University of Maryland, College Park

Dept. of Physics

PHYSICS 161 Lubna Rana

Spring 2003 Exam II Monday, April 14, 2003

Solutions

Special Notes:

1). This is a CLOSED BOOK examination. No Calculators, Notes or Electronic Devices are allowed.

2). There are EIGHT (8) Problems on this test.

Problem 1-4; Free Body Diagrams: 10 Points Each

Problem 5,6: 15 Points Each

Problem 7: 25 Points

Problem 8: 25 Points

3). There are SEVEN PAGES on this test.

4). The FORMULA SHEET is on the last page. You may tear it off for easy reference.

5). DO NOT UNSTAPLE OR SEPARATE ANY PAGES OTHER THAN THE FORMULA SHEET.

6).Show COMPLETE WORK and/or REASONING for CREDIT. When asked to make plots or draw vectors, draw carefully. DO NOT SCRIBBLE. If things are not drawn clearly they will be MARKED WRONG.

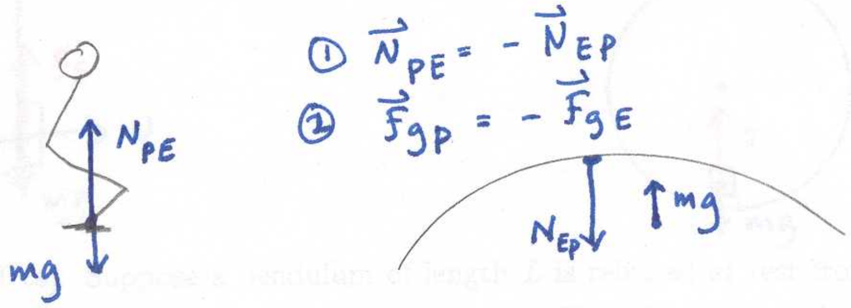
7). If a question is unclear, please ASK IMMEDIATELY.

Lots of Luck!

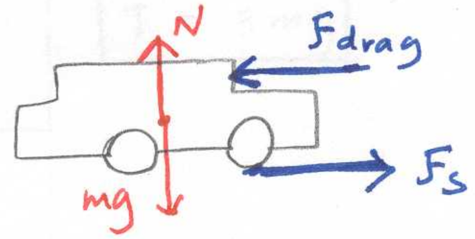
NAME: ______________________________

SECTION: ______________________________

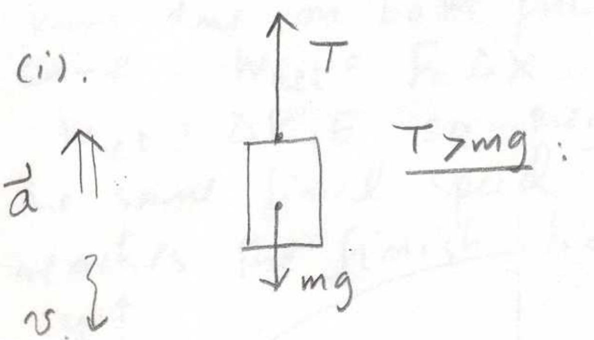
P1 [10 Pts] . Imagine that a person jumps off the floor. (i) Draw a free body diagram of the person at some instant while the person is **beginning the jump but hasn't yet left the floor**. The length of the force vectors you draw should be indicative of their relative magnitudes. (ii) Draw a separate diagram showing the forces on the earth. (iii) List the pair(s) of forces (if any) that are third law partners.

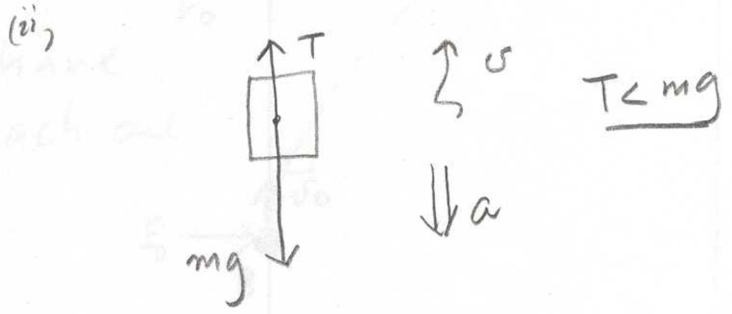


P2 [10 Pts] . A car travels at a **constant velocity** along a level, straight highway. Draw an accurate free body diagram of the car. DO NOT IGNORE AIR DRAG. The length of the force vectors should be indicative of their relative magnitudes.

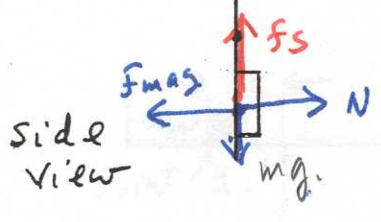


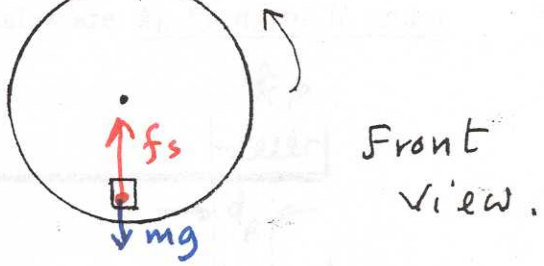
P3 [10 Pts]). Consider an elevator being moved by an attached supporting cable. (a). Draw a free body diagram of the elevator when the elevator is: (i) moving *down* with *decreasing speed* and (ii) moving *up* with *decreasing speed*. The length of the force vectors should be indicative of their relative magnitudes.





P4 [10 Pts]. A small magnet sits on a metallic disk rotating with constant speed. The magnet does not slide relative to the disk. Draw a free body diagram of the magnet when its at the bottom of its circular path. For clarity, draw a front view and a side view. Pay attention again to the relative length of the force vectors.





P5 [15 Pts]. Suppose a pendulum of length L is released at rest from an angle of 90^0 with respect to the vertical. Find the tension T in the string at $\theta = 0$ in terms of m, g and L only.

(i) $\Delta E = W_{ext} = 0$

$\Delta P.E_g + \Delta K.E = 0$

$\Rightarrow P.E_i + K.E_i = P.E_f + K.E_f$

$mgL = 0 + \frac{1}{2} m v_B^2$

$\Rightarrow \boxed{m v_B^2 = 2mgL}$ eq 1.

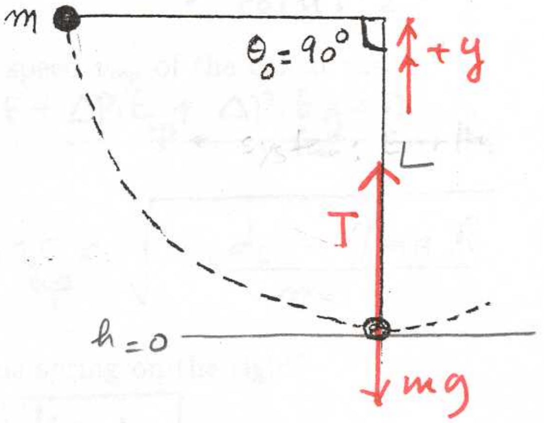
$\Sigma F_{net,r} = m a_r$

$T - mg = m \frac{v_B^2}{L}$

$\Rightarrow T = mg + \frac{m v_B^2}{L}$

$\Rightarrow T = mg + \frac{2mgL}{L}$

$\boxed{T = 3mg}$



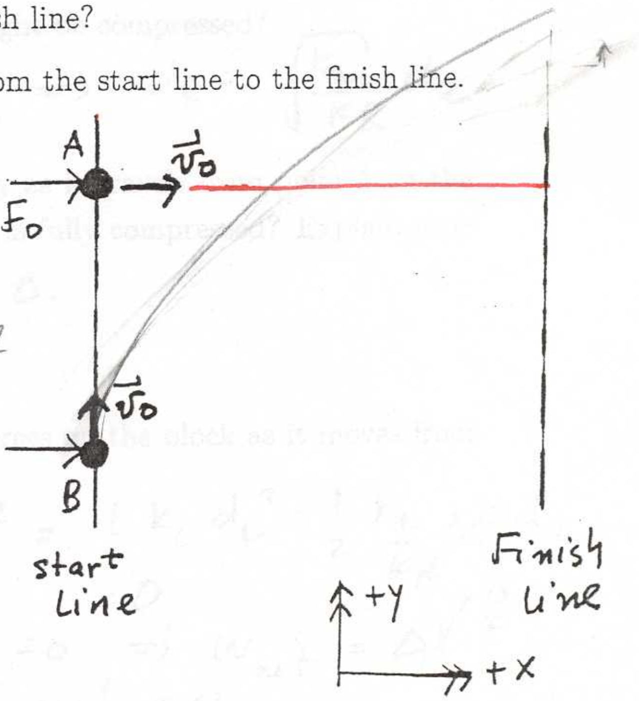
P6 [15 Pts]. Identical constant forces push two identical pucks A and B (i.e., $m_A = m_B$) continuously from a starting line to a finish line. At $t = 0$ A has an initial velocity in the $+x$ direction and B has an initial velocity v_0 in the $+y$ direction.

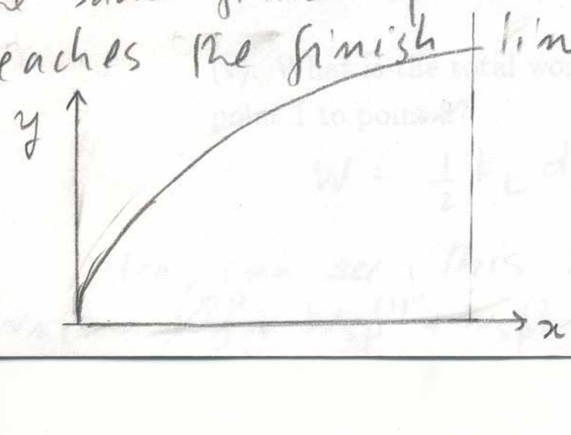
(i) What is the ratio of their speeds $\frac{v_A}{v_B}$ at the finish line?

(ii) Draw the y vs x plot of each puck's motion from the start line to the finish line. Please draw carefully, do not scribble.

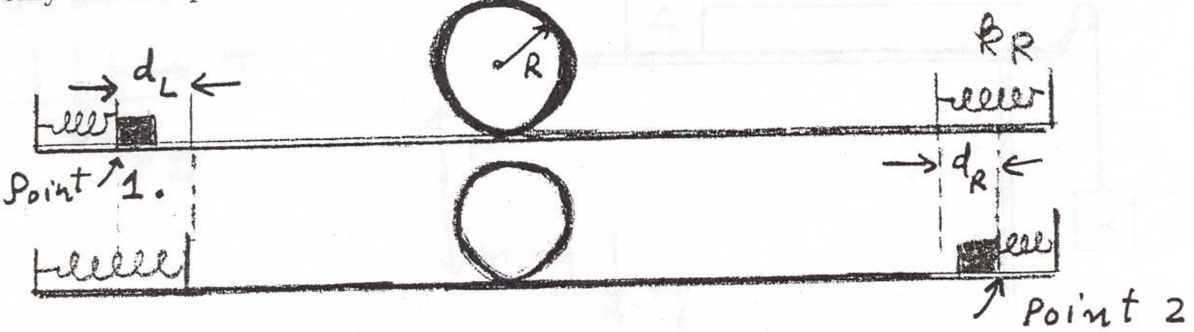
Work done on both pucks is the same – $W_{net} = F_0 \Delta x$

$W_{net} = \Delta K.E$ so they both have the same final speed when each one reaches the finish line.





P7: [25 Points; 5 Pts per part]. Consider the toy model of a loop-the-loop ride shown below. The two springs at each end of the track are NOT identical. The left spring has spring constant k_L and the right spring k_R. To operate the toy, you press a toy car of mass m say against the left spring compressing it by an amount d_L. The radius of the circular part of the track is R. Assume the track to be frictionless. The only allowed quantities in answers to the questions below are: $k_L, k_R, d_L, m, R,$ and g



(i). Assuming that the car stays on the track, find the speed v_{top} of the car at the top of the loop. $\Delta E = W_{ext}^{\,0} \Rightarrow \Delta K.E + \Delta P.E_{sp} + \Delta P.E_g = 0$

$\Rightarrow P.E_{sp\,i} = P.E_{g\,f} + K.E_f$

$\frac{1}{2} k_L d_L^2 = 2mgR + \frac{1}{2} m v^2$

$\Rightarrow m v^2 = k_L d_L^2 - 4mgR$

$\Rightarrow v_{top} = \sqrt{\dfrac{k_L d_L^2 - 4mgR}{m}}$

(ii). What is the speed with which the car approaches the spring on the right?

$P.E_{sp\,i} = K.E_f$

$\frac{1}{2} k_L d_L^2 = \frac{1}{2} m v^2$

$v^2 = \dfrac{k_L d_L^2}{m}$

$\Rightarrow v = \left(\dfrac{k_L}{m}\right)^{1/2} d_L$

(iii). By what amount d_R will the spring on the right be compressed?

$P.E_{sp\,i} = P.E_{sp\,f}$

$\Rightarrow \frac{1}{2} k_L d_L^2 = \frac{1}{2} k_R d_R^2 \Rightarrow d_R = \sqrt{\dfrac{k_L}{k_R}}\, d_L$

(iv). What is the work done on the car by gravity as it travels from point 1 on the left to point 2 on the right where the right spring is fully compressed? Explain your answer briefly. since $\Delta y = 0$, $W_g = 0$.

(v). What is the total work done by the spring forces on the block as it moves from point 1 to point 2?

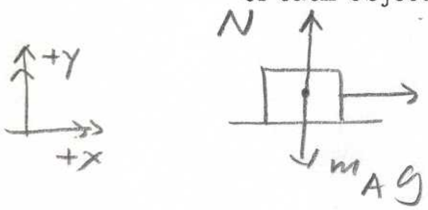
$W = \frac{1}{2} k_L d_L^2 - \frac{1}{2} k_R d_R^2 = \frac{1}{2} k_L d_L^2 - \frac{1}{2} k_R \frac{k_L}{k_R} d_L^2 = 0$

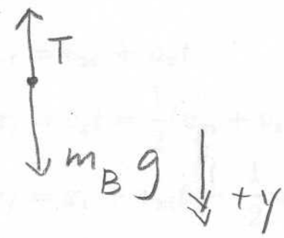
Also, can see this using $\Delta K.E = 0 \Rightarrow W_{net} = \Delta K.E^{\,0}$

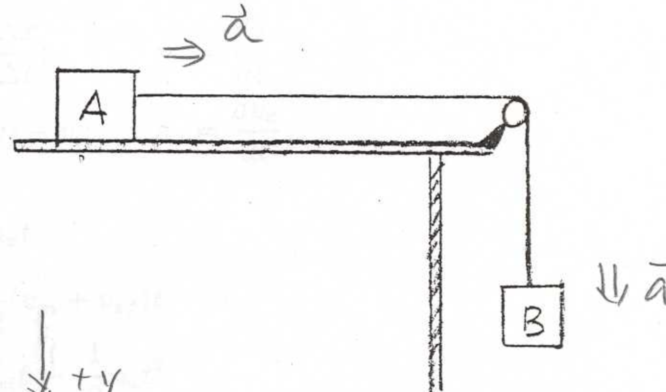
$W_{net} = W_g^{\,0} + W_{sp}^{(1)} + W_{sp}^{(2)} \Rightarrow W_{sp}^{1} + W_{sp}^{2} = 0$

Problems 8: [25 Points] __Consider the situation shown in the figure below. The system accelerates when object B is released. Assume that the masses of the pulley and the string are negligible and that friction is absent.

a). [5 Pts] Draw a free body diagram of each object.







b). [10 Pts]) Find the acceleration of each object. $\boxed{a_A = a_B = a}$

$\Sigma F_{net,x} = m_A a_x$

$\boxed{T = m_A a}$ eq 1

$\Sigma F_{net,y} = m_B a_y$

$\boxed{-T + m_B g = m_B a}$ eq 2

Substitute T from eq 1 into eq'n 2.

$-m_A a + m_B g = m_B a$

$\Rightarrow (m_A + m_B) a = m_B g$

$\Rightarrow$ (4) $\boxed{a = \dfrac{m_B g}{m_A + m_B}}$ eq 3

c). [10 Pts] Explicitly check to see if your result above gives you the answer you would expect in the following two cases: (i) $m_A >> m_B$ and (ii) $m_A << m_B$.

(i) If $m_A >> m_B$, expect $a = 0$ $\Rightarrow$ m_B negligible compared to m_A. i.e $m_B \sim 0$

yes, $a = \dfrac{m_B g}{m_A + m_B} = 0$

(ii) If $m_A << m_B$, expect block B to essentially fall freely.

In this case $m_A \sim 0$ (or $\frac{m_A}{m_B} \sim 0$) $\Rightarrow a = \frac{m_B g}{m_B} \Rightarrow a = g$ ✓

Extra Credit; [5 Pts] Suppose blocks A and B are connected by a rope with significant mass rather than by a "massless" string. Will the acceleration of the system be uniform or non-uniform? If non-uniform, will the acceleration increase or decrease as object B descends. non-uniform, increase