PHYS 2211 Test 4
Fall 2014

Name(print) ~~~ Test ~ Key ~~~ **Lab Section** ☺

Schatz(N), Bongiorno(M)					
Day	12-3pm	2-5pm	3-6pm	5-8pm	6-9pm
Monday		M01			
Tuesday	M03 N01		M06 N02		N03
Wednesday		M02 N07		M07	
Thursday	M04 N04		M05 N05		N06

Instructions

- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- You must show all work, including correct vector notation.
- **Correct answers without adequate explanation will be counted wrong.**
- Incorrect work or explanations mixed in with correct work will be counted wrong. Cross out anything you do not want us to grade
- Make explanations correct but brief. You do not need to write a lot of prose.
- Include diagrams!
- **Show what goes into a calculation, not just the final number, e.g.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^4$
- Give standard SI units with your results.

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet, including equations corresponding to the fundamental concepts. If a formula you need is not given, you must derive it.

If you cannot do some portion of a problem, invent a symbol for the quantity you can not calculate (explain that you are doing this), and use it to do the rest of the problem.

Honor Pledge

"In accordance with the Georgia Tech Honor Code, I have neither given nor received unauthorized aid on this test."

Armin Tamzarian

Sign your name on the line above

Period 10, December 11th (Thu) at 8:00am - 10:50am

Every semester, someone receive a zero on the final exam because they missed the exam. Please don't let this happen to you!

Stressing over a conflict?

Complete "PHYS 2211 Final Exam Schedule" on WebAssign.

Are you an ADAPTS Student? Don't forget to schedule your final with the ADAPTS office. Don't delay, spaces are limited.

PHYS 2211

Do not write on this page!

Problem	Score	Grader
Problem 1 (20 pts)		
Problem 2 (25 pts)		
Problem 3 (25 pts)		
Problem 4 (30 pts)		

Problem 1 (20 Points)

All or nothing

(a 5pts) On thanksgiving morning you take a turkey with mass 6.8 kg and temperature 10° C and placed into an oven and stay theres until the temperature of the turkey is 73° C. Determine the change in thermal energy for the turkey (circle one). The specific heat C for turkey is 2.81 J/(g C).

1.586×10^6 J $\quad$ 1.011×10^6 J $\quad$ 1.395×10^6 J $\quad$ $\boxed{1.203 \times 10^6 \text{ J}}$ $\quad$ 0.191×10^6 J $\quad$ 0 J

$$\Delta E_{th} = mC\Delta T = (6.8\,\cancel{kg})\left(\frac{1000\,\cancel{g}}{1\,\cancel{kg}}\right)\left(2.81\,\frac{J}{\cancel{g}\cancel{C}}\right)(73\cancel{C} - 10\cancel{C}) = 1.203e6\text{ J}$$

(b 5pts) You place the turkey into an oven preheated to a temperature of 177° C. During the cooking time of the turkey, the air in the oven is maintained at that same constant temperature. Determine the change in thermal energy for the oven (circle one). The specific heat C for air is 1.01 J/(g C) and the mass of air in the oven is 0.0647 kg.

1.157×10^4 J $\quad$ 1.011×10^3 J $\quad$ 9.802×10^3 J $\quad$ 0.403×10^3 J $\quad$ 0.191×10^2 J $\quad$ $\boxed{0 \text{ J}}$

$$\Delta E_{th} = mC\Delta T \longrightarrow \Delta T = 0 \longrightarrow \Delta E_{th} = 0$$

(c 5pts) It takes you 5 hours to to bring the turkey from 10° C to 73° C. During that time, the electrical grid transfers a constant 2400 Watts of power into the the oven. Take the turkey and the air in the oven to be your system. What was the thermal transfer of energy Q between the system and the surroundings (circle one)?

$\boxed{-4.20 \times 10^7 \text{ J}}$ $\quad$ -4.83×10^5 J $\quad$ 0 J $\quad$ 4.83×10^5 J $\quad$ 4.20×10^7 J

$$\Delta E_{turkey} + \cancelto{0}{\Delta E_{air}} = Q + (\text{Power})(\Delta t)$$

$$\Rightarrow Q = -\left(2400\,\frac{J}{\cancel{s}}\right)\left(\frac{60\,\cancel{sec}}{1\,\cancel{min}}\cdot\frac{60\,\cancel{min}}{1\,\cancel{hr}}\right)(5\,\cancel{hr}) + 1.203e6\text{ J} = -4.2e7\text{ J}$$

(d 5pts) You remove the turkey from the oven when it reaches 73° C and place it on the counter. You quickly cut off a piece of turkey with mass 0.5 kg and place cold cranberry sauce on the turkey. The sauce has mass 59 grams and a specific heat of 3.91 J/(g C) and initial temperature of 10° C. Assuming the turkey and cranberry sauce are a closed system, determine the final equilibrium temperature of this system (circle one).

10° C $\quad$ 14° C $\quad$ 34° C $\quad$ 54° C $\quad$ $\boxed{64° \text{ C}}$ $\quad$ 73° C J

$$\Delta E_{turkey} + \Delta E_{cranberry} = 0 \longrightarrow m_T C_T (T_f - T_T) + m_c C_c (T_f - T_c) = 0$$

$$T_f = \frac{m_T C_T T_T + m_c C_c T_c}{m_T C_T + m_c C_c} = \frac{(0.5\,\cancel{kg})(1000\,\cancel{g}/\cancel{kg})(2.81\,J/\cancel{g}C)(73\,C) + (59\,\cancel{g})(3.91\,J/\cancel{g}C)(10\,C)}{(0.5\,\cancel{kg})(1000\,\cancel{g}/\cancel{kg})(2.81\,J/\cancel{g}C) + (59\,\cancel{g})(3.91\,J/\cancel{g}C)}$$

$$= 64°C$$

Problem 2 (25 Points)

Below is an incomplete code to update the position of a ball hanging from a spring under the influence of gravity. The spring is "anharmonic" with a force proportional to the cube of the stretch $|\vec{F}_s| = k * |s|^3$, where k is a positive constant and s is the stretch of the spring. The potential energy of this spring is given by $U(s) = (1/4)ks^4$.

```
from visual import *
## constants and data
g = 9.81          ## acceleration due to gravity m/s^2
mball = 0.2099 ## mass in kg of the ball used in lab
L0 = 0.3          ## the relaxed length (m) of the spring
k = 12            ## the spring constant (N/m^3)
deltat = 1e-3  ## the time step (s)
t = 0             ## start counting time at zero

ceiling = box(pos=(0,0,0), size = (0.2, 0.01, 0.2)) ## origin is at ceiling
ball = sphere(pos=(-0.1284, -0.1434, -0.1905), radius=0.025, color=color.orange)
spring = helix(pos=ceiling.pos, color=color.cyan, thickness=.003, coils=40, radius=0.015)
spring.axis = ball.pos - ceiling.pos
ball.v = vector(-0.17, -0.371, 0.258)
## calculation loop
while t < 6.03:
## (a 10pts) Calculate the net force on the ball
```

5pts
```
L= ball.pos - ceiling.pos
s= mag(L) - L0
Lhat = norm(L)
Fspring = -k * s ** 3 * Lhat
```

5pts
```
Fgrav = vector(0, -mball * g, 0)
Fnet = Fgrav + Fspring
```

```
## (b 5pts) Update the position of the ball
```

3pts
```
ball.v = ball.v + (Fnet/mball) * deltat
```

2pts
```
ball.pos = ball.pos + ball.v * deltat
```

```
## (c 10pts) Calculate the total energy for the spring+ball system
```

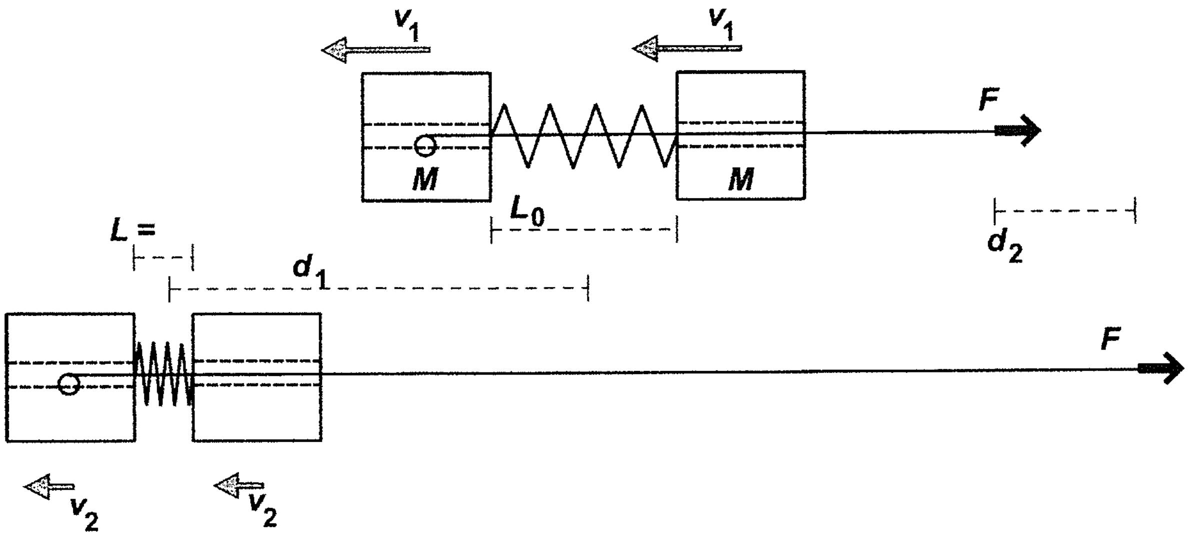
5pts 5pts
```
E = ((1/4) * k * s ** 4) + ((1/2) * mball * (mag(ball.v)) ** 2)

t = t + deltat ## update time
```

→ if mgball.pos.y is included no penalty

Problem 3 (25 Points)

Two blocks with the same mass M slide on a low-friction surface and are connected by a spring of stiffness k_s. A string is wound around a spool that is at the center of the left-hand block. The string then goes through a hole in the right-hand block. The mass of the string is negligible compared to the masses of the two blocks.



Initially the blocks are moving to the left, each with speed v_1, and the spring has its unstretched length L_0. You slow the blocks down (and compress the spring to a length L) by pulling on the string with a constant force F directed to the right. At the instant, the blocks have a smaller speed v_2 to the left and the center of mass (of the spring-blocks system) has moved a distance d_1 to the left. At that instant your hand has moved a distance d_2 to the right from where you started pulling.

(a 10pts) What is the change in the translational kinetic energy for this system?

$$\Delta K_{trans} = W$$

$$= \vec{F}_{net} \cdot \Delta\vec{r}_{cm}$$

$$= -F \cdot d_1$$

$$\begin{bmatrix} -0.5 \\ -1.5 \\ -3.0 \\ -8.0 \end{bmatrix}$$

$$\boxed{\Delta K_{trans} = -Fd_1}$$

~ or ~ $\Delta K_{trans} = \frac{1}{2}(2M)v_f^2 - \frac{1}{2}(2M)v_i^2$

$$= M(v_2^2 - v_1^2)$$

(b 15pts) Consider the real system of the two blocks, the spool, and the spring. Determine the change in the relative kinetic energy of the system (including the rotational kinetic energy of the spool) ΔK_{rel}.

$$\Delta K_{rel} + \Delta K_{trans} + \Delta U = W$$

$$\Delta K_{rel} = -\Delta K_{trans} - \Delta U + W$$

$$= -(-Fd_1) - \frac{1}{2}k(s_f^2 - \cancel{s_i^2}) + Fd_2$$

$$= Fd_1 + Fd_2 - \frac{1}{2}k(L - L_0)^2$$

$$\boxed{\Delta K_{rel} = F(d_1 + d_2) - \frac{1}{2}k(L - L_0)^2}$$

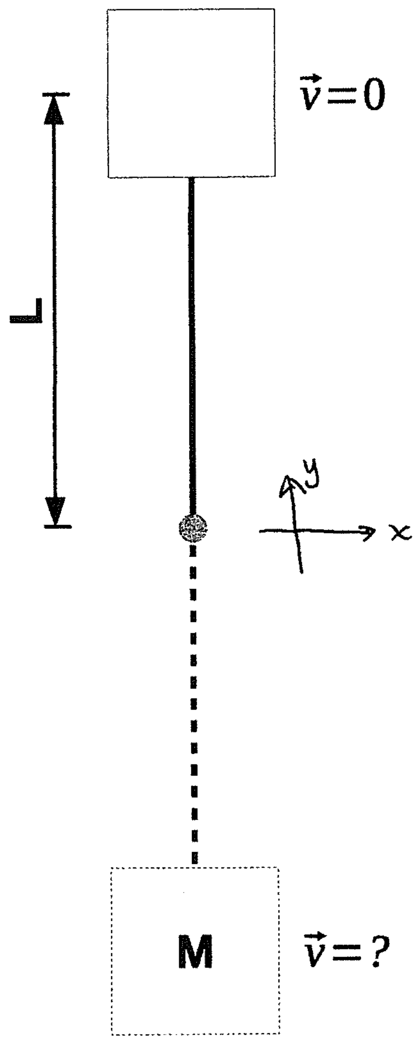
~or~ from (a)

$$\Delta K_{rel} = -M(v_f^2 - v_i^2) - \frac{1}{2}k(L - L_0)^2 + Fd_2$$

-1.0
-2.0
-4.5
-12.0

Problem 4 (30 Points)

(a 10pts) Consider a block of mass M attached to a rod of length L with negligible mass. Determine the minimum speed of the block necessary to make the block rotate through an angle of 180° as indicated in the diagram. As usual, there is a constant gravitational force pointing down.



Initial: block @ bottom

Final: block @ top

$$\Delta E = \Delta K + \Delta U = 0$$

$$\frac{1}{2}M(\cancel{v_f^2} - v_i^2) + Mg\Delta y = 0$$

$$-\frac{1}{2}Mv_i^2 + Mg(L-(-L)) = 0$$

$$\frac{1}{2}\cancel{M}v_i^2 = 2\cancel{M}gL$$

$$v_i^2 = 4gL$$

$$\boxed{v_i = 2\sqrt{gL}}$$

- 0.5
- 1.5
- 3.0
- 8.0

(b 10pts) Now consider a bullet of mass m that is traveling with an unknown speed before passing straight through the block. Before the collision, the block is motionless. After the collision the bullet leaves the block with exactly half of its initial speed and the block has exactly the speed required to rotate through an angle of 180° (i.e. to go over the top) as found in part (a). Calculate the initial speed of the bullet.

Initial: just before collision: $V_{block_i} = 0$, $V_{bullet_i} = V$

Final: just after collision: $V_{block_f} = 2\sqrt{gL}$, $V_{bullet_f} = \frac{V}{2}$

$$mV = m\frac{V}{2} + M(2\sqrt{gL}) \quad \leftarrow \text{conservation of linear momentum}$$

$$mV - \frac{1}{2}mV = 2M\sqrt{gL}$$

$$\frac{1}{2}mV = 2M\sqrt{gL}$$

$$\boxed{V = \frac{4M\sqrt{gL}}{m}}$$

−0.5
−1.5
−3.0
−8.0

(c 10pts) Calculate the change in internal energy of the block and bullet system from just before to just after the collision.

$$\Delta E = \Delta K_{block} + \Delta K_{bullet} + \Delta E_{int} = 0$$

$$\frac{1}{2}M\left(V_{f_{block}}^2 - \cancel{V_{i_{block}}^2}^{\,0}\right) + \frac{1}{2}m\left(V_{f_{bullet}}^2 - V_{i_{bullet}}^2\right) + \Delta E_{int} = 0$$

$$\frac{1}{2}M(4gL) + \frac{1}{2}m\left[\left(\frac{1}{2}\frac{4M\sqrt{gL}}{m}\right)^2 - \left(\frac{4M\sqrt{gL}}{m}\right)^2\right] + \Delta E_{int} = 0$$

$$2MgL + \frac{1}{2}\cancel{m}\left(\frac{4M^2gL}{m^{\cancel{2}}} - \frac{16M^2gL}{m^{\cancel{2}}}\right) + \Delta E_{int} = 0$$

$$2MgL - \left(\frac{M^2gL}{m}\right)6 + \Delta E_{int} = 0$$

$$\boxed{\Delta E_{int} = \frac{M^2gL}{6m} - 2MgL}$$

−0.5
−1.5
−3.0
−8.0

This page is for extra work, if needed.

Things you must have memorized

The Momentum Principle Definition of Momentum	The Energy Principle Definition of Velocity	The Angular Momentum Principle Definition of Angular Momentum
Definitions of angular velocity, particle energy, kinetic energy, and work		

Other potentially useful relationships and quantities

$$\gamma \equiv \frac{1}{\sqrt{1-\left(\frac{|\vec{v}|}{c}\right)^2}}$$

$$E^2 - (pc)^2 = \left(mc^2\right)^2$$

$$\frac{d\vec{p}}{dt} = \frac{d|\vec{p}|}{dt}\hat{p} + |\vec{p}|\frac{d\hat{p}}{dt}$$

$$\vec{F}_{\parallel} = \frac{d|\vec{p}|}{dt}\hat{p} \text{ and } \vec{F}_{\perp} = |\vec{p}|\frac{d\hat{p}}{dt} = |\vec{p}|\frac{|\vec{v}|}{R}\hat{n}$$

$$\vec{F}_{grav} = -G\frac{m_1 m_2}{|\vec{r}|^2}\hat{r}$$

$$U_{grav} = -G\frac{m_1 m_2}{|\vec{r}|}$$

$$\left|\vec{F}_{grav}\right| \approx mg \text{ near Earth's surface}$$

$$\Delta U_{grav} \approx mg\Delta y \text{ near Earth's surface}$$

$$\vec{F}_{elec} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|^2}\hat{r}$$

$$U_{elec} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|}$$

$$\left|\vec{F}_{spring}\right| = k_s s$$

$$U_{spring} = \frac{1}{2}k_s s^2$$

$$U_i \approx \frac{1}{2}k_{si}s^2 - E_M$$

$$\Delta E_{thermal} = mC\Delta T$$

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \ldots}{m_1 + m_2 + \ldots}$$

$$I = m_1 r_{1\perp}^2 + m_2 r_{2\perp}^2 + \ldots$$

$$K_{tot} = K_{trans} + K_{rel}$$

$$K_{rel} = K_{rot} + K_{vib}$$

$$K_{rot} = \frac{L_{rot}^2}{2I}$$

$$K_{rot} == \frac{1}{2}I\omega^2$$

$$\vec{L}_A = \vec{L}_{trans,A} + \vec{L}_{rot}$$

$$\vec{L}_{rot} = I\vec{\omega}$$

$$\omega = \sqrt{\frac{k_s}{m}}$$

$$v = d\sqrt{\frac{k_{si}}{m_a}}$$

$$Y = \frac{F/A}{\Delta L/L} \text{ (macro)}$$

$$Y = \frac{k_{si}}{d} \text{ (micro)}$$

$$\Omega = \frac{(q+N-1)!}{q!\,(N-1)!}$$

$$S \equiv k\ln\Omega$$

$$\frac{1}{T} \equiv \frac{\partial S}{\partial E}$$

$$\Delta S = \frac{Q}{T} \text{ (small } Q\text{)}$$

$$\text{prob}(E) \propto \Omega\,(E)\,e^{-\frac{E}{kT}}$$

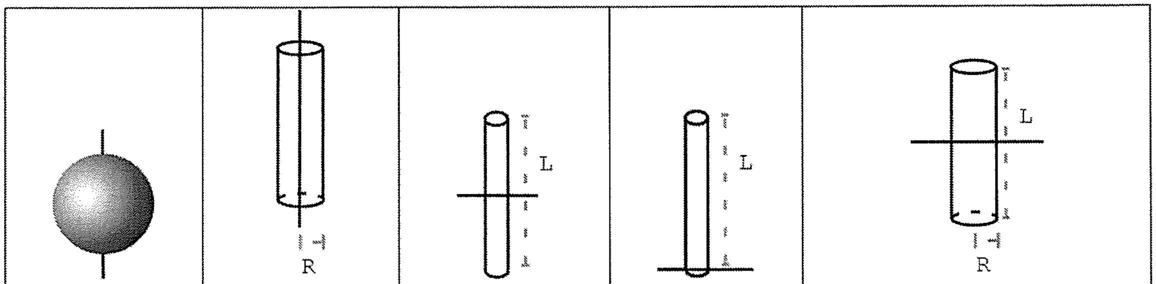
$$E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1,2,3\ldots$$

$$E_N = N\hbar\omega_0 + E_0 \text{ where } N = 0,1,2\ldots \text{ and } \omega_0 = \sqrt{\frac{k_{si}}{m_a}} \text{ (Quantized oscillator energy levels)}$$

Moment of intertia for rotation about indicated axis

The cross product

$$\vec{A} \times \vec{B} = \langle A_y B_z - A_z B_y, A_z B_x - A_x B_z, A_x B_y - A_y B_x \rangle$$



$I = \frac{2}{5}MR^2$	$I = \frac{1}{2}MR^2$	$I = \frac{1}{12}ML^2$	$I = \frac{1}{3}ML^2$	$I = \frac{1}{12}ML^2 + \frac{1}{4}MR^2$

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N $\cdot$ m^2/kg^2
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 N $\cdot$ m^2/C^2
Proton charge	e	1.6×10^{-19} C
Electron volt	1 eV	1.6×10^{-19} J
Avogadro's number	N_A	6.02×10^{23} atoms/mol
Plank's constant	h	6.6×10^{-34} joule $\cdot$ second
hbar $= \frac{h}{2\pi}$	$\hbar$	1.05×10^{-34} joule $\cdot$ second
specific heat capacity of water	C	4.2 J/g/K
Boltzmann constant	k	1.38×10^{-23} J/K

milli	m	1×10^{-3}	kilo	K	1×10^{3}
micro	μ	1×10^{-6}	mega	M	1×10^{6}
nano	n	1×10^{-9}	giga	G	1×10^{9}
pico	p	1×10^{-12}	tera	T	1×10^{12}