PHYS 2211 Test 3
Spring 2012

Name(print)_____ Lab Section_____

Lab section by day and time: Greco(M), Schatz(K,N)			
Day	12:05pm-2:55pm	3:05pm-5:55pm	6:05pm-8:55pm
Monday	M01 K01	M02 N01	
Tuesday	M03 N03	M04 K03	K02 N02
Wednesday	K05 N05	M05 N06	M06 K06
Thursday	K07 N07	M07 K08	M08 N08

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.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8 \times 10^{-3})(5 \times 10^{6})}{(2 \times 10^{-5})(4 \times 10^{4})} = 5 \times 10^{4}$

- 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.

The final exam is scheduled for Monday April 30th from 8:00 to 10:50 AM. If you have a conflict, please contact Dr. Greco by April 23rd with the following

Your full name, Lab section, Conflicting class.

ADAPTS Student will need to schedule their final exam with the ADAPTS office as soon as possible.

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

Problem 1 (25 Points)

An alpha particle (two protons and two neutrons) moving with momentum p is shot toward a carbon-12 nucleus (containing six protons and six neutrons) that is moving with the same momentum p toward the alpha particle. The speeds are non-relativistic.

(a 6pts) For this process, as a function of the separation r between the alpha particle and the carbon-12 nucleus, plot $K_1 + K_2$ (the sum of the kinetic energies of the two nuclei), plot the potential energy, and plot the sum of the kinetic energies and the potential energy. Label each of the three plots clearly.


(b 9pts) What is the minimum momentum p necessary, so that the alpha particle and carbon-12 nucleus come in contact? The radius of the alpha particle is R_α and the radius of the carbon-12 nucleus is R_c. Your answer should be symbolic.

(c 10pts) After coming into contact, the two particles fuse creating an oxygen-16 nucleus (containing eight protons and eight neutrons) and a photon. Determine the sum of the kinetic energy of the oxygen nucleus and the energy of the photon. Your answer should be symbolic.

Problem 2 (25 Points)

A spring with stiffness k and relaxed length
L_0 stands vertically on a table. A mass M
sits on the spring in static equilibrium.
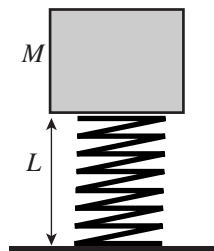
(a 5pts) What is the compressed length of the spring L in terms of the variables given above and any known constants.

(b 10pts) Using your hand, you compress the spring so that the spring now has a length of $L/3$ and you hold the spring motionless at this position. Calculate how much work your hand did? Explain if the sign you obtained for this work is reasonable using a different argument from the one you employed to calculate the work.

(c 10pts) You let go of the block and watch it shoot straight up into the air. How high does the block go before it starts to fall back towards the ground? Be sure to express your answers in terms of the variables given above.

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Problem 3 (25 Points)
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The following two problems deal with the motion of a baseball near the surface of the Earth. For both of these problems, you will need to take into account the force of air resistance $\vec{F}_{air} = -\frac{1}{2}\rho C A v^2 \hat{v}$ acting on the baseball. A typical baseball has mass 0.155 kg and radius 0.035 m. Take the density of air to be 1.3 $\frac{kg}{m^3}$ and the bluntness coefficient for the baseball to be $C = 0.35$.

(a 15pts) At a certain instant in time the baseball's position is $\langle 25.00, 12.00, 3.00 \rangle$ m and its velocity is $\langle 40.00, 30.00, 0 \rangle$ m/s. Calculate the net force acting on the baseball. Your answer should be a vector.

(b 10pts) A second baseball is released from rest at a very great height. Determine the terminal speed of the baseball as it falls to the Earth.

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Problem 4 (25 Points)
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You put a thin metal pot containing 2 liters (2000 grams) of room-temperature (20°C) water on a hot electric stove. You also stir the water vigorously with a 100 watt electric beater, which does 100 J of work on the water every second. You observe that after 5 minutes (300 s) the water starts to boil (temperature 100°C).

(a 10pts) What was the change $\Delta E_{\text{thermal}}$ in the water?

(b 10pts) What was the transfer of energy Q due to a temperature difference into the water from the surroundings?

(c 5pts) What was the change $\Delta E_{\text{surroundings}}$ in the rest of the Universe (the surroundings, including the stove and the beater)?

This page is for extra work, if needed.

Things you must have memorized

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

Other potentially useful relationships and quantities

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

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

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

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

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

$$\left|\vec{F}_{spring}\right| = k_s s \qquad\qquad U_{spring} = \frac{1}{2}k_s s^2$$

$$U_i \approx \frac{1}{2}k_{si}s^2 - E_M \qquad\qquad \Delta E_{thermal} = mC\Delta T$$

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \dots}{m_1 + m_2 + \dots} \qquad\qquad I = m_1 r_{1\perp}^2 + m_2 r_{2\perp}^2 + \dots$$

$$K_{tot} = K_{trans} + K_{rel} \qquad\qquad K_{rel} = K_{rot} + K_{vib}$$

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

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

$$\omega = \sqrt{\frac{k_s}{m}} \qquad\qquad v = d\sqrt{\frac{k_{si}}{m_a}}$$

$$Y = \frac{F/A}{\Delta L/L} \text{ (macro)} \qquad\qquad Y = \frac{k_{si}}{d} \text{ (micro)}$$

$$\Omega = \frac{(q + N - 1)!}{q!\,(N - 1)!} \qquad\qquad S \equiv k\ln\Omega$$
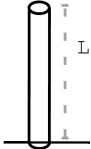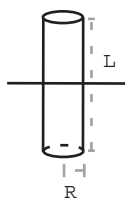
$$\frac{1}{T} \equiv \frac{\partial S}{\partial E} \qquad\qquad \Delta S = \frac{Q}{T} \text{ (small } Q)$$

$$\text{prob}(E) \propto \Omega\left(E\right)e^{-\frac{E}{kT}} \qquad\qquad E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1, 2, 3\dots$$

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

Moment of intertia for rotation about indicated axis

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

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	$\dfrac{1}{4\pi\epsilon_0}$	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 $= \dfrac{h}{2\pi}$	$\hbar$	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}