INSTRUCTIONS: Write your NAME and your LECTURE (8:30 = Ruchti, 10:40 = Hildreth, 3:00 = Karmgard) on the front of the blue exam booklet. The exam is closed book, and you may have only a pens/pencils and a calculator (no stored equations or programs and no graphing). Show all of your work in the blue book. For problems II-V, an answer alone is worth very little credit, even if it is correct - so show how you get it.

Suggestions: Draw a diagram when possible, circle or box your final answers, and cross out parts which you do not want us to consider.

Some useful equations

Constants:

$$g = 9.8\,\mathrm{m/s^2}$$

Vectors:

$$|\vec{B}| = \sqrt{B_x^2 + B_y^2 + B_z^2} \quad \hat{i} = \hat{x}; \quad \hat{j} = \hat{y}; \quad \hat{k} = \hat{z} \quad \vec{v}_{A,C} = \vec{v}_{A,B} + \vec{v}_{B,C}$$

If $\vec{B} = B_x\hat{i} + B_y\hat{j}$ then the direction of $\vec{B}$ is defined by $\theta = \tan^{-1}\left(\frac{B_y}{B_x}\right)$

Kinematics:

$$\text{Constant } a_x : \quad x = x_0 + v_{0,x}t + \tfrac{1}{2}a_x t^2 \quad v_x = v_{0,x} + a_x t \quad v_x^2 = v_{0,x}^2 + 2a_x(x - x_0)$$

$$\vec{v} = \frac{d\vec{r}}{dt} = v_x\hat{i} + v_y\hat{j} + v_z\hat{k} = \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j} + \frac{dz}{dt}\hat{k}$$

$$\vec{a} = \frac{d\vec{v}}{dt} = a_x\hat{i} + \ldots = \frac{dv_x}{dt}\hat{i} + \ldots = \frac{d^2x}{dt^2}\hat{i} + \ldots$$

General:

$$at^2 + bt + c = 0 \Rightarrow t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\sum \vec{F} = \vec{F}_{\text{tot}} = m\vec{a}$$

I. Multiple Choice Questions

Instructions: Read each question carefully. Write the SINGLE correct answer in the grid provided on the INSIDE of your blue exam book (The one on the front is for grading!). No explanation is required, and no paritial credit will be given. (20 points total)

1. A cannonball is fired straight up into the air with an initial velocity $\vec{v} = v_0\,\hat{j}$. It rises to a height h, and falls back to the ground.
1) What is the velocity of the cannonball when it returns to its starting point?

a) $-\sqrt{2gh}\,\hat{j}$ b) $-9.8\frac{m}{s}\,\hat{j}$ c) $v_0\,\hat{j}$ d) $-v_0\,\hat{j}$.

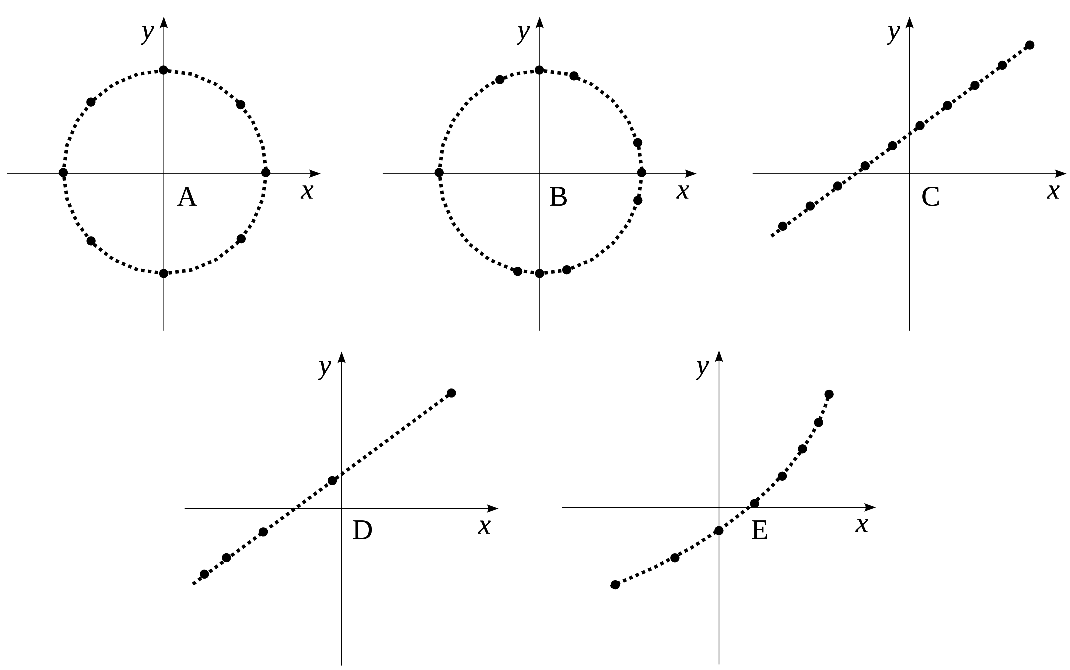
2. What is the average acceleration of the cannonball over the entire trip?

a) $\vec{g}\,\hat{j}$ b) $-\vec{g}\,\hat{j}$ c) $\vec{0}\,\hat{j}$ d) $2\vec{g}\,\hat{j}$ e) $\frac{1}{2}\vec{g}\,\hat{j}$

3. If two metal blocks of different masses slide freely down the same frictionless incline, which one of the following is true?

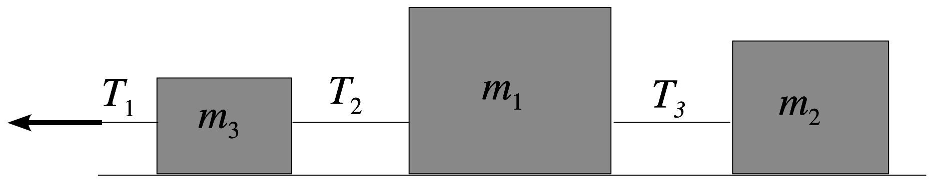
a.) They have equal accelerations.
b.) They have unequal accelerations, but the forces acting on them are equal.
c.) The more massive block reaches the bottom first.
d.) The less massive block reaches the bottom first.
e.) None of these is correct.

4. The following graphs show trajectories of a single particle in the $x-y$ plane. The dots on the trajectories indicate the positions at time intervals separated by one second. Which of the following is indicative of a constant *speed*?.
a.) A and B b.) C and D c.) A and C d.) B and D e.) E only



5. Three masses are connected by massless strings that do not stretch. If $m_1 > m_2 > m_3$, which of the following gives the appropriate ordering of the magnitudes of the tensions in the strings? (Note that the blocks are not in numerical order.)

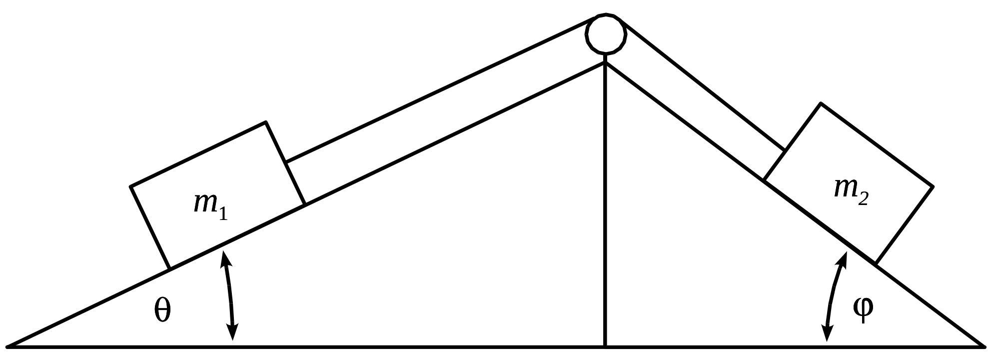
a.) $T_1 > T_2 > T_3$
b.) $T_2 > T_1 > T_3$
c.) $T_3 > T_2 > T_1$
d.) $T_3 > T_1 > T_2$
e.) None of these is correct.



Problems

(20 points each) Write the complete solutions in your blue book. Remember that no partial credit will be given for an answer with no supporting work.

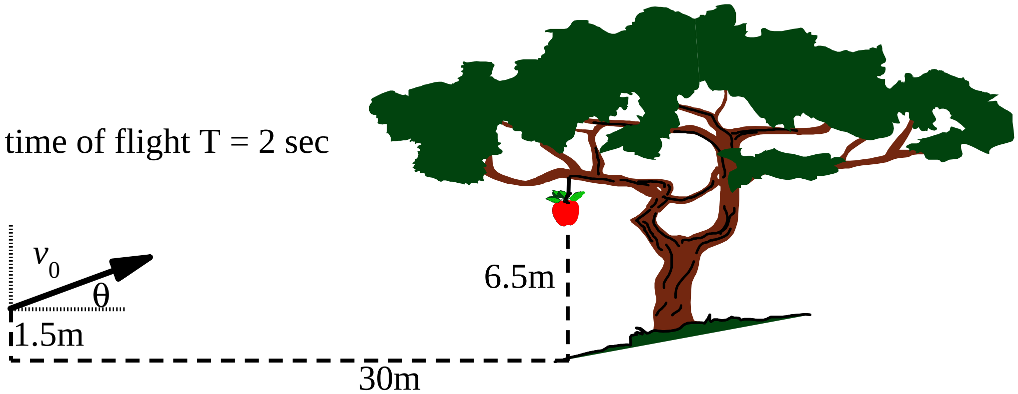
Problem II:



Two blocks m_1 and m_2 are place on frictionless planes inclined at angles θ and ϕ respectively. The blocks are connected by a massless string via a massless, frictionless pulley. The angles are $\theta = 30°$ and $\varphi = 37°$, and $m_1 = 10$kg.

a) Draw a free body diagram for each of the blocks.
b) If neither block is moving what is the tension is the string?
c) If neither block is moving what is the ratio of the masses $\frac{m_1}{m_2}$? From this ratio find m_2.
d) Under what condition on m_2 will the two blocks move toward the right? The left?

Problem III:



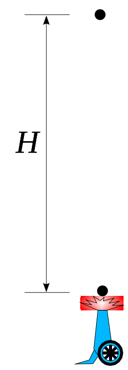
Young William "Willi" Tell practices shooting at apples hanging on an apple tree. In one trial he is 30 meters away from an apple in the horizontal direction, and the apple is hanging 6.5 meters above ground level. Assume that he shoots his arrow from an initial elevation of 1.5 meters above the ground and the flight time of the arrow from launch to striking the apple is 2 seconds.

a) Write down an expression relating the x position of the arrow in terms of x_0, v_0, t, and possibly g. Clearly indicate the coordinate system you are using, including axes and origin.
b) Write down an expression relating the y position of the arrow in terms of y_0, v_0, t, and possibly g. Clearly indicate the coordinate system you are using, including axes and origin.
c) Use these to find the initial angle (θ) with which the arrow must be launched.
d) Find the magnitude of the velocity (v_0) at which the arrow is launched.

Problem IV:

A cannonball is dropped from the edge of a cliff of height H. At the same instant, a second cannonball is fired directly upward. The cannonball shot from below is fired with a velocity such that it would just reach a maxiumum height H, but the cannonballs collide before this happens. The cannon has negligible height.

a.) Do the balls collide *above* $H/2$, *below* $H/2$, or exactly *at* $H/2$? Argue your answer *in words only* (and/or draw a picture).
b.) Find the initial velocity of the cannonball shot from below.
c.) Now, using this information and your knowledge of projectile motion, find the height at which they collide.
d.) Describe, in words not equations, what you would change if you wanted the cannonballs to collide at a height of $H/3$.



Problem V:

A block of mass 5 kg slides down a frictionless ramp with a $40°$ angle of inclination. It starts from rest at a height of 1 m. After sliding across a frictionless floor, it begins to slide up another frictionless ramp, whose angle of inclination is $30°$. No velocity is lost in the transitions from the ramps to the floor.

a.) Draw free body diagrams for the block as it sits on the $40°$ and the $30°$ planes. Indicate with arrows all of the forces that act on the block in each case.
b.) Find the acceleration of the block on each of the ramps. Indicate the axes you are using clearly in each case.
c.) Find the velocity of the block as it crosses between the ramps.
d.) How high up the second ramp does the block travel? (*i.e., what is its final height h above the flat, level surface?*)