

**Midterm # 1: Physics 131**  
(Winter 2005, 9:30 Section)

Name: \_\_\_\_\_ **SOLUTIONS** \_\_\_\_\_

Recitation Instructor: \_\_\_\_\_

**The duration of the midterm is 48 min.**

**There are four problems to the midterm.**

**Put your name on all sheets of paper.**

**Use the back of the sheets for extra space (label your work clearly).**

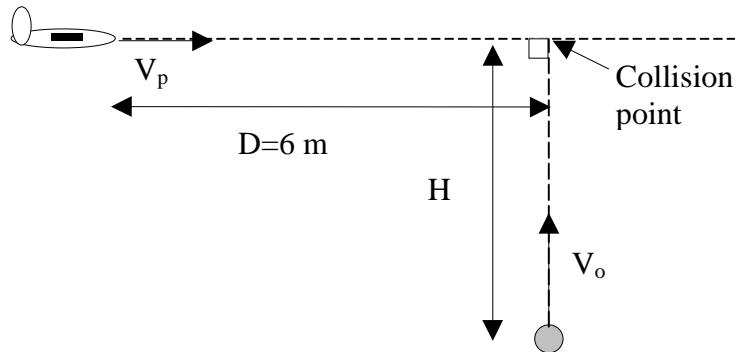
**A formula sheet is attached as the last page. You may remove this for ease of use.  
Do NOT put any work on the sheet and turn it in with your test.**

**GOOD LUCK!**

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Problem 1 [25 pts] A boy is flying his toy airplane with a constant velocity of 6 m/s above a horizontal yard. His younger sister throws a rock straight up in the air when the plane is a **horizontal distance** of 6 m away from straight above her head. Just as the rock reaches its maximum height the plane crashes into the rock sending the plane crashing into the ground. (a) [8 pts] How long did it take the rock to fly through the air to reach the plane? (b)[8 pts] What was the initial speed of the rock? (c)[9 pts] How far vertically above the point where the girl released the rock was the plane? (After the plane crashed into the ground a chase ensued....but that's a different problem.)



- a) **The time for the rock to fly through the air to reach the plane is just the time that it takes the plane to arrive at the location directly above the girl.**

$$D = V_p t \rightarrow t = D/V_p = (6 \text{ m})/(6 \text{ m/s}) = 1 \text{ s}$$

- b) **Since the rock reaches its peak height when it hits the plane, the final velocity of the rock is zero (just before the plane hits it). So**

$$0 = V_o - g t \rightarrow V_o = g t = g (D/V_p) = (9.8 \text{ m/s}^2)(6 \text{ m})/(6 \text{ m/s}) = 9.8 \text{ m/s}$$

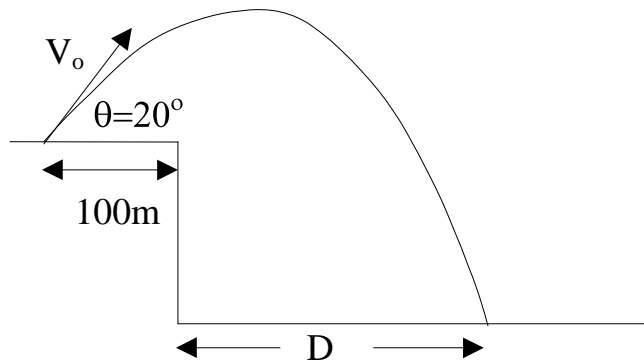
- c) **The height above the release point can be determined from**

$$V^2 = (V_o)^2 - 2gH \rightarrow H = (V_o)^2/2g = \frac{1}{2} gD^2/(V_p)^2 = 4.9 \text{ m}$$

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Problem 2 [25 pts] A cannon is placed 100 m from the edge of a vertical cliff at the ocean. It shoots a cannonball at an angle of  $20^\circ$  with respect to horizontal with an initial speed of 50 m/s. After firing the cannon, it takes 6 seconds for the cannonball to splash into the ocean. (a) [7 pts] How far from the base of the cliff does the cannonball hit the water? (b) [7 pts] What is the height of the cliff? (c) [7 pts] What is the velocity (magnitude and direction) of the cannonball when it hits the water. (d) [4 pts] What is the acceleration of the cannonball just before it hits the water? (You may ignore the size and height of the cannon.)



a) The total horizontal distance that the cannonball travels is given by

$$x = V_0 \cos \theta t = 282 \text{ m} \quad \text{so } D = x - 100 \text{ m} = 182 \text{ m}$$

b) The y position of the cannonball after 6 secs in flight will be given by

$$y = y_0 + V_0 \sin \theta t - \frac{1}{2}gt^2 = 0 + V_0 \sin \theta t - \frac{1}{2}gt^2 = -74 \text{ m}$$

So the height of the cliff is 74 m.

c) The velocity of the cannonball when it hits the water can be determined from the components

$$\begin{aligned} V_x &= V_{0x} = V_0 \cos \theta = 47 \text{ m/s} \\ V_y &= V_{0y} - g t = V_0 \sin \theta - g t = -42 \text{ m/s} \end{aligned}$$

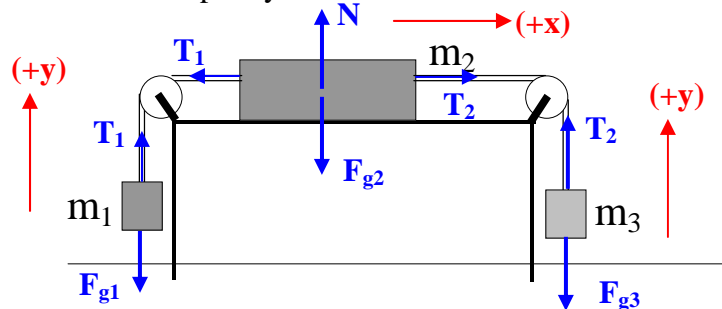
$$V = 63 \text{ m/s} \quad \phi = \arctan (|V_y|/|V_x|) = 42^\circ \text{ (below horizontal)}$$

d) The acceleration is  $a = -g \mathbf{j} = -9.8\mathbf{j} \text{ m/s}^2$  through the entire flight.

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Problem 3 [25 pts] Three blocks with mass  $m_1 = 3.0$  kg,  $m_2 = 3.0$  kg, and  $m_3 = 4.0$  kg are connected by a massless and unstretchable ropes that passes over massless pulleys as shown in the diagram below. The pulleys and surfaces are frictionless.



- a) [5 pts] On the plot above, label all the forces that are acting on each block.  
 b) [6 pts] Write down Newton's 2<sup>nd</sup> law for each block.

$$\text{Block \#1: } \sum F_x = T_1 - F_{g1} = m_1 a_1 = m_1 a$$

$$\text{Block \#2: } \sum F_x = T_2 - T_1 = m_2 a_2 = m_2 a$$

$$\sum F_y = N - F_{g2} = 0$$

$$\text{Block \#3: } \sum F_y = T_2 - F_{g3} = m_3 a_3 = -m_3 a$$

**If we assume that block #3 is going down, then block #2 is going to the right and block #1 is going up. Therefore we take**

$$\mathbf{a_1 = a_2 = -a_3 = a}$$

**When solving for "a" if it is a < 0, then the blocks are all accelerating the other direction**

- c) [7 pts] Determine the acceleration of the blocks.

$$\text{From Block \#1: } T_1 = m_1 a + m_1 g \quad \text{and from Block \#3: } T_2 = -m_3 a + m_3 g$$

**Substituting these into the equation for the x direction of block #2 we find**

$$-m_3 a + m_3 g - (m_1 a + m_1 g) = m_2 a$$

$$(m_3 - m_1) g = (m_1 + m_2 + m_3) a$$

$$\mathbf{a = (m_3 - m_1) g / (m_1 + m_2 + m_3) = (1/10)(9.8 \text{ m/s}^2) = 0.98 \text{ m/s}^2}$$

- d) [7 pts] Determine the tension in each rope.

**From the first two equations of part (c)**

$$T_1 = m_1(a + g) = (3 \text{ kg})(10.8 \text{ m/s}^2) = 32 \text{ N}$$

$$T_2 = m_3(g - a) = (4 \text{ kg})(9.8 - 0.98 \text{ m/s}^2) = 35 \text{ N}$$

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Problem 4 [25 pts] (Circle your answer)

4a) [4 pts] You are driving behind a truck at the same speed as the truck. A crate falls off the back of the truck. Is it possible for your car to hit the crate **before** the crate hits the ground if you neither brake nor accelerate?

- 1) Yes
- 2) No ←

4b) [4 pts] A book resting on a horizontal table feels a normal force of 1 N upward from the table and a 1 N downward force of gravity from the earth. These two forces form an “action-reaction” pair according to Newton’s 3<sup>rd</sup> law

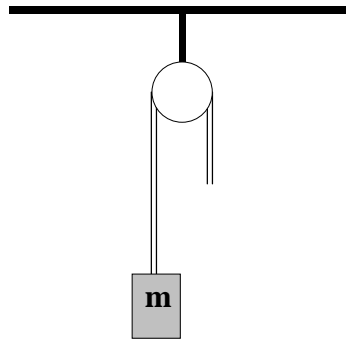
- 1) True
- 2) False ←

4c) [4 pts] If the acceleration is less than zero, then the objects speed is being reduced.

- 1) True
- 2) False ←

4d) [4 pts] A person is holding onto one end of the rope and lowering a box with a constant velocity (shown below). The magnitude of the tension is

- 1)  $T > mg$
- 2)  $T = mg$  ←
- 3)  $T < mg$



4e) [5 pts] Suppose a particle is accelerated through space by a 10-N force. Suddenly, the particle encounters an additional force of 10 N in the opposite direction of the first force. The particle:

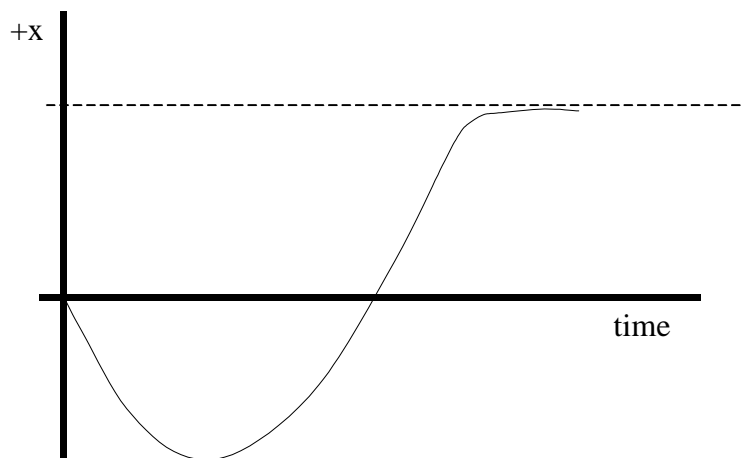
- 1) is brought to a rapid halt
- 2) decelerates gradually to a halt
- 3) continues at the speed it had when it encountered the second force ←
- 4) none of these

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4f) [4 pts] Shown below is the position versus time plot for a particle moving in 1 dimension. For most of the time shown below the acceleration is

- 1) greater than zero. ←
- 2) equal to zero.
- 3) less than zero.



**Useful Equations and Constants:**

$$g = 9.8 \text{ m/s}^2 = 32 \text{ ft/s}^2$$

$$m_e = 9.11 \times 10^{-31} \text{ kg (electron mass)}$$

$$m_p = 1.67 \times 10^{-27} \text{ kg (proton mass)}$$

$$\frac{4}{3}\pi r^3 \text{ (Volume of a sphere)}$$

$$4\pi r^2 \text{ (Surface area of a sphere)}$$

$$2\pi rL \text{ (area of the sides of a cylinder)}$$

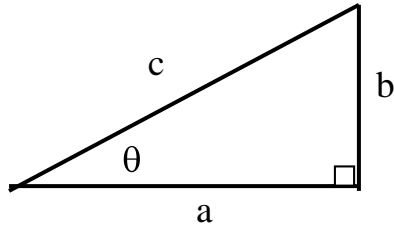
$$\pi r^2 L \text{ (volume of a cylinder)}$$

$$\pi r^2 \text{ (area of a circle)}$$

$$2\pi r \text{ (circumference of a circle)}$$

$$\mathbf{A+B} = (A_x+B_x)\mathbf{i} + (A_y+B_y)\mathbf{j} + (A_z+B_z)\mathbf{k}$$

$$\mathbf{A-B} = (A_x-B_x)\mathbf{i} + (A_y-B_y)\mathbf{j} + (A_z-B_z)\mathbf{k}$$



$$a^2 + b^2 = c^2 ; \sin \theta = b/c ; \cos \theta = a/c ; \tan \theta = b/a ; \sin^2 \theta + \cos^2 \theta = 1 ; 2\sin \theta \cos \theta = \sin 2\theta$$

$$\text{If } ax^2 + bx + c = 0, \text{ then } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\vec{v} = \frac{d\vec{r}}{dt} \text{ by components: } v_x = \frac{dx}{dt} \quad v_y = \frac{dy}{dt} \quad v_z = \frac{dz}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2} \text{ by components: } a_x = \frac{dv_x}{dt} = \frac{d^2x}{dt^2} \quad a_y = \frac{dv_y}{dt} = \frac{d^2y}{dt^2} \quad a_z = \frac{dv_z}{dt} = \frac{d^2z}{dt^2}$$

Equations of Motion:

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 \quad v_x = v_{0x} + a_x t \quad v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$$

$$\text{Horizontal Range: } R = \frac{v_0^2}{g} \sin 2\theta \quad \text{Projectile Motion: } y = x(\tan \theta_0) - \frac{gx^2}{2(v_0 \cos \theta_0)^2}$$

Forces:

$$\sum \vec{F} = m\vec{a} \text{ by components: } \sum F_x = ma_x \quad \sum F_y = ma_y \quad \sum F_z = ma_z$$

$$\mathbf{F}_g = \mathbf{W} = m\mathbf{g} \text{ (Weight)}$$

$$1 \text{ N} = 1 \text{ kg m/s}^2$$

Conversion Factors:

$$1 \text{ mi} = 1.61 \text{ km} = 5280 \text{ ft} \quad 1 \text{ m} = 3.28 \text{ ft} \quad 1 \text{ in} = 2.54 \text{ cm}$$

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