Physics 2048 Test 2 Solutions Fall 2002
Dr. Saul

Problem 1 (Short Answer: 13 points) no explanation required, but no partial credit either.

A worker is pushing a cart along the floor. At first, the worker has to push hard in order to get the cart moving. After a while, the cart is easier to push as it moves with constant speed. Finally, the worker has to pull back on the cart in order to bring it to a stop before it hits the wall. The force exerted by the worker on the cart is purely horizontal. Take the direction the worker is going as positive.

Below are shown graphs of some of the physical variables of the problem from the time the cart started moving to when the cart came to a stop. Match the graphs with the variables in the list below. You may use a graph more than once or not at all.
(Note: the time axes are to the same scale, but the ordinates {"y axes"} are not.)

(a) friction force
(b) force exerted by the worker
(c) net force
(d) acceleration
(e) velocity.

Key points to keep in mind:

- *All the graphs shown represent either a force or motion quantity. Only 1 graph is the correct one for each quantity*
- *Since we start considering the motion after the cart has started moving, friction is negative and constant*
- *The cart speeds up in the + direction, goes at constant speed, and then slows down.*

Problem 2 (Estimation Problem: 15 points)

A. Estimate the amount of force needed to bring every car in the greater Orlando area from rest to highway speed in 8 seconds assuming the force is constant. Remember to state explicitly all assumptions and estimations used in solving this problem.

There are ~ 1.5 million residents in the Orlando metropolitan area. Let's say that half the residents own cars (A family of four would own 2 cars while a couple would also own two cars. But some people don't own cars at all => 1 car for every two people should be correct within a factor of 2)

The number of cars in Orlando $N = (1.5 \times 10^6$ *people)* $\times$ *1 car/2 people =* 7.5×10^5 *cars*
We assume that each car accelerates from 0-60 MPH in 8 seconds. (We hear advertisements that a sports car can go from 0-60 MPH in 6-8 seconds. Since most cars are slower, assume it takes longer on average for a car to accelerate from rest to highway speeds (60 MPH ~ 100 km/h)

$V_0 = 0$ m/s, $v_f = 100$ km/h x 1000m/km x 1h/3600 s = (100/3.6) m/s
The mass of a typical car is about 2000 lb. or ~1000 kg. If we include minivans and trucks, our average mass increases to 1500 kg or ~ 3000 lb.

Newton's second law => $\vec{a} = \dfrac{\sum \vec{F}_{cars}}{m_{cars}} = \dfrac{\vec{F}^{net}_{cars}}{m_{cars}}$

Solving for f and using the definition of acceleration

$$\left|\vec{F}^{net}_{cars}\right| = m_{cars}\left|\vec{a}\right| = (N * mass\ of\ average\ car) * \left(\frac{v_f - v_i}{\Delta t}\right)$$

$$= (7.5 \times 10^5 cars * 1500 kg / car) * \left(\frac{(100/3.6)\, m/s - 0\, m/s}{8s}\right)$$

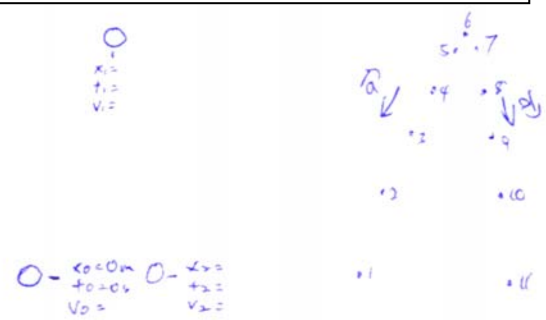
$F^{net} = 4 \times 10^9$ kg x m/s/s $= 4 \times 10^9$ N

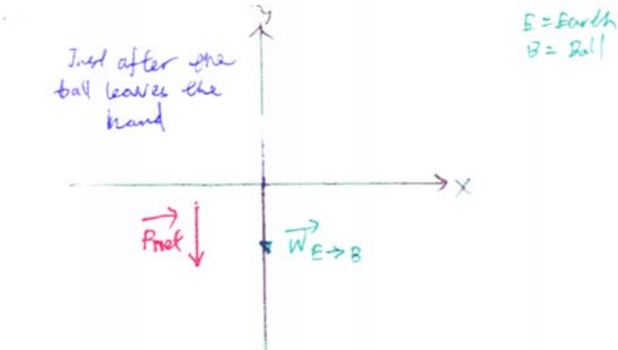
B. Now consider the amount of force needed to bring all those cars moving at highway speed to a sudden stop. Is this force larger, the same size or smaller than the force you calculated in part A. Explain your reasoning.

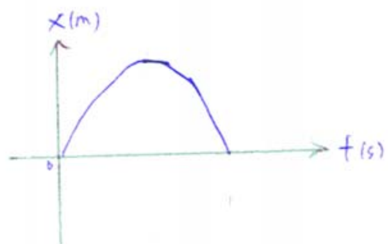
The force to come to a complete stop would be larger because most people decelerate (brake) in less time than they accelerate (gas).
If the amount of time is less when deceleratin then the acceleration will be higher. If the acceleration is higher then so will the force.

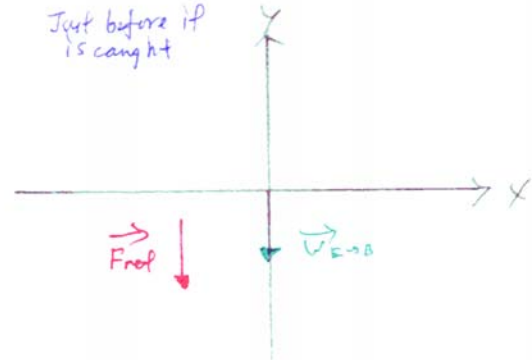
Problem 3 (Essay 10 points)
You may use words, diagrams, and equations but no calculations in your response for this problem.

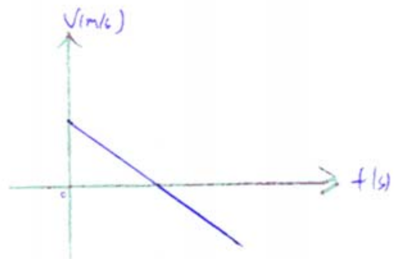
Recall that you were asked to assume that air resistance is negligible on this test.





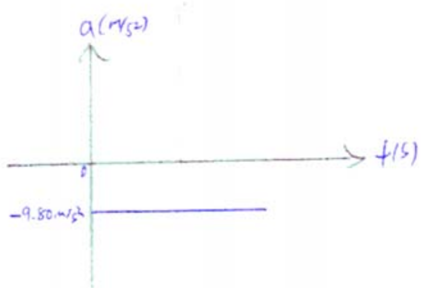




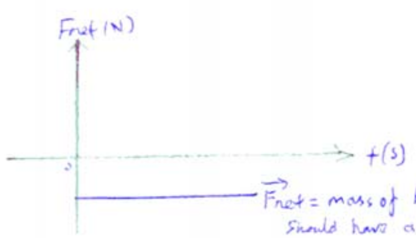


As the ball leave the bat, it move upward but with a decreasing velocity as the gravity of earth is acting on it.

At its highest pt, Velocity = 0 m/s
It starts to fall back to earth increasing its speed($|\vec{v}|$) because the gavity of the earth is now in the same direction as the velocity, pointed downward.



While this is a good answer to the question of what happens to the ball between the time it is hit and when it is caught, it doesn't discuss the ball's motion in terms Newton's Laws of motion. It does have good graphs and free body diagrams.



$\vec{F}_{net}$ = mass of ball × acceleration
Should have a positive magnitude but pointing downward.

Problem 3 (cont.)

To be complete, a solution should mention the following points: According to Newton's 0^{th} law, objects only feel forces that act on the object at the moment in question. Thus once the ball leaves the bat, it forgets about the bat and only feels the gravitational force due to gravity from the earth. After the ball leaves the bat, the ball has an upward velocity. Between the time the ball is hit and when it is caught, by Newton's 1st law, since there is a net force there must be a change in the velocity of the ball. From Newton's 2^{nd} law, the acceleration of the ball equals the net force acting on the ball divided by the mass of the ball. Since the net force is equal the weight force, the magnitude of $a = mg/m = g$ and the direction of a is downward in the direction of the net force. Thus a is downward and equal in magnitude to g for the entire time the ball is in the air between the time it is hit and when it is caught, even at maximum height when the velocity = zero m/s.

Comment: While we can say that a ball has a downward acceleration, an acceleration cannot pull down on a ball. Pulling or pushing requires a force.

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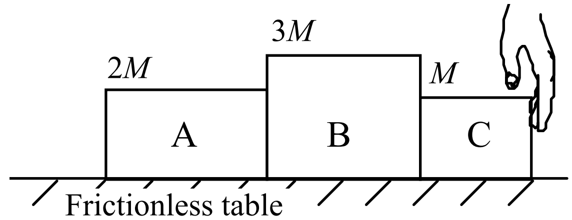
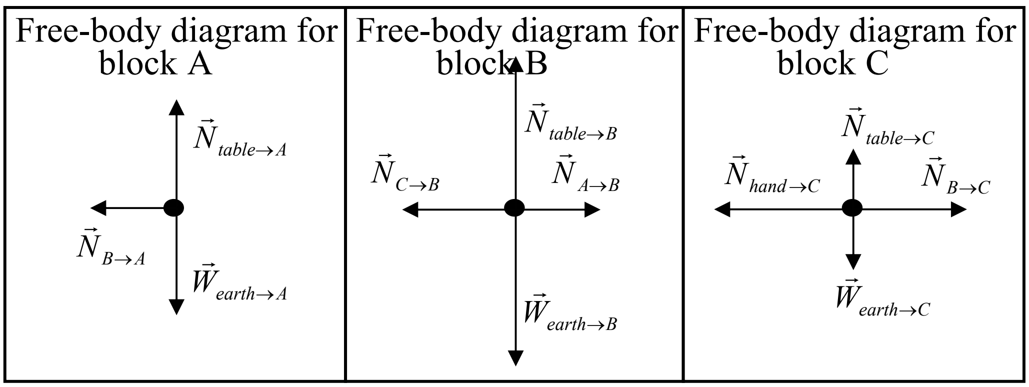
Problem 4

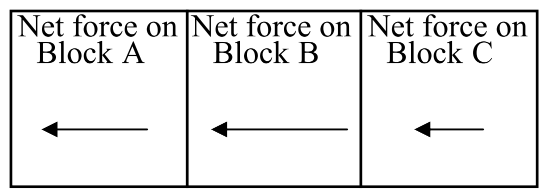


A, B, and C are being pushed across a frictionless table by a hand that exerts a constant horizontal force. Block A has mass $2M$, block B has mass $3M$ and block C has mass M.

A. Draw separate free-body diagrams for each of the three blocks. Label your forces to make clear (1) the object on which the force acts, (2) the object exerting the force, and (3) the type of force (normal, frictional, gravitational, etc.)



B. In the spaces at right, draw a vector that represents the *net force* on each block. Make sure your vectors are drawn with correct relative magnitudes. Explain how you knew to draw the net force vectors as you did.



If we treat the three blocks as a system, the net force = the force of the hand on block C which will cause the system to accelerate. Each block is accelerating to the left at the same rate so by Newton's 2nd law, the net force for each block is inversely proportional to the mass so that the ratio of F^{net}/m is constant for each block.

C. [12pts] Suppose the mass of block B were doubled (the other blocks are left unchanged) and the hand pushes with the ***same force*** as in part A.

i. Has the *magnitude* of the acceleration of block A *increased, decreased,* or *remained the same?* Explain.

Decreased. The three blocks accelerate as one system and since $\vec{a} = \dfrac{\vec{F}^{net}}{m}$*, if you increase the mass of the system and keep the net force on the system the same (i.e. the force of the hand), the acceleration of the system of three blocks must decrease. Since each block accelerates at the same rate as the system, the acceleration of block A has decreased*

ii. Has the *magnitude* of the net force on block A *increased, decreased,* or *remained the same?* Explain.

Decreased. If the acceleration of block A decreases and the mass of A doesn't change, using $\vec{a} = \dfrac{\vec{F}^{net}}{m}$ *then the net force needed to cause that acceleration is less.*

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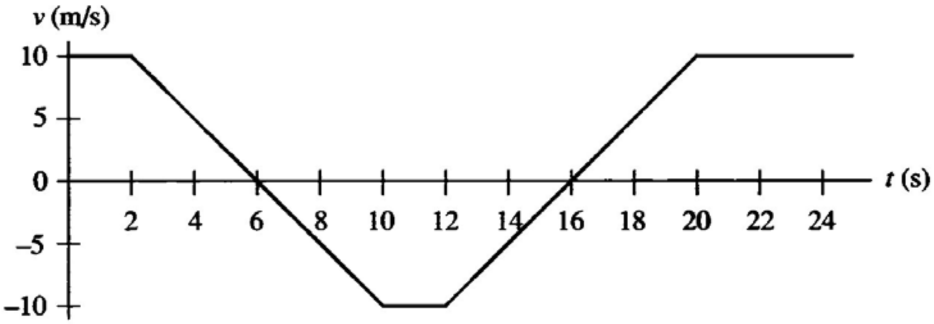
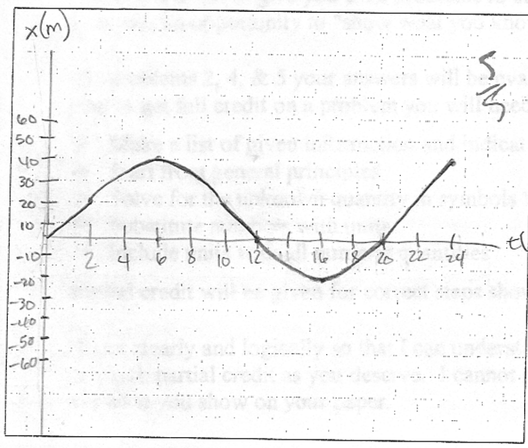
Problem 5 (16 points)

The graph below is velocity verses time graph for a particle having an initial position $x_0 = x\ (t=0) = 0$. Draw the corresponding position and acceleration graphs, complete with numeric scales, below from t = 0 s to t = 20 s.





$\Delta x = \int v(t)\,dt$ ✓

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0-2s = $10(2) = 20m$

2-6s = $\frac{1}{2}(4)(10) = 20m$

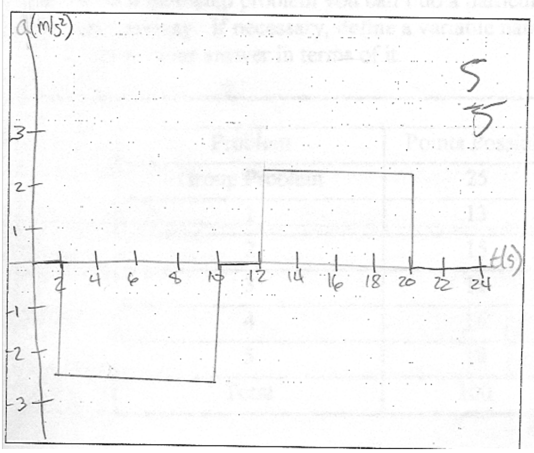
6-10s = $\frac{1}{2}(4)(-10) = -20m$

10-12 = $2(-10) = -20m$

12-16 = $\frac{1}{2}(4)(-10) = -20m$

16-20 = $\frac{1}{2}(4)(10) = 20m$

20-24 = $10(4) = 40m$



5/5

$a = \frac{\Delta v}{\Delta t}$ ✓

$\frac{10-10}{2-0} = 0$

$\frac{-10-10}{10-2} = -2.5\ m/s^2$

$\frac{-10-(-10)}{12-10} = 0$

$\frac{10-(-10)}{20-12} = 2.5\ m/s^2$

$\frac{10-10}{24-20} = 0$

Dr. Saul's comments: This solution is almost perfect. The graphs are accurate and nicely drawn complete with axis labels, numeric values, and units. In addition, the reasoning and calculations needed to create the graphs are clearly shown. Only very minor improvements are needed. For the position graph, the student calculated the area under the curve rather than integrate a function. This should have been indicated. Also, while is useful to label the time interval for each time period, you cannot write equations where time = distance. For the acceleration graph, it would have been good to indicate the time period for which each slope was calculated. And in both cases, all numbers should have been labeled with the appropriate units.