Physics 121, Winter 2006, Exam 1

Name: SOLUTION O.V.

This section of the exam has 10 multiple choice questions, each worth 5 points. Use the Scantron sheet (bubble sheet) to answer them. You may circle your answer and write on these white sheets for reference at a later time. You must turn in the complete exam at the end of class, but exam will be returned to you after grading. The material in these white sheets will not be graded or used for grading.

The first three questions refer to the statement below. Vectors will be indicated by **BOLD** letters, and the x and y components of a vector will be in parenthesis right after the vector symbol. For example, **R**(x,y) is a position vector with components x and y. The x and y axis are perpendicular to each other, with x being the horizontal (left to right) axis.

Two friends depart from the same place at time t = 0. Ten seconds later they find themselves at positions $\mathbf{R}_1(10,4)$ and $\mathbf{R}_2(-3,4)$, with coordinates in meters.

Question 1. The magnitude of the vector $\mathbf{R}_2$ is (fill in bubble sheet) $|\vec{R}_2| = |\sqrt{(-3)^2+4^2} = \sqrt{9+16} = +5$

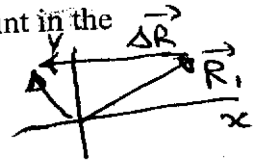
A. -1 m B. +1 m C. $-(7)^{1/2}$ m D. +5 m E. $+(7)^{1/2}$ m

Question 2. The VECTOR $(\mathbf{R}_2 - \mathbf{R}_1) = \Delta\mathbf{R}$ representing the difference between the positions of the two friends is $\vec{\Delta R} = \vec{R}_2 - \vec{R}_1 = (-3-10)\hat{i} + (4-4)\hat{j} = -13\hat{i} + 0\hat{j}$

$\vec{\Delta R}(-13,0)$

A. $\Delta\mathbf{R}(-13,0)$ B. $\Delta\mathbf{R}(-7,0)$ C. $\Delta\mathbf{R}(-7,8)$ D. $\Delta\mathbf{R}(+13,0)$ E. $\Delta\mathbf{R}(+13,8)$

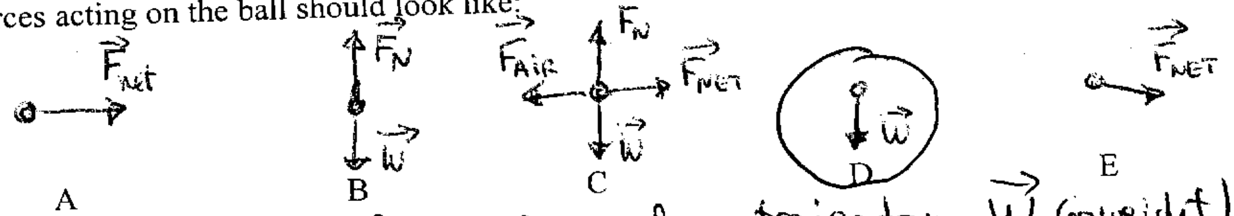
Question 3. The difference vector $\Delta\mathbf{R}$ of the previous question is likely to point in the direction



A. ↓ B. ↑ C. → D. ← E. ↖

The next three questions refer to this statement. Oscar launches a baseball from home plate (the origin) with an initial velocity of magnitude 20 m/s making an angle of 45 degrees with the playing field. Assume no air friction.

Question 4. At the highest point of the trajectory of the ball the free body diagram for the forces acting on the ball should look like:



There is only one force along trajectory, $\vec{W}$ (or weight)

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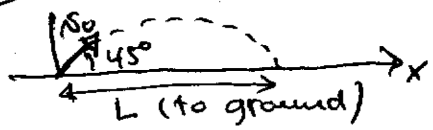
Question 5. Laura is expecting to catch the ball. When the ball is launched (20 m/s, 45° with field) she is standing 50 meters away from home plate. To catch the ball before it touches the ground Laura must:

Calculation had to be done here.



A. Stay where she is
B. Run left
C. Run forward
D. Run backwards
E. Run right

$L = v_0 \cos 45° \, t$ ← x motion.

y-motion: $0 = 0 + v_0 \sin 45° \, t - \frac{1}{2} g t^2 \Rightarrow t = \frac{2 v_0 \sin 45°}{g}$

$L = \frac{v_0^2 \, 2 \cos 45° \sin 45°}{g} = \frac{(20\ \text{m/s})^2 \times 2 \times (\cos 45°)^2}{9.8} = 40.9\ \text{m} < 50\ \text{m}.$

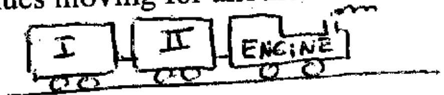
Question 6. While the ball is being caught, from the moment the ball touches the glove until it stops (W is the weight of the ball and $\mathbf{F_{gb}}$ the force exerted by the glove on the ball) The glove has to provide a force larger than the weight of the ball in order to have a net force to slow and stop the ball.

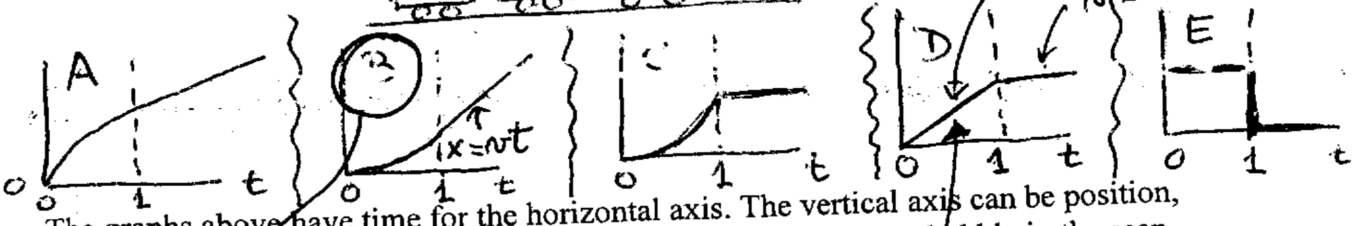
A. $|\mathbf{W}| > |\mathbf{F_{gb}}|$ B. $|\mathbf{W}| = |\mathbf{F_{gb}}|$ C. $|\mathbf{W}| < |\mathbf{F_{gb}}|$ D. $\mathbf{F_{gb}} = \mathbf{ma}$ E. $\mathbf{W} = \mathbf{ma}$

The next four questions refer to this statement and picture: A train engine of mass 20,000 kg is pulling on two cars, I and II. Each car has a mass of 10,000 kg. Assume essentially frictionless motion for the cars (the engine needs friction to have traction, but it is not used in this problem). Imagine that starting from rest at a station, the train moves away along a straight track. It reaches a speed of 2 m/s in one minute while moving at constant acceleration, then continues moving for another minute at the same speed.

$v = 0 + at$ for uniform accelerated motion.

v = constant.





The graphs above have time for the horizontal axis. The vertical axis can be position, velocity or acceleration. For questions 7 and 8 fill the appropriate bubble in the scan sheet.

$x = \frac{1}{2} a t^2$ for uniform accelerated motion

B Question 7. Which graph best represents the position of the train as a function of time?

D Question 8. Which graph best represents the velocity of the train as a function of time?

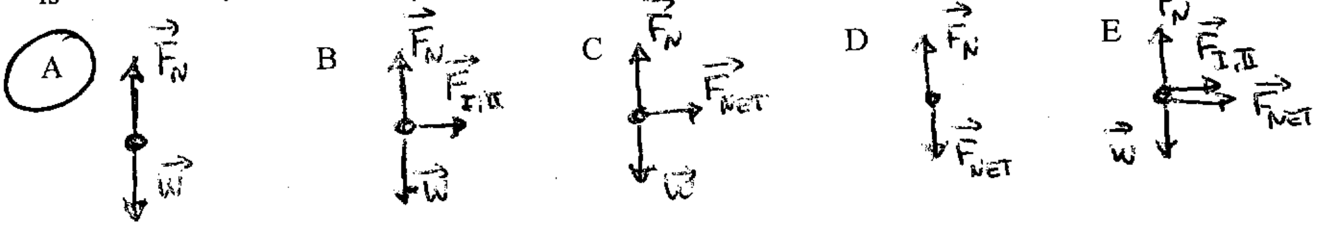
Question 9. During the first minute of motion, the net force on car II is: $F_{NET} = ma$

A. 666 N B. 20,000 N C. 40,000 N D. 333 N E. 1,330 N

$ma = 10^4\ \text{kg} \times \frac{2\ \text{m/s} - 0}{60\ \text{s}} = 333\ \text{N}$

Question 10. During the second minute of travel, the free body diagram of forces on car I is

There is no force needed to keep car moving with constant velocity.



Solution O.V

Phys 121, First Exam, Winter 2006
Problem I

During crash testing, a car traveling at 30 mph collides with an "immovable" concrete wall. An air bag deploys instantly at contact. A 90 kg dummy is 2 m behind the front bumper (initial point of contact) not wearing a seatbelt. By the end of the crash the dummy is at rest 0.50 m in front of the wall. Assume no vertical motion of the dummy during the crash.

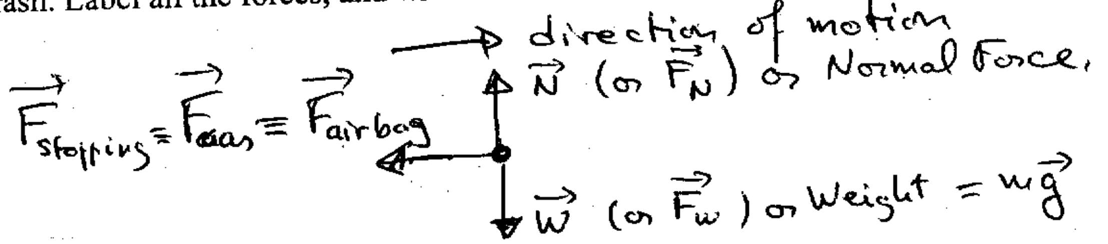
In this problem please show all your work. Write on back of this sheet if additional space is needed. 1 mile = 1,600 m

A (3 points). Convert 30 mph to m/s.

$$30 \text{ mph} \times \frac{1600\text{m}}{\text{mile}} \frac{1}{3600\frac{s}{h}} = 13.3 \text{ m/s} \text{ or } 13\tfrac{1}{3} \text{ m/s}$$

actually $\frac{\text{miles}}{\text{hour}}$

B (5 points). Draw a free body diagram of all the forces acting on the dummy during the crash. Label all the forces, and write two or three words explaining what force it is.

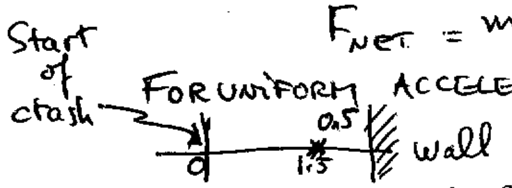


C (8 points). Calculate the magnitude and direction of the average acceleration of the dummy during the crash (positive direction is the direction of the initial velocity).

direction of initial velocity.

$$\vec{F}_{NET} = m\vec{a}$$

For uniform accelerated motion, $a = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{0 - (13.3\text{ m/s})^2}{2(1.5\text{m} - 0\text{m})}$



$$a \cong -59 \text{ m/s}^2$$

D (9 points) In general, a force exerted by the bag on the dummy larger than 10 times its weight is fatal to anyone (including the dummy). Calculate the maximum velocity that the car could have had given the same stopping conditions outlined above. An actual quantitative answer is not essential for full credit. Write your procedure clearly though!

$$10 \times mg = F_{net\,max} = m a_{max} \Rightarrow a_{max} = 10g. \quad \text{For } v_f^2 = 0$$

Since there is only one force, $F_{air\,bag}$ on person.

$$\frac{-v_{i\,max}^2}{2 \times 1.5\text{m}} = -9.8\frac{\text{m}}{\text{s}^2} \times 10 = -98 \text{ m/s}^2$$

$$v_{initial\,max} = \sqrt{2 \times 1.5\text{m} \times 98 \text{ m/s}^2} = 17.1 \text{ m/s} \cong 39 \text{ mph}.$$

Conversion to mph not necessary

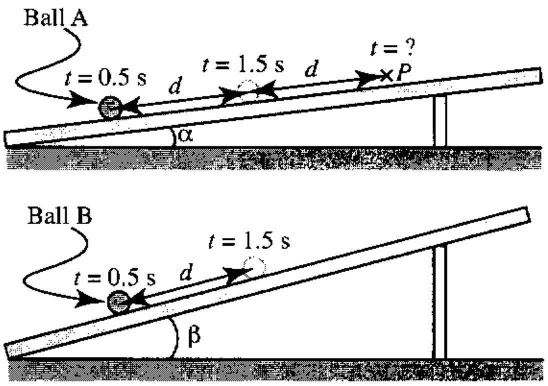
Name ______________________________ **Student ID** ____________ **Score** ________

last   **first**

II. [25 points total]

$\beta > \alpha$

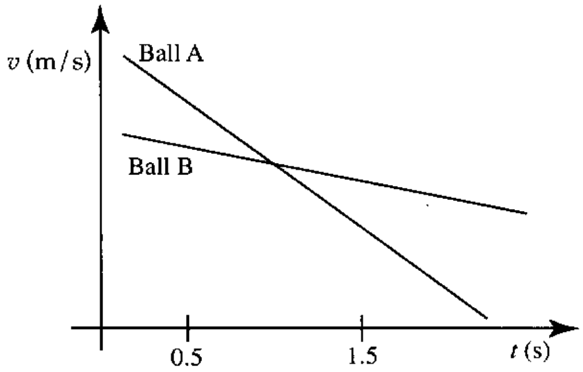
A. Two balls, A and B, roll up ramps inclined at angles α and β respectively ([redacted]). Each ball travels a distance d up the ramp between $t = 0.5$ s and $t = 1.5$ s.



i. [7 pts] At time $t = 0.5$ s, is the speed of Ball A *greater than*, ***<u>less than</u>***, or *equal to* the speed of ball B? Explain.

The acceleration of Ball B will have a greater magnitude than that of Ball A, since its ramp is inclined at a steeper angle. This means that in 1 second, its velocity will decrease by a greater amount. Since both balls travel the same distance in the same amount of time, they must have the same average speed over the interval from 0.5 s to 1.5 s. If both balls had the same speed at t = 0.5 s, Ball B would have a slower average speed over the next 1 s time interval, and would not go as far as Ball A. Similarly, if it had a smaller speed than Ball A at 0.5 s, it would not go as far in the next second. If, however, it starts with a greater speed than Ball A, it can still have the same average speed as Ball A over the 1 s interval.

ii. [6 pts] On the axes shown at right, sketch a qualitatively correct graph of v versus t for each ball. Label your plots "Ball A" and "Ball B" as appropriate. Explain why you drew the graph as you did.

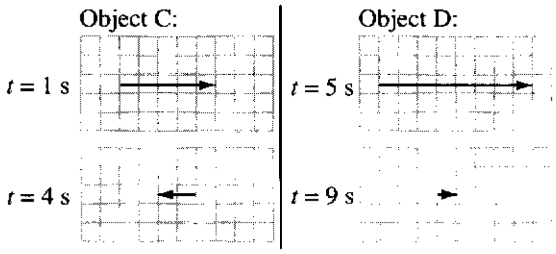


Since both blocks are on straight ramps, they must both have constant acceleration, so their velocity-time graphs must be straight lines with constant slope. In order for both balls to have the same average speed over the interval from 0.5 to 1.5 s, Ball B must start out with a greater speed than Ball A, and end with a slower speed.

iii. [6 pts] Will Ball A pass point P (located a distance d up the ramp from the location of Ball A at $t = 1.5$ s) *before* time $t = 2.5$ s, ***<u>after</u>*** time $t = 2.5$ s, or *at* time $t = 2.5$ s? Assume that Ball A is still traveling up the ramp at point P. Explain.

Ball A will pass point P after t = 2.5 s. Since the ball is constantly slowing down as it moves up the ramp, it will travel less far between t = 1.5 s and 2.5 s than it did between t = 0.5 s and 1.5 s. This means that at t = 2.5 s, it will not yet have reached point P.

B. [6 pts] Shown at right are velocity vectors for object C at two times, and for object D at two later times. Is the magnitude of the average acceleration of object C ***<u>greater than</u>***, *less than*, or *equal* that of object D? Explain.



Both objects have the same change in velocity, 7 units. Since object C undergoes this change in velocity in 3 seconds, while it takes 4 seconds for object D to undergo the same change in velocity, the magnitude of the average acceleration of Object C must be greater than that of object D.