Physics 2101, First Exam, Spring 2006

January 24, 2006

Name : ________________KEY______________________

Section: (Circle one)

1 (Rupnik, MWF 7:40am)	4 (Kirk, MWF 2:40pm)
2 (Rupnik, MWF 9:40am)	5 (Kirk, TTh 10:40am)
3 (Rupnik, MWF 11:40am)	6 (González, TTh 1:40pm)

- Please be sure to write your name and circle your section above.
- For the 17-point problems, you *must* show all your work. Let us know what you were thinking when you solved the problem! Lonely right answers will not receive full credit, lonely wrong answers will receive no credit.
- For the 8-point questions, no work needs to be shown (there is no partial credit).
- Please carry units through your calculations when needed, lack of units will result in a loss of points.
- You may use scientific or graphing calculators, but you must derive your answer and explain your work.
- Feel free to detach, use and keep the formula sheet. No other reference material is allowed during the exam.
- Be sure to get extra credit by answering the question below.
- **GOOD LUCK!**

EXTRA CREDIT (5 pts):

Did you take Physics 1100 during the fall semester of 2005? Yes No

If you responded "yes", then please circle your grade if you remember it. A B C D

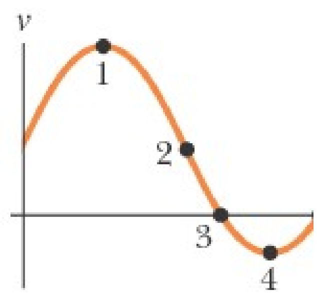
Did you place out of Physics 1100 during spring testing? Yes No

Have you taken Physics 2101 at LSU before? Yes No

If you responded "yes", then how many times before have you taken Phys 2101? ____________

Question 1 - 8 points

The figure shows the velocity of a particle moving along an axis. Point 1 is at the highest point in the curve; point 4 is at the lowest point.



(a) (2pts) **What is the direction of travel at t=0?**

Forward Backward The particle is stopped

The velocity is positive at $t = 0$, so the particle is moving forward.

(b) (3 pts) **At which of the four numbered points does the particle reverse its direction of travel?**

1 2 **3** 4

The velocity is positive before $t = t_3$, so the particle is moving forward before point 3; the velocity is negative after $t = t_3$, so the particle is moving backwards after point 3. At $t = t_3$, the velocity is zero and the particle reverses its direction of motion.

(c) (3 pts) **At which of the four numbered points is the magnitude of the acceleration largest?**

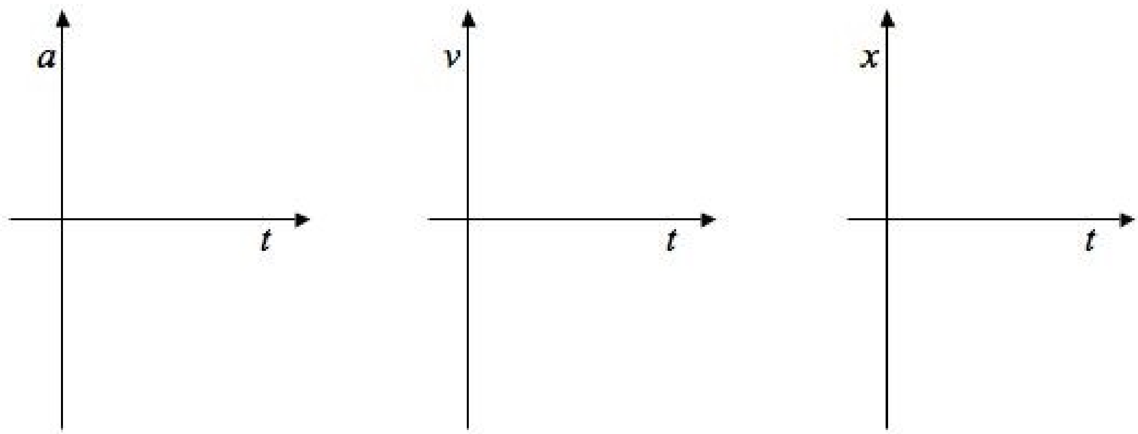
1 **2** 3 4

The slope of $v(t)$ has maximum magnitude (is steepest) at $t = t_2$; since the acceleration is the derivative of the velocity with respect to time, the acceleration will have maximum magnitude at $t = t_2$ (but notice that the acceleration is negative while the velocity is positive, so the particle is slowing down).

Problem 1 - 17 points

A hot air balloon is ascending at the rate of 12m/s and is 80 m above the ground when a package is dropped from the balloon.

(a) (6 pts) Sketch the acceleration, position, and velocity of the package as a function of time after it has been dropped from the balloon, setting t=0 at the time the package is dropped. Use the axes plotted below for your sketches.



(b) (7 pts) **What is the maximum height above the ground reached by the package ?**

Since the package is dropped from the moving balloon, its initial velocity is the same as the balloon's, 12 m/s upwards. The package will be in free fall after dropped, with a constant acceleration $a = -g$. The package will reach its maximum height when its velocity is zero:

$$v = v_0 - gt = 0 \Rightarrow t = v_0/g = \frac{12\text{m/s}}{9.8\text{m/s}^2} = 1.2\text{s}$$

At that time, the position of the package is

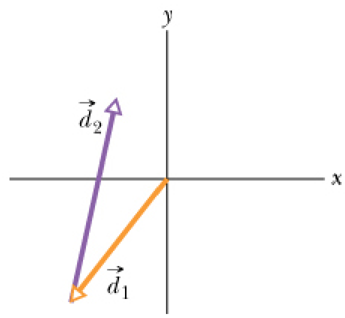
$$x = x_0 + v_0 t - \frac{1}{2}gt^2 = 80\text{m} + 12\text{m/s} \times 1.2\text{s} - 4.9\text{m/s}^2 \times (1.2\text{s})^2 = 87.3\text{m}$$

(c) (4 pts) **How much higher than the package are the people in the balloon, when the balloon reaches maximum height?**

The balloon kept rising at a constant velocity, so at $t = 1.2s$ the balloon is at $x_b = x_0 + v_0 t = 80\text{m} + 12\text{m/s} \times 1.2\text{s} = 94.4\text{m}$. When the package reaches maximum height, the balloon is then at a distance $\Delta x = 94.4\text{m} - 87.3\text{m} = 7.1\text{s}$ above the package.

Question 2

The two vectors shown in the figure lie in an xy plane. What is the sign of...



(a) (2pts) the x component of $\vec{d_1} - \vec{d_2}$?   Positive   **Negative**   Zero

$\vec{d_1}$ has a negative x component, $\vec{d_2}$ has a positive x component, so $\vec{d_1} - \vec{d_2}$ has a negative x-component.

(b) (3pts) $\vec{d_1} \cdot \vec{d_2}$?   Positive   **Negative**   Zero

The angle ϕ between $\vec{d_1}$ and $\vec{d_2}$ is larger than 90^o and smaller than 180^o, so $\vec{d_1} \cdot \vec{d_2} = d_1 d_2 \cos\phi$ is negative.

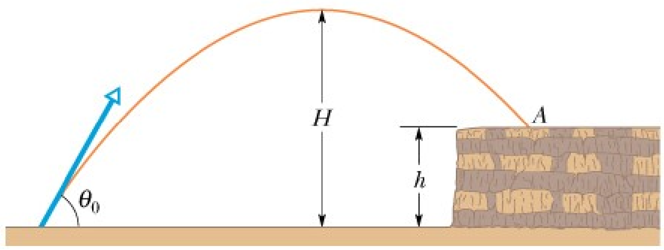
(c) (3 pts) The vector $\vec{d_1} \times \vec{d_2}$ points ...

out of the page   **into the page**

We use the right hand rule.

Problem 2 - 17 points

A stone is projected at a cliff of height h with an initial speed $v_0 = 42.0\text{m/s}$, directed at an angle $\theta_0 = 60^o$ above the horizontal, as shown in the figure. The stone strikes at A, 5.50 s after launching.



(a) (5pts) **What is the height h of the cliff?**

The height h will be the vertical coordinate of the particle when it strikes at A at time $t = 5.50s$, whcih is given by

$$\begin{aligned} y &= y_0 + (v_0 \sin\theta_0)t - \frac{1}{2}gt^2 \\ h &= 0\text{m} + 42.0\text{m/s} \sin 60^o \times 5.50\text{s} - \frac{1}{2} 9.8\text{m/s}^2 (5.50\text{s})^2 \\ &= 0\text{m} + 200\text{m} - 148\text{m} = 52\text{m} \end{aligned}$$

(b) (6 pts) **What is the speed of the stone just before impact at A?** The vertical component of the velocity at $t = 5.50s$ is

$$v_y = v_0 \sin\theta_0 - gt = (42.0\text{m/s}) \sin 60^o - 9.8\text{m/s}^2 \times 5.50\text{s} = 36.4\text{m/s} - 53.9\text{m/s} = -17.5\text{m/s}.$$

The horizontal component of the velocity is constant, equal to

$$v_x = v_0 \cos\theta_0 = 42.0\text{m/s} \cos 60^o = 21.0\text{m/s}.$$

The magnitude of the velocity just before impact is then

$$v = \sqrt{v_x^2 + v_y^2} = 27.3\text{m/s}.$$

The direction of the velocity vector is given by the angle

$$\theta = \tan^{-1} v_y/v_x = -17.5/27.3 = -32^o.$$

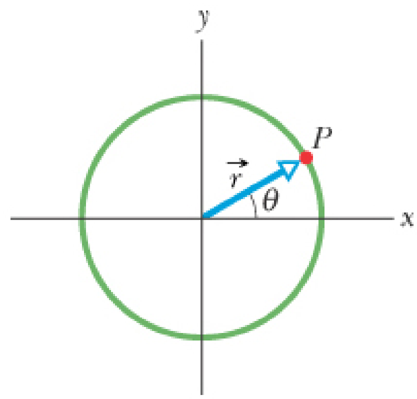
or 32^o below the horizontal.

(c) (6 pts) **How long after launching does the stone reaches the maximum height H above the ground?** When the stone reaches its maximum height, the vertical component of the velocity will be zero:

$$v_y = v_0 \sin\theta_0 - gt = 0 \Rightarrow t_H = v_0 \sin\theta_0/g = 42.0\text{m/s} \times \sin 60^o/9.8\text{m}^2 = 3.7\text{s}.$$

Question 3 - 8 points

The particle P in the figure is in uniform circular motion, moving counterclockwise, centered in the origin of an xy coordinate system. At what value of θ is...



(a) (4 pts) ... the vertical component of the velocity vector, v_y, the greatest?

$\underline{\theta = 0^o}$ $\theta = 90^o$ $\theta = 180^o$ $\theta = -90^o$

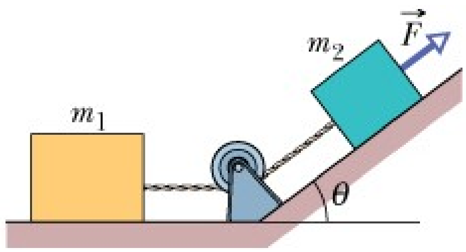
(b) (4 pts) ... the vertical component of the force vector, F_y, the greatest?

$\theta = 0^o$ $\theta = 90^o$ $\theta = 180^o$ $\underline{\theta = -90^o}$

Problem 3 - 17 points

A force $\vec{F}$ is applied to a box of mass $m_2 = 1.0$ kg. The force is directed up a plane tilted by an angle $\theta = 30^o$. The box is connected to a box of mass $m_1 = 3.0$ kg on the floor. The floor, the plane, and the pulley are all frictionless. The box with mass m_1 moves with a constant acceleration of magnitude 6.0m/s^2.

(a) (5 pts) Draw a free body diagram for *each* of the masses (you can use the figure, or draw the free body diagrams next to the figure)



(b) (4 pts) **What is the tension in the cord?** Newton's law for m_1 in the horizontal direction is

$$T = m_1 a = 3.0\text{kg} \times 6.0\text{m/s}^2 = 18\text{N}.$$

(c) (3 pts) **What is the magnitude and direction of the acceleration of the mass m_2 on the tilted plane?**

The mass m_2 moves on the plane, so the direction of its acceleration is along the plane, at an angle $\theta = 30^o$ above the horizontal direction.

As long as the string is tense, the mass m_2 moves the same distance along the plane than m_1 moves on the horizontal plane, so the magnitude of its acceleration is also $a_2 = 6.0\text{m/s}^2$.

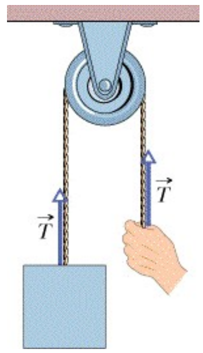
(d) (5 pts) **What is the magnitude of the force $\vec{F}$?**

Newton's law along the direction of the plane, taking "up the plane" as the positive direction:

$$\begin{aligned} F - T - m_2 g \sin\theta &= m_2 a \Rightarrow \\ F = T + m_2(a + g\sin\theta) &= 18\text{N} + 1.0\text{kg} \times (6.0\text{m/s}^2 + 9.8\text{m/s}^2 \sin 30^o) = 24.5\text{N} \end{aligned}$$

Question 4 - 8 points

The suspended body in the figure has a mass M, and a weight equal to Mg. A person is applying a force to the other end of the cord. Is the magnitude of the tension T equal to, greater than, or less than Mg when the mass M is moving upward...



(a) (4 pts) ... at a constant speed?

$\underline{T = Mg}$ $\qquad$ $T > Mg$ $\qquad$ $T < Mg$

If the body is moving with constant velocity, its acceleration is zero. Since the total force is $F = T - mg$ and $F = ma = 0$, then $F = 0 \rightarrow T = Mg$.

(b) (4 pts) ... at decreasing speed?

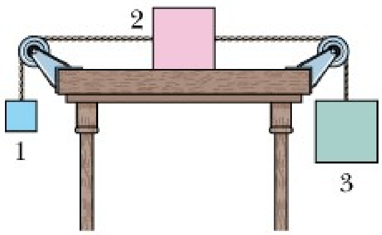
$T = Mg$ $\qquad$ $T > Mg$ $\qquad$ $\underline{T < Mg}$

If the body is moving up but with decreasing speed, its acceleration is negative, and the net force must be down, so $T < Mg$.

Problem 4 - 17 points

Three boxes are connected by strings and pulleys as shown in the figure. Box 1 hanging on the left has $m_1 = 1$ kg, Box 2 on the table has $m_2 = 2.5$kg, and Box 3 hanging on the right has $m_3 = 3$kg. There is friction between the table and Box 2. The system is in equilibrium, and the boxes are not moving.

(a) (5 pts) Draw a free body diagram for each of the masses.



(b) (3 pts) **What is the tension in the cord between Boxes 1 and 2?** Newton's law for Box 1, in equilibrium:

$$T_1 - m_1 g = 0 \rightarrow T_1 = m_1 g = 1.0\text{kg} \times 9.8\text{m/s}^2 = 9.8\text{N}.$$

(c) (3 pts) **What is the tension in the cord between Boxes 2 and 3?**

Newton's law for Box 3, in equilibrium:

$$T_2 - m_3 g = 0 \rightarrow T_2 = m_3 g = 3.0\text{kg} \times 9.8\text{m/s}^2 = 29.4\text{N}.$$

(d) (4pts) **What is the magnitude and direction of the friction force on Box 2?** Newton's law for Box 2, in equilibrium, in the horizontal direction (using the directions for forces as shown in the drawing)

$$T_2 - T_1 - f_s = 0 \rightarrow f_s = T_3 - T_1 = 19.6\text{N}.$$

Since we got a positive number, it means the friction force is pointing the way it is drawn. We can also tell the friction will point left, because in the absence of friction, the mass m_2 will move towards the right (because m_3 is heavier than m_1).

(e) (2 pts) **What is the minimum value of the static coefficient of friction between Box 2 and the table?** The friction force calculated above must be equal or smaller than than maximum static friction force, given by $f_{s,max} = \mu_s F_N$. The normal force on Box 2 can be calculated from Newton's law in the vertical direction:

$$F_N - m_2 g = 0 \rightarrow F_N = 2.5\text{kg} \times 9.8\text{m/s}^2 = 24.5\text{N}.$$

Then, we can use the calculated friction force:

$$f_s \leq f_{s,max} = \mu_s F_N \Rightarrow \mu_s \geq \frac{f_s}{F_N} = \frac{19.6\text{N}}{24.5\text{N}} = 0.8.$$

The mininum value of the static coefficient of friction is then $\mu_{s,mon} = 0.8$ (but it could be, and most likely is, larger). We cannot calculate the actual value of the static coefficient of friction from the values given in this problem; to measure the coefficient we would have to keep increasing m_3 or decreasing m_1 or m_2 until we find the maximum value for $T_2 - T_1$ just before the system begins moving, and only then we can assume that $f_s = f_{s,max} = \mu_s F_N$.