Physics 200 Name KEY

Exam 1 – Kinematics and Force 94

September 27, 2007

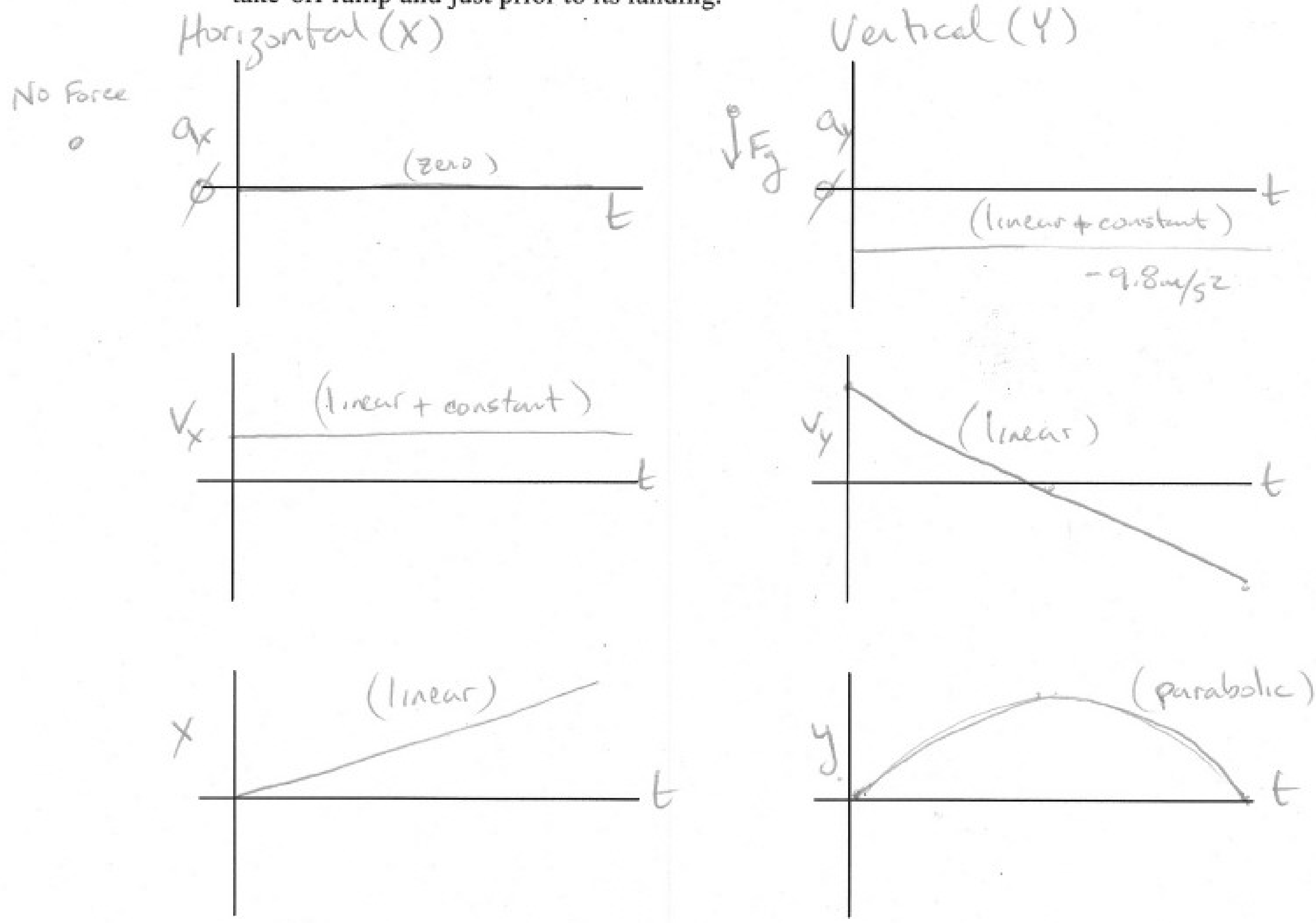
This is a closed book examination. There is extra scratch paper available.

A general reminder about problem solving:

1. Draw a picture then create a simplified free body diagram with all forces
2. Write down what you know including coordinate frame
3. Write down what you don't know and/or want to know
4. List mathematical relationships
5. Simplify and solve
6. Check your answer – Is it reasonable? Are units correct?

- Show all work!

1. [18 PTS] You are watching stunt-junkies on the Discover© channel. The stunt driver is demonstrating how to jump over barrels on a motorcycle. You note that there is ramp for both the take-off and landing. Neglecting friction, draw graphs of position, velocity and acceleration as a function of time for the motorcycle in both the horizontal (x) and vertical (y) directions. Draw these graphs for the motorcycle right after it has left the take-off ramp and just prior to its landing.



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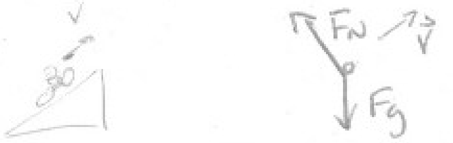
Draw free body diagrams (i.e. label all forces) for the following situations.

2. [3 PTS] The above stunt driver and motorcycle system while moving up the take-off ramp. Ignore friction.

Assume the motorcycle is not providing a thrust up the ramp



(velocity positive in x and y)

3. [3 PTS] The above stunt driver and motorcycle system just after leaving the take-off ramp. Ignore friction.

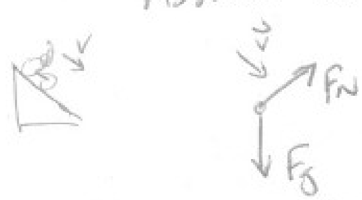
In free-fall – velocity positive in both x and y

4. [3 PTS] The above stunt driver and motorcycle system just before landing on the ramp. Ignore friction.

In free-fall – velocity negative in y and positive in x

5. [3 PTS] The above stunt driver and motorcycle system while moving down the landing ramp. Ignore friction.

Assume the motorcycle is not braking on the ramp



Please explain your answers for multiple-choice questions - your explanation is worth 3/4 of the points.

6. [4 PTS] You kick a rather old yellow and black soccer ball as hard as you can at approximately 30^0 to the horizon. Assume up is the positive direction. When the ball is at the highest point of its trajectory
   a) its acceleration is zero.
   b) its velocity is zero but its acceleration is non-zero.
   c) its acceleration is zero but its velocity is non-zero.
   d) its acceleration and velocity are both non-zero.
   e) not enough information is given.

Acceleration is always −g in the vertical direction. Velocity in the horizontal direction is constant. Only the vertical velocity changes and is briefly ∅ at top of trajectory

$\boxed{6}$

7. [4 PTS] A mom and her young son are ice-skating. While standing in the middle of the (frictionless) ice they push off each other. The mom has a weight 4 times that of her son's weight and does not travel as fast as her son after the push. It follows that
   a) the mom pushed on the son with a greater magnitude force.
   b) the mom and son pushed on each other with equal magnitude forces.
   c) the mom pushed on the son with a smaller magnitude force.
   d) there is insufficient data given to determine the relative magnitudes of the two forces.

For every force there is an equal opposite force

~~[2 PTS]~~ The next three questions involve two carts that are identical except they have different masses. The mass of cart 1 is twice the mass of cart 2 ($m_1 = 2m_2$).

8. [8 PTS] The two carts are pushed with the same force for the same amount of <u>time</u>. Which cart has a greater velocity?
   a) Cart 1 is traveling faster: $v_1 = 2v_2$
   b) Cart 1 is traveling faster: $v_1 = \sqrt{2}v_2$
   c) Both carts have the same velocity. $v_1 = v_2$
   d) Cart 2 is traveling faster: $v_1 = \frac{1}{\sqrt{2}}v_2$
   e) Cart 2 is traveling faster: $v_1 = \frac{1}{2}v_2$

$a = \frac{F}{m}$

$a_1 = \frac{F}{2m}$ $\quad a_2 = \frac{F}{m}$

$v_1 = a_1 t$ $\quad v_2 = a_2 t$

$\frac{1}{2}v_2 = v_1 = \frac{F}{2m}t$ $\quad v_2 = \frac{F}{m}t =$

9. [8 PTS] The two carts are pushed with the same force for the same <u>distance</u>. Which cart has a greater velocity?
   a) Cart 1 is traveling faster: $v_1 = 2v_2$
   b) Cart 1 is traveling faster: $v_1 = \sqrt{2}v_2$
   c) Both carts have the same velocity. $v_1 = v_2$
   d) Cart 2 is traveling faster: $v_1 = \frac{1}{\sqrt{2}}v_2$
   e) Cart 2 is traveling faster: $v_1 = \frac{1}{2}v_2$

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $\quad v = v_0 + at$

$x - x_0 = d = \frac{1}{2}at^2$ $\quad t = \frac{v}{a}$ $\quad v_0 = 0$

$= \frac{1}{2}a\left(\frac{v^2}{a^2}\right)$

$d = \frac{v^2}{2a}$ so $v = \sqrt{2da}$

$v_1 = \sqrt{2d\frac{F}{2m}}$ $\quad v_2 = \sqrt{2d\frac{F}{m}}$

$v_1 = \frac{1}{\sqrt{2}}v_2$

10. [8 PTS] The two carts roll down the <u>same incline</u>. Which cart has a greater velocity?
   a) Cart 1 is traveling faster: $v_1 = 2v_2$
   b) Cart 1 is traveling faster: $v_1 = \sqrt{2}v_2$
   c) Both carts have the same velocity. $v_1 = v_2$
   d) Cart 2 is traveling faster: $v_1 = \frac{1}{\sqrt{2}}v_2$
   e) Cart 2 is traveling faster: $v_1 = \frac{1}{2}v_2$

$a = \frac{F_g}{m}$ $\quad F_g = mg\sin\theta$

$a = -g\sin\theta$ both carts have same acceleration!

$\boxed{28}$

11. [4 PTS] A car is traveling in a circle with a constant speed.
   a) The car has a net force normal to the surface of the circle (pointing radially out).
   b) The car has zero net force.
   c) The car has a net force towards the center of the circle (pointing radially inwards).
   d) The car has a net force pointing tangential to the circle (pointing in the direction of travel).

The velocity is changing (direction!) so $\Delta\vec{V} \neq 0$ and you have a net acceleration and hence net force is needed. Force must point in

12. [4 PTS] You drop a golf ball from a roof and immediately throw a baseball straight up into the air. Assume the mass of the baseball is 3 times the mass of the golf ball and ignore air drag. When the baseball is at the top of its trajectory,
   a) the acceleration of the golf ball is <u>greater than</u> the acceleration of the baseball.
   b) the acceleration of the golf ball is <u>equal to</u> the acceleration of the baseball.
   c) the acceleration of the golf ball is <u>less than</u> the acceleration of the baseball.

$\Sigma F = ma$ so $m(-g) = ma$ $a = -g$

Mass does not matter – all objects experience the same acceleration.

The next problems may be done on the back of your exam or on additional paper.

13. [12 PTS] What force is needed to throw a baseball at 90 mph? Assume the baseball has a mass, $m = 0.15\text{kg}$, the pitcher maintains contact with the ball for 0.5 meters and that the pitcher throws the ball horizontally.

14. [12 PTS] A 90 mph baseball is thrown horizontally towards a catcher standing behind home plate 20 meters away. How long does it take the ball to reach the catcher? How far does the ball drop vertically? Assume the baseball has a mass, $m = 0.15\text{kg}$.

Possibly useful mathematical relationships:

$\sin^2(\theta) + \cos^2(\theta) = 1 \qquad \sin(2\theta) = 2\sin(\theta)\cos(\theta)$

$\cos(2\theta) = \cos^2(\theta) - \sin^2(\theta) = 2\cos^2(\theta) - 1 = 1 - 2\sin^2(\theta)$

Derivative of a polynomial $\frac{d}{du}Cu^n = nCu^{n-1}$

Anti-derivative (integral) of a polynomial $\int Cu^n du = \frac{1}{n+1}Cu^{n+1} + const.$

The Chain Rule $\frac{d}{dz}f(u) = \frac{d}{dz}u\frac{d}{du}f(u)$

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$\boxed{13}$

$V_0 = 0\,m/s$ $\qquad$ $V_f = 90\,mph$

$|\leftarrow d = 0.5\,m \rightarrow|$

$$\frac{90\,\text{miles}}{\text{hour}} \cdot \frac{1600\,m}{\text{mile}} \cdot \frac{\text{hour}}{3600\,\text{sec}} = 40\,m/s$$

$$F = ma \qquad v = v_0 + at \qquad x = x_0 + v_0 t + \tfrac{1}{2} a t^2$$

$$\frac{v - v_0}{a} = t \qquad d = x - x_0 = v_0 t + \tfrac{1}{2} a t^2$$

$$= \frac{v_0(v - v_0)}{a} + \frac{1}{2} a \frac{(v - v_0)^2}{a^2}$$

$$= \frac{v_0 v - v_0^2}{a} + \frac{1}{2a}(v^2 - 2vv_0 + v_0^2)$$

$$= \cancel{\frac{v_0 v}{a}} - \frac{v_0^2}{a} + \frac{v^2}{2a} - \cancel{\frac{vv_0}{a}} + \frac{v_0^2}{2a}$$

$$= \frac{-v_0^2}{2a} + \frac{v^2}{2a} = \frac{-v_0^2 + v^2}{2a}$$

$$d = \frac{v^2 - v_0^2}{2a} \quad \text{or} \quad a = \frac{v^2 - v_0^2}{2d}$$

useful result...

$$F = m \frac{v^2 - v_0^2}{2d} \qquad \text{but } v_0 = 0\,m/s$$

$$F = m \frac{v^2}{2d} \quad \text{☑ units check}$$

$$= (0.15\,kg)\left(\frac{(40\,m/s)^2}{(2 \cdot 0.5\,m)}\right)$$

$$\boxed{F = 240\,N}$$

Note: $a = 1600\,m/s^2$ is large but that is because you have such a light object

$\boxed{14}$

$\downarrow -g = a_y$ (ball is thrown horizontally)

$$x = x_0 + v_0 t + \tfrac{1}{2} a_x t^2 \qquad a_x = 0$$

$$x - x_0 = v_0 t \qquad t = \frac{20\,m}{40\,m/s} = 0.5\,s$$

$v_x = v_0$ thrown horizontally $\quad$ ↑(horizontal)

↓(vertical)

$$y = y_0 + v_{y} t + \tfrac{1}{2} a_y t^2$$

$$y - y_0 = -\tfrac{1}{2} g t^2 \qquad d \doteq -\tfrac{1}{2}\, 10\tfrac{m}{s^2} (0.5\,s)^2 \doteq 1.25\,m$$

ball drops 1.25 meters (gravity pulls it down)