just numbers are given. 1 pt for knowing correct conversion to cm – or for being able to find it on your calculator. 5 points for the correct calculation. -2 if powers of 10 notation not used in answer.)

**4. (10 points)** *In this class, we have identified a few critical equations and have commented that equations can be used to "organize your conceptual knowledge." Do you agree with this? Select one "critical equation." State it as an equation in symbols, describe briefly what it says in words, and discuss what conceptual knowledge is needed to interpret it and how it can be used to draw qualitative conclusions. Note: This is an essay question. Your answer will be judged not solely on its correctness, but for its depth, coherence, and clarity.*

There are a half dozen rather important equations with conceptual content in this class. I'll discuss one so as to show the structure of the kind of answer that is being sought.

The focal equation in this class so far is Newton's second law, $\vec{a} = \vec{F}^{net} / m$. This says that an object changes it's velocity according to how much unbalanced force is acting upon it divided by the object's mass. This requires a lot of conceptual knowledge to interpret, such as "What is meant by acceleration?" One needs to understand that acceleration is the rate of change of velocity. One needs to understand what a "net force" is; that it is the vector sum of all the forces acting on the object we are considering at the time we are considering it. (There is a lot of other conceptual knowledge that could be mentioned, such as: what a force is, what the vectors mean, etc.) One example of how it can be used in qualitative reasoning was when we were considering the fact that objects of different mass fall with the same acceleration. The equation tells us that if the acceleration is the same for two objects of different masses, then the net forces they feel must be different (and in proportion to their mass – so that the bigger mass feels a bigger force). If you said your equation could be used to calculate something given something else you did not receive credit for a qualitative conclusion.

(Grading: 2 for a correct equation, 2 for a correct description of what it says in words. 2 each for at least two conceptual knowledge elements needed to interpret it, 2 for a qualitative conclusion that can be drawn.)

**5. (25 points**) *Rebecca has put her puppy, Molly, on a skateboard, and has attached a rope to the skateboard in order to give Molly a ride. At time $t = 0$, Rebecca starts pulling on the rope. She is pulling upward at an angle of $37^o$. Once she is up to speed (at time $t_1$), she runs along at a constant rate until a time $t_2$. A little after that, her mother yells at her and she stops.*

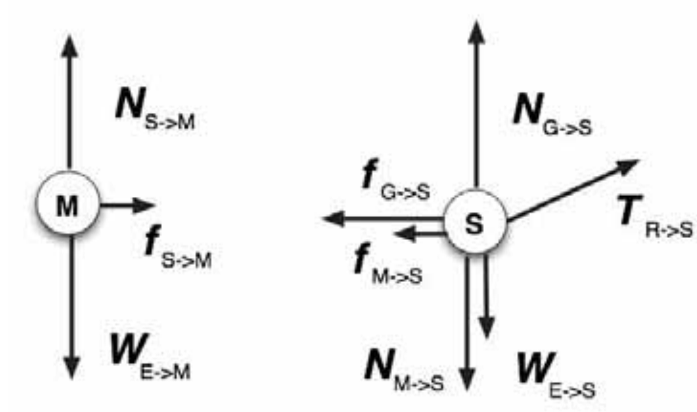
*(a) While Rebecca is pulling, draw free-body diagrams for Molly and the skateboard. Label the forces so as to identify the kind of force (N, T, f, W) and the actors (the one feeling the force and the one causing it). (10 pts)*

*(b) In the spaces provided below, sketch appropriate graphs representing Molly's position, velocity, acceleration, and the friction force Molly is experiencing. (5 pts. each)*

(a) Molly feels her weight (the earth pulling on her), the normal force of the skateboard holding her up and keeping her from falling to the floor, and the friction of the accelerating skateboard trying to keep her from sliding back on the skateboard. The friction force is in the forward direction and is what is accelerating Molly. (If you considered the forces at a time when Molly and the skateboard were moving at a constant velocity there would be no friction force.)

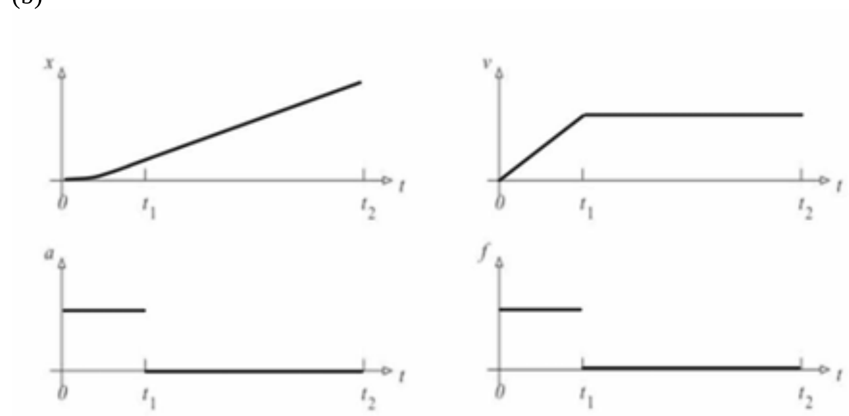
The skateboard feels its weight (the earth pulling down), the Newton's third law pair of the forces Molly feels from the skateboard (Normal and Friction), a normal force from the ground holding it up, and a tension force from the rope.

The forces are shown in the diagrams below.




(Grading: One point for each force. 1 points for no extra forces. If there is no friction force on Molly, the horizontal component of the tension must approximately match the force of friction from the ground and your *f* graph below must have some region where *f* is zero.)

(b)




(Grading: x – curved till $t_1$ [2], straight line after [2], no kink at join [1];
v – straight increase until $t_1$ [2], constant after [2], positive [1]'
a – constant positive until $t_1$ [3], zero after [3];
f – like a but -1 for not same as a.)