Last Name: ______________________ First Name: ______________________

Physics 101 Fall 2003: Test 1—Free Response and Instructions

- Print your LAST and FIRST name on the front of your blue book, on this question sheet, the multiple-choice question sheet and the multiple-choice answer sheet.
- TIME ALLOWED 75 MINUTES
- The test consists of three free-response questions and ten multiple-choice questions.
- The test is graded on a scale of 100 points; the first free-response question accounts for 25 points, the second for 30 points, the third for 15 points and the multiple-choice questions account for 30 points.
- Answer the three free-response questions in your blue book. Answer the multiple-choice questions by marking a dark X in the appropriate column and row in the table on the multiple-choice answer sheet.
- Consult no books or notes of any kind. You may use a hand-held calculator in non-graphing, non-programmed mode.
- Do NOT take test materials outside of the class at any time. Return this question sheet along with your blue book and multiple-choice question sheet.
- Write and sign the Pledge on the front of your blue book.

Show your work for the free-response problems, including neat and clearly labelled figures, in your blue book. It is possible that answers without explanation (even correct answers) will not be given credit.

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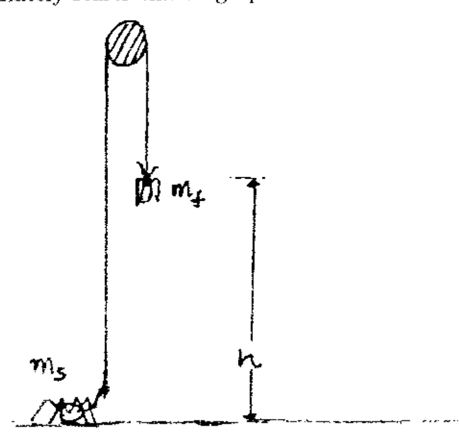
1. (**25pts**)A spider of mass m_s drapes a lubricated (frictionless) silky thread of negligible mass over a stick. The far end is a height h above the ground. The spider holds the thread and waits patiently on the ground until a fly of mass m_f (with $m_f > m_s$) lands on the far end of the thread and gets stuck to it (call this time $t = 0$). Assume that the spider and fly both have zero velocity at this instant. The acceleration due to gravity has a value g. Express all answers in terms of some or all of m_s, m_f, h and g.

   Suppose the spider immediately starts climbing up her end of the thread



   (a) Derive an expression for the acceleration, a_s, with which the spider must climb such that the fly remains at rest and does not fall?

   (b) What is the tension in the thread for this choice of the spider's acceleration?

   Consider now the situation where the spider does nothing at all and just holds on to the thread.

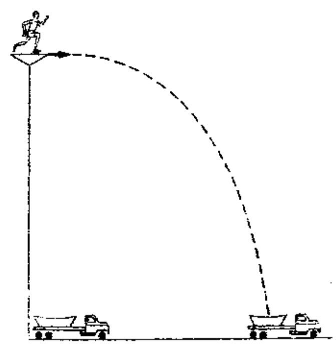
   (d) What are now the accelerations a_s and a_f of the spider and of the fly respectively?

   (e) What is now the tension in the thread?

(f) Where and when, are the spider and the fly at the same elevation above the ground?

2. **(30pts)**A student standing on the express platform of the Concorde Metro (subway) station in Paris notes that the first 3 cars of an arriving train pass him in 3.0 sec and the next 3 cars pass him in 5.0 sec. The cars are each 20 m long, and the braking acceleration of the train is constant. When the train comes to a stop, the student finds himself opposite the rear section of the last car of the train. How long is the train?

3. **(15pts)**A stunt performer is to run and dive off a tall platform and land in a net in the back of a truck below (See the figure below). Originally the truck is directly under the platform; it starts forward with a constant acceleration A at the same instant the performer leaves the platform. If the platform is H above the net in the truck, what horizontal speed V must the performer have as he leaves the platform? (Express your answer in terms of some or all of A, h and g.)



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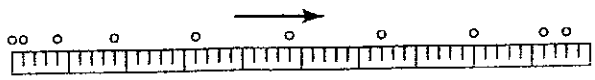
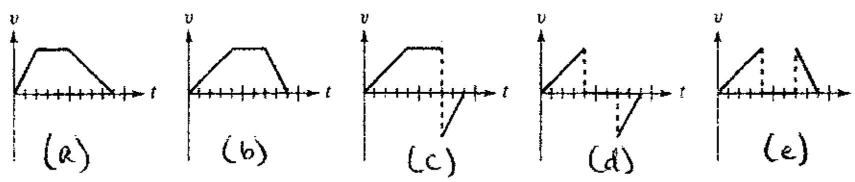
Physics 101 Fall 2003: Test 1—Multiple-Choice Questions

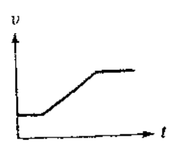
1. This diagram represents a multiflash photograph of an object moving along a horizontal surface. The positions indicated in the diagram are separated by equal time intervals. The first flash occurred just as the object started to move and the last just as it came to rest.

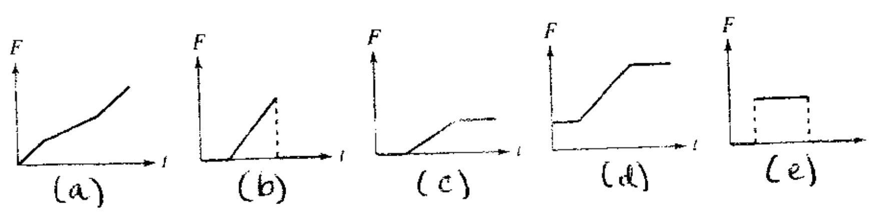


Which of the graphs a-e below best represents the object's velocity as a function of time?



2. The velocity of an object as a function of time is shown in the following graph. Which of the graphs a-e best represents the net-force vs. time relationship for the object?

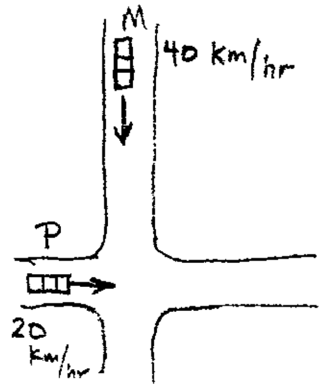


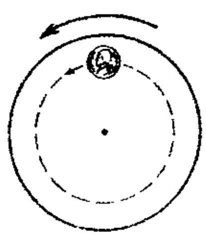


3. A diver initially moving horizontally with speed v dives off the edge of a vertical cliff and lands in the water a distance d from the base of the cliff. How far from the base of the cliff would the diver have landed if the diver initially had been moving horizontally with speed $2v$?

   (a) d
   (b) $\sqrt{2}\,d$
   (c) $2d$
   (d) $4d$
   (e) It cannot be determined unless the height of the cliff is known.

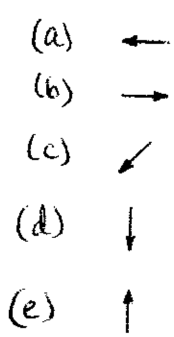
4. Two highways intersect, as shown in the figure below. At the instant shown, a police car P is approaching the intersection at 20 km/hr. Motorist M is approaching the intersection and moving at 40 km/hr. Which of the following vectors a-e best indicates the velocity of the motorist with respect to the police car?





View from Above

5. The horizontal turntable shown above rotates at a constant rate. As viewed from above, a coin on the turntable moves counterclockwise in a circle as shown. Which of the following vectors best represents the direction of the frictional force exerted on the coin by the turntable when the coin is in the position shown?



6. A locomotive pulls a series of wagons. Which is the correct analysis of the situation?

   (a) The train moves forward because the locomotive pulls forward slightly harder on the wagons than the wagons pull backward on the locomotive.

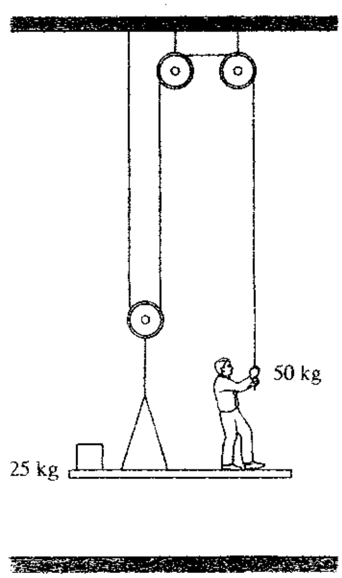
   (b) Because action always equals reaction, the locomotive cannot pull the wagons–the wagons pull backward just as hard as the locomotive pulls forward, so there is no motion.

   (c) The locomotive gets the wagon to move by giving them a tug during which the force on the wagons is momentarily greater than the force exerted by the wagons on the locomotive.

   (d) The locomotive's force on the wagons is as strong as the force of the wagons on the locomotive, but the frictional force on the locomotive is forward and large while the backward frictional force on the wagons is small.

   (e) The locomotive can pull the wagons forward only if it weighs more than the wagons.

7. A 50-kg person stands on a 25-kg platform. He pulls on the rope that is attached to the platform via the frictionless pulley system shown here. If he pulls the platform up at a steady rate, with how much force is he pulling on the rope? Ignore friction and assume $g = 10\ \mathrm{m/s^2}$.



   (a) 750 N

   (b) 250 N

   (c) 625 N

   (d) 75 N

   (e) Impossible to determine.

8. A block of weight W is pulled along a horizontal surface at constant speed v by a force F, which acts at an angle of θ with the horizontal, as shown below. The normal force exerted on the block by the surface has magnitude

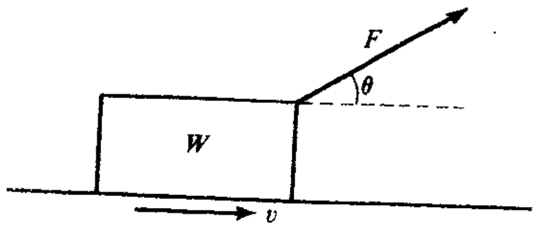
(a) $W - F\cos\theta$

(b) $W - F\sin\theta$

(c) W

(d) $W + F\cos\theta$

(e) $W + F\sin\theta$



9. A uniform rope of weight 50 newtons hangs from a hook as shown below. A box of weight 100 newtons hangs from the rope. What is the tension in the rope?

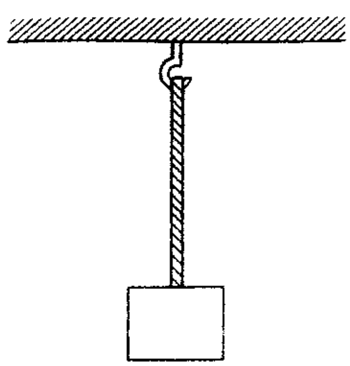
(a) 50 N throughout the rope

(b) 75 N throughout the rope

(c) 100 N throughout the rope

(d) 150 N throughout the rope

(e) It varies from 100 N at the bottom of the rope to 150 N at the top of the rope.



10. When an object of weight W is suspended from the center of a massless string as shown below, the tension at any point in the string is

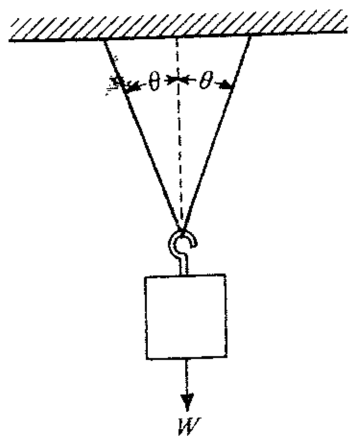
(a) $2W \cos\theta$

(b) $\frac{W \cos\theta}{2}$

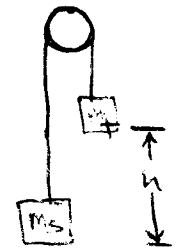
(c) $W \cos\theta$

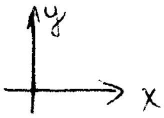
(d) $\frac{W}{2\cos\theta}$

(e) $\frac{W}{\cos\theta}$

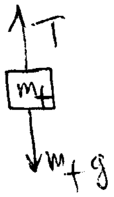


1





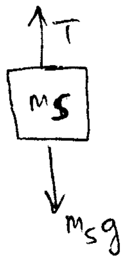
(a) EBD



$\sum_x F = 0$; $\sum_y F_y = T - m_f g = m_f \overset{0}{\cancel{a_f}}$

$\Rightarrow$ $T = m_f g$ #

Spider!



$\sum F_x = 0$; $\sum F_y = T - m_s g = m_s a_s$

$\Rightarrow$ $\frac{T - m_s g}{m_s} = a_s$

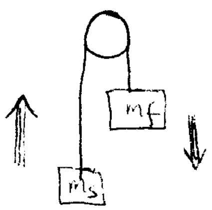
But $T = m_f g$

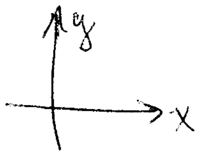
So $a_s = \frac{m_f g - m_s g}{m_s} = \left(\frac{m_f - m_s}{m_s}\right) g$ #

(b) Tension: $T = m_f g$ #

1

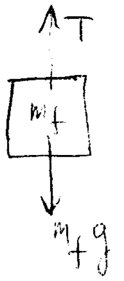
(d)





$$a_s = -a_f = a$$

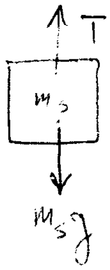
m_f: $\sum F_y = T - m_f g = m_f(-a)$



$\sum F_x = 0$

① $T - m_f g = -m_f a$

m_s: $\sum_y F = T - m_s g = m_s a$



② $T - m_s g = m_s a$

Rewrite ① $T = m_f(g-a)$

Use expression in ② to find $\underline{a}$.

$m_f(g-a) - m_s g = m_s a$

$m_f g - m_s g = m_s a + m_f a = (m_s + m_f) a$

$$a = \frac{(m_f - m_s)g}{(m_s + m_f)}$$

#

1

(e) $T = m_f(g - a)$

$$T = m_f g - m_f\left(\frac{(m_f - m_s)}{(m_s + m_f)} g\right)$$

$$T = m_f g - m_f g\left(\frac{m_f - m_s}{m_f + m_s}\right)$$

$$T = m_f g\left(1 - \frac{(m_f - m_s)}{m_f + m_s}\right) = m_f g\left(\frac{m_f + m_s - m_f + m_s}{m_f + m_s}\right)$$

$$T = m_f g\left(\frac{2m_s}{m_f + m_s}\right) \#$$

$$\Rightarrow T = \frac{2m_s m_f g}{(m_f + m_s)} \#$$

1(f) Want $y_s = y_f$

$$y_s = y_{0s} + v_{0y_s} t + \frac{1}{2} a_s t^2 \qquad \text{with } y_{0s} = 0 \,;\, v_{0y_s} = 0$$

$$y_f = y_{0f} + v_{0y_f} t + \frac{1}{2} a_f t^2 \qquad \text{with } y_{0f} = h \,;\, v_{0y_f} = 0$$

$y_s = y_f$:

$$\frac{1}{2} a_s t^2 = h + \frac{1}{2} a_f t^2$$

$$-h = \frac{1}{2}(a_f - a_s) t^2$$

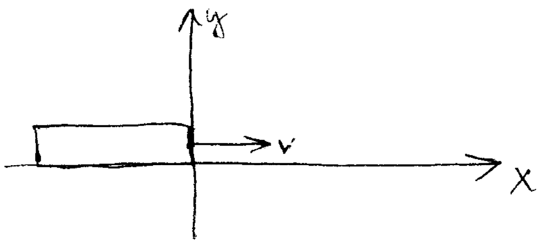
$$t^2 = \frac{-2h}{(a_f - a_s)} \qquad \text{But } a_f = -a_s$$

$$t^2 = \frac{-2h}{-2a_s} = \frac{h}{a_s}$$

when: $\Rightarrow$ $$t_1 = \sqrt{\frac{h}{a_s}} = \sqrt{\frac{h(m_s + m_f)}{(m_f - m_s) g}}$$ #

where: $$y_s(t_1) = \frac{1}{2} a_s t_1^2 = \frac{1}{2} a_s \frac{h}{a_s} = \frac{1}{2} h$$ #

2



$x_1 = 3 \times 20m = 60\ m$
$t_1 = 3$ seconds

$x_f = x_0 + v_{0x}t + \frac{1}{2}at^2$

$x_2 = 60m + 60m = 120\ m$

$t_2 = 3$ seconds $+ 5$ seconds $= 8\ s$

$\Rightarrow\ 60m = 0 + v_{0x}t_1 + \frac{1}{2}at_1^2 = v_{0x}(3s) + \frac{1}{2}a(9s^2)$

(1) $60m = 3s\ v_{0x} + \frac{9s^2}{2}a$

Also we have:

$120m = 0 + v_{0x}t_2 + \frac{1}{2}at_2^2 = v_{0x}(8s) + \frac{1}{2}a(64s^2)$

(2) $120\ m = 8s\ v_{0x} + \frac{64}{2}s^2\ a$

$60m = 3s\ v_{0x} + \frac{9}{2}s^2 a \Rightarrow v_{0x} = \frac{1}{3}\left(60m - \frac{9}{2}s^2a\right)$

$v_{0x} = 20\frac{m}{s} - \frac{3}{2}s\,a$ (from (1))

Plug v_{0x} expression into (2)

$120m = 8s\left(20\frac{m}{s} - \frac{3}{2}s\,a\right) + \frac{64}{2}s^2a$

$\Rightarrow 120m = 160m - \frac{24}{2}s^2\ a + \frac{64}{2}s^2\ a = 160m + \frac{40}{2}s^2a$

$\Rightarrow -40m = \frac{40}{2}s^2a \Rightarrow$ $\boxed{a = -2\ m/s^2}$

$$\Rightarrow v_{0x} = 20\,m/s - \frac{3\,s}{2}\left(-2\,m/s^2\right) = 20\,m/s + 3\,m/s = \underline{23\,m/s}$$

$v_{0x} = 23\,m/s$; $a_x = -2\,\frac{m}{s^2}$; $v_{fx} = 0\,m/s$

$$v_f = v_0 + at$$

$$\frac{v_f - v_0}{a} = t = \frac{0 - 23\,m/s}{-2\,m/s^2} = \frac{23}{2}\,s$$

with this information:

$$x_f = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$

$$x_f = 0 + 23\frac{m}{s}\left(\frac{23}{2}s\right) + \frac{1}{2}\left(-2\,m/s^2\right)\left(\frac{23}{2}\right)^2 s^2$$

$$x_f = \left[\frac{(23)^2}{2} - \left(\frac{23}{2}\right)^2\right]m = (23)^2\left[\frac{1}{2} - \frac{1}{4}\right]m$$

$$x_f = (23)^2\left(\frac{1}{4}\right) = \underline{132.25\,m}\ \#$$

So the train has $\frac{132.25\,m}{20\,m} = 6.6$ cars $\Rightarrow$ <u>7 cars</u>

or The train has <u>7 cars</u>.

Alternate Solution for (2)

$$\Rightarrow \quad v_{0x} = \frac{20\,m}{s} - \frac{3}{2}s\left(-2\,m/s^2\right)$$

$$v_{0x} = 20\,m/s + 3\,m/s \Rightarrow 23\,m/s \;\#$$

$$v_f = 0\,m/s$$

$$v_f^2 = v_i^2 + 2a(x_f - x_0)$$

$$x_f - x_0 = \frac{v_f^2 - v_i^2}{2a} = \frac{0 - (23)^2\,m^2/s^2}{-4\,m/s^2} = 132.25\,m$$

so the train has $\frac{132.25\,m}{20\,m} = 6.6$ cars $\Rightarrow$ 7 cars

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3

$$x_{truck} = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$

$$= 0 + 0 + \frac{1}{2}At^2$$

$$x_{truck} = \frac{1}{2}At^2$$

$$x_{stunt} = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$

$$x_{stunt} = 0 + Vt + 0$$

$$y_{stunt} = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$$

$$y_{stunt} = H + 0 - \frac{1}{2}gt^2$$

$$0 = H + 0 - \frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2H}{g}}$$

$$x_{truck} = x_{stunt} \quad ; \quad \frac{1}{2}At^2 = Vt \Rightarrow V = \frac{1}{2}At$$

$$V = \frac{1}{2}A\sqrt{\frac{2H}{g}} = A\sqrt{\frac{H}{2g}}$$

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Last Name: ______________________ First Name: ______________________

Physics 101 Fall 2003: Test 1—Multiple-Choice Answers

	A	B	C	D	E
1		X			
2					X
3			X		
4		X			
5				X	
6				X	
7		X			
8		X			
9					X
10				X	