Physics 2101, Second Exam, Fall 2006

September 26, 2006

Name: KEY

SSN (if your Name can not be read clearly) ________________

Signiture: ________________________________

Section: (Circle one)

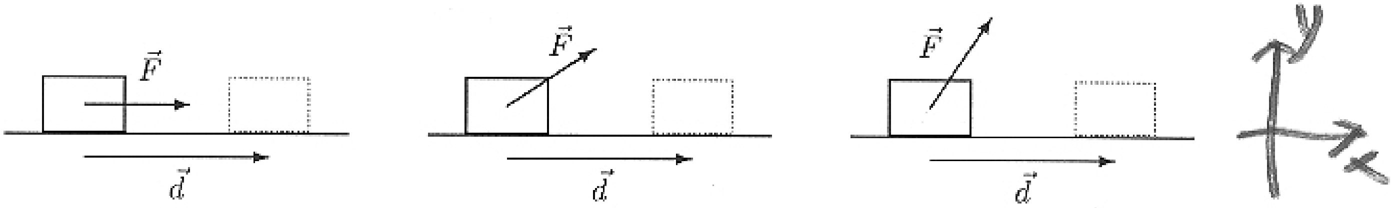
1 (Ahmad, MWF 7:40 AM)	4 (Lehner, TTh 9:10 AM)
2 (Rupnik, MWF 9:40 AM)	5 (Ahmad, TTH 12:10 PM)
3 (Rupnik, MWF 2:40 PM)	6 (Ahmad, TuTh 6:10 PM)

- Please be sure to write your name and circle your section above.
- For the *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 *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.
- **GOOD LUCK!**

Question 1 (10 points)

Three blocks of the same mass can move along a horizontal table where there is no friction. A constant force $\vec{F}$ acts on each block but in different directions as shown in cases labeled A, B, and C.

Circle the correct answer to each of the questions below.



(A) (B) (C)

(a) (2.5 pts) In which case is the acceleration of the block the least?

(i) A.
(ii) B.
(iii) C.
(iv) All tie.

$a = \frac{F_x}{m}$ $\quad F_x$ ... the smallest in (C)

(b) (2.5 pts) In which case is the work done by the force $\vec{F}$ on the block the largest? Assume that the blocks travel the same horizontal distance.

(i) A.
(ii) B.
(iii) C.
(iv) All tie.

$W = \vec{F} \cdot \vec{d} = |\vec{F}||\vec{d}|\cos\theta_{F,d}$ = max for

$\theta_{F,d}$ is the smallest at (A)

(c) (2.5 pts) Is the work done by the force of gravity in the three cases:

(i) Positive?
(ii) Zero?
(iii) Negative?

$m\vec{g} \perp \vec{d} \Rightarrow W_g = 0$

(d) (2.5 pts) Assume there is friction between the blocks and the horizontal surface. Is the work done by friction in the three cases:

(i) Positive?
(ii) Zero?
(iii) Negative?

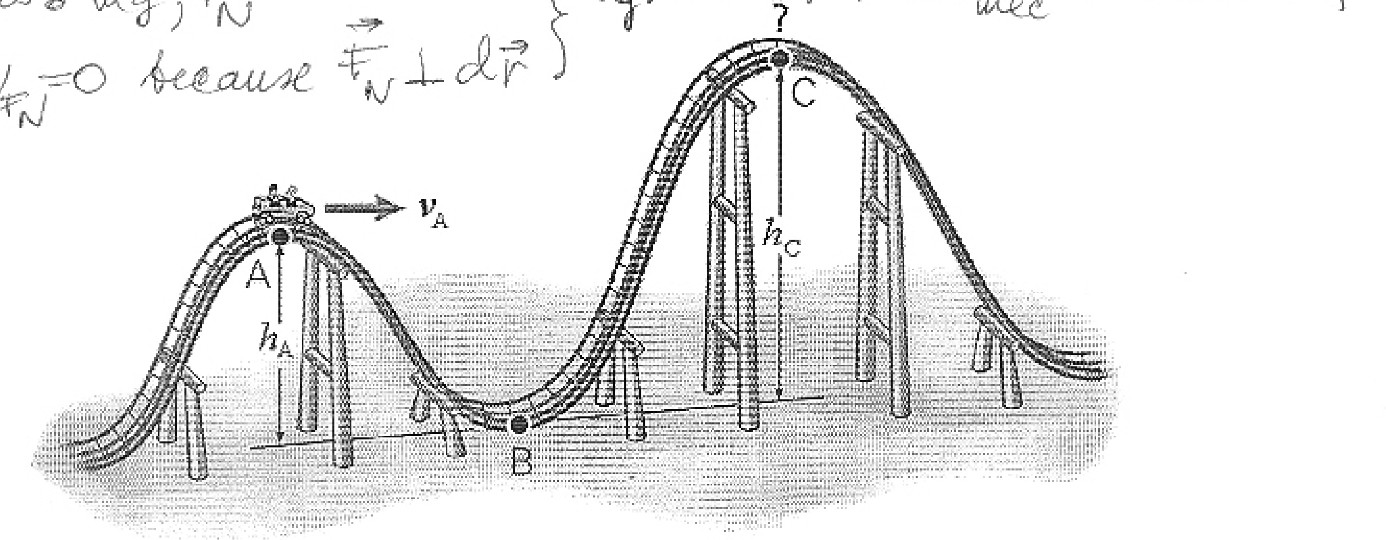
$W_F = -f_k d < 0 \quad (\theta_{f_k,d} = 180^\circ)$

Problem 1 (20 points)

A roller coaster travels on a frictionless track as shown in the figure, where $h_A = 5.5\,\text{m}$, $h_C = 8.0\,\text{m}$, and $h_B = 0\,\text{m}$. **Give the reasoning behind your approach to solve the problem.**

forces: mg, $\vec{F}_N$ $\Big\}$ $W_g \neq 0$ only $\Rightarrow \Delta E_{mec} = 0 = \Delta K + \Delta U$

$W_{F_N} = 0$ because $\vec{F}_N \perp d\vec{r}$



(a) (7 pts) If the speed of the roller coaster at point A is $v_A = 4.5\,\text{m/s}$, what is its speed at point B, v_B?

$\Delta K = -\Delta U$

$K_B - K_A = U_A - U_B$

$\frac{1}{2}\cancel{m}(v_B^2 - v_A^2) = \cancel{m}gh_A - \cancel{m}gh_B$

$v_B = \sqrt{v_A^2 + 2g(h_A - h_B)} = \sqrt{(4.5\,\frac{m}{s})^2 + 2(9.8\,\frac{m}{s^2})(5.5m - 0m)} = \underline{11.3 \simeq 11\,m/s}$

(b) (10 pts) What speed at point A would be required to reach point C with no speed left?

$\Delta K = -\Delta U$

$K_C - K_A = U_A - U_C$

$0 - \frac{1}{2}\cancel{m}v_A^2 = \cancel{m}g(h_A - h_C)$

$v_A = \sqrt{2g(h_C - h_A)} = \sqrt{2(9.8\,\frac{m}{s^2})(8.0m - 5.5m)} = \underline{7.0\,m/s}$

(c) (3 pts) If the mass of the roller coaster is doubled, would the required speed at point A increase, decrease, or remain the same? Circle the right answer. v_A does not depend on m

(i) increase (ii) decrease (iii) remain the same.

Question 2 (10 points)

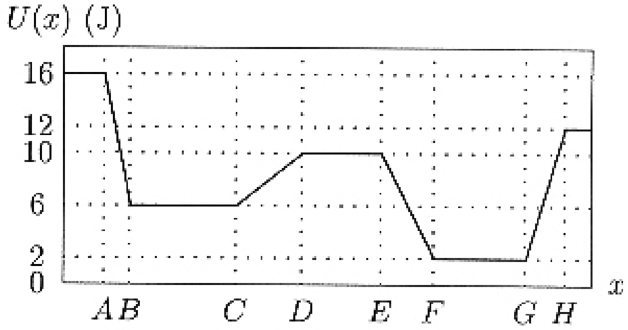
The figure below shows the potential energy U versus position x of a particle that can travel only along an x axis.
Circle the correct answer to each of the questions below.

(a) (2.5 pts) Which region has the largest force in negative direction exerted on the particle?

(i) AB
(ii) BC
(iii) CD
(iv) DE
(v) FG
(vi) GH

$F = -\frac{dU}{dx}$

the steepest slope in positive direction



(b) (2.5 pts) In which of the regions will the particle be accelerated in the $+x$ direction?

(i) AB and EF
(ii) CD and GH
(iii) BC, DE, and FG

a in $+x$ direction $\Rightarrow$ F is positive (regions with negative slope)

(c) (2.5 pts) Suppose that the particle has a mechanical energy of 12.0 J. In which region would it have the greatest kinetic energy?

(i) CD
(ii) DE
(iii) EF
(iv) FG

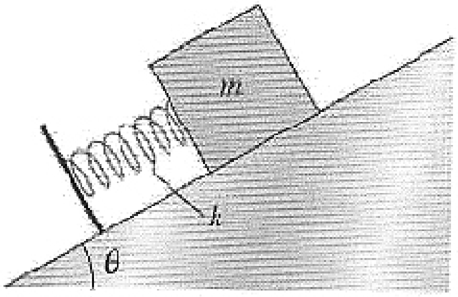
$E_{mec} = K + U$

the region with smallest U has largest K

(d) (2.5 pts) In which of the following regions, if any, would the particle be in neutral equilibrium if its mechanical energy is 10.0 J?

(i) BC and FG
(ii) DE
(iii) AB and EF
(iv) CD and GH
(v) None of the regions.

in neutral equilibrium $K=0$ and $F=0$ for a whole region of x



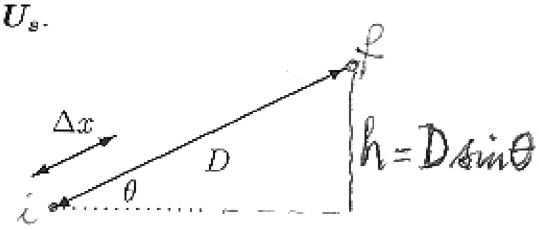
Problem 2 (20 points) A block with mass m is placed against a spring on an incline with angle θ and an unknown coefficient of kinetic friction μ_k, $\mu_k > 0$. The block is not attached to the spring. The spring, with spring constant k, is compressed by Δx and then released. $v_i = 0$ The block moves a distance D, $D > \Delta x$, along the incline before it momentarilly stops. $v_f = 0$

forces: mg, F_s, f_k, F_N

Answer the following questions related to the motion to the highest point, in terms of known quantities $\boldsymbol{m, g, D, \theta, \Delta x, k}$, and numerical constants, as necessary.

(a) (3 pts) Write down the change of the spring potential energy, $\boldsymbol{\Delta U_s}$.

$$\Delta U_s = U_{sf} - U_{si} = 0 - \frac{1}{2}k\Delta x^2 = \underline{-\frac{1}{2}k\Delta x^2}$$



(b) (3 pts) Write down the change of the block's gravitational potential energy, $\boldsymbol{\Delta U_g}$.

$$\Delta U_g = U_{gf} - U_{gi} = \underline{mgD\sin\theta}$$

(c) (4 pts) Write down the change of thermal energy of the system, $\boldsymbol{\Delta E_{\text{th}}}$, using μ_k too ($\boldsymbol{\Delta E_{\text{th}} = -W_{f_k}}$).

$$\Delta E_{th} = f_k D = \underline{\mu_k mg(\cos\theta) D}$$

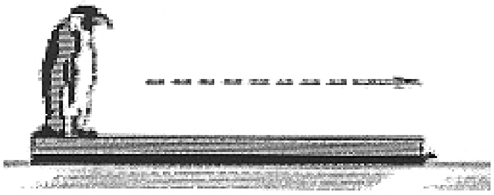
(d) (10 pts) Find the coefficient of kinetic friction, μ_k.

$W_{F_N} = 0 \Rightarrow W = \Delta K + \Delta U + \Delta E_{th}$ where $W = 0$, $\Delta U = \Delta U_g + \Delta U_s$, $\Delta K = 0$

$$\cancelto{0}{\Delta K} + \Delta U_g + \Delta U_s + \Delta E_{th} = 0$$

$$mgD\sin\theta - \frac{1}{2}k\Delta x^2 + \mu_k mgD\cos\theta = 0$$

$$\Rightarrow \mu_k = \frac{\frac{1}{2}k\Delta x^2 - mgD\sin\theta}{mgD\cos\theta} = \underline{\frac{k\Delta x^2}{2mgD\cos\theta} - \tan\theta}$$

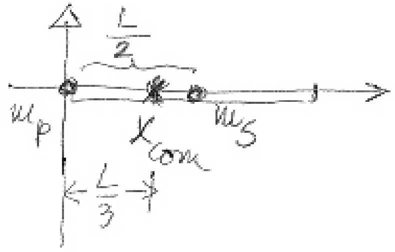


Question 3 (10 points) A penguin stands at the left edge of a uniform sled of length L, which lies stationary on **frictionless ice**. The penguin's weight is half that of the sled.

$m_p = \frac{1}{2} m_s \Rightarrow m_s = 2 m_p$

(a) (2.5 pts) The center of mass of the sled-penguin system, measured from the left end of the sled is at a distance

(i) 0.
(ii) $L/2$.
(iii) $L/3$.
(iv) $L/4$.



$x_{com} = \frac{m_p \cdot 0 + m_s \frac{L}{2}}{m_p + m_s} = \frac{2 m_p \frac{L}{2}}{3 m_p}$

$x_{com} = \frac{L}{3}$

(b) (2.5 pts) The penguin then walks to the right edge of the sled. The sled

(i) remains stationary
(ii) moves to the left
(iii) moves to the right.

the total linear momentum has to stay the same (initialy zero) $\Rightarrow \vec{p}_{pf} = -\vec{p}_{sf}$

$0 = \vec{p}_{pf} + \vec{p}_{sf}$

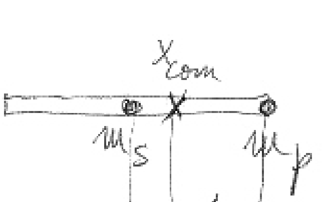
(c) (2.5 pts) When the penguin reaches the right end of the sled, how far did it move with respect to the sled?

penguin moved along the whole sled

(i) L
(ii) $L/3$
(iii) $L/2$
(iv) $2/3L$.

(d) (2.5 pts) How far did the penguin move relative to the center of mass (com) of the penguin sled system?

(i) L
(ii) $L/3$
(iii) $L/2$
(iv) $2/3L$.



• the center of mass is now $\frac{L}{3}$ from the right edge, where the penguin is (the same distance from the penguin as originally)

• so, relative to com penguin moved $\frac{L}{3} + \frac{L}{3} = 2\frac{L}{3}$

(ii) ... How far is the penguin now from com?

Problem 3 (20 points)

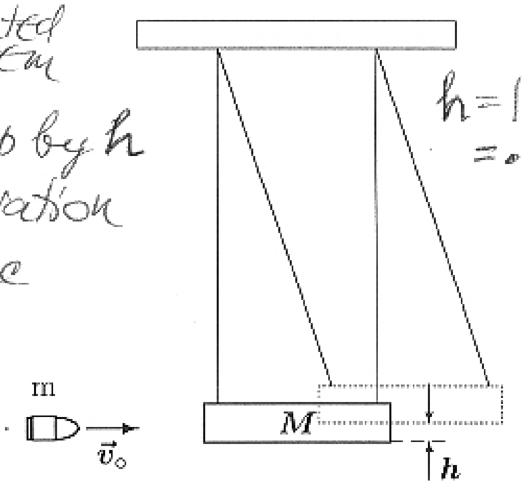
A bullet of mass $m = 10\,\text{g}$ is fired into a block of mass $M = 12\,\text{kg}$ which is hanging from a cord of length $L = 8\,\text{m}$. After the impact, the bullet comes quickly to rest inside the block. The block (with the bullet inside) swings upwards to a height of $h = 15\,\text{cm}$. The collision is complitely inelastic.
Give the reasoning behind your approach to solve the problem.

Δt of the collision $\simeq 0 \Rightarrow$ bullet-block system is isolated, $W_g = 0$

(a) (10 pts) What is the speed of the block + bullet system just after the collision?

- during collision: $W_T = 0$, $W_g = 0 \Rightarrow$ isolated system
- after collision: block-bullet moves up by h
  $W_g \neq 0$, $W_T = 0 \Rightarrow$ conservation of E_{mec}

$h = 15\,\text{cm} = .15\,\text{m}$



$$(K + \cancel{U})^{\neq 0}_{\text{bottom}} = (\cancel{K}^{0} + U)_{\text{at height } h}$$

$$\tfrac{1}{2}(m+M)v^2 = (m+M)gh$$

$$v = \sqrt{2gh} = \sqrt{2(9.8\,\tfrac{m}{s^2})(.15\,m)} = 1.7\ m/s$$

(b) (10 pts) What is the initial speed of the bullet, v_o?

$\sum p_i = \sum p_f$ … conservation of linear momentum during collision

$m v_o = (m+M)v$ … complitely inelastic collision

$$v_o = \frac{m+M}{m}v = \frac{(0.01 + 12)\,kg}{0.01\,kg}\left(1.7\,\tfrac{m}{s}\right) = 2.04 \times 10^3\ m/s$$

$$\simeq 2.0\ km/s$$