PHYS 2211 Test 3
Spring 2013

Name(print) $\boxed{\text{KEY}}$ Lab Section

Fenton(K), Curtis(N), Greco(HP/M)			
Day	12-3pm	3-6pm	6-9pm
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.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^{4}$
- 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."

Cave Johnson

Sign your name on the line above

PHYS 2211

Do not write on this page!

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

Problem 1 (25 Points)

You stand on a spherical asteroid of uniform density whose mass is 2×10^{16} kg and whose radius is 10 km (1×10^4 m). These are typical values for small asteroids.

(a 15pts) How fast do you have to throw a rock straight up so that it never comes back to the asteroid and ends up traveling at a speed of 5 m/s when it is very far away?

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

$$K_f - K_i + \cancel{U_f} - U_i = 0$$

$$\frac{1}{2}m(v_f^2 - v_i^2) - \left(\frac{-GMm}{r}\right) = 0$$

$$\frac{1}{2}\cancel{m}(v_f^2 - v_i^2) = -\frac{GM\cancel{m}}{r}$$

$$v_f^2 - v_i^2 = \frac{-2GM}{r}$$

$$-v_i^2 = \frac{-2GM}{r} - v_f^2$$

$$v_i^2 = \frac{2GM}{r} + v_f^2$$

$$\rightarrow v_i^2 = \frac{(2)(6.67e{-}11)(2e16)}{1e4} + (5)^2$$

$$= 266.8 + 25$$

$$v_i^2 = 291.8$$

$$\star \boxed{v_i = 17.08 \text{ m/s}} \star$$

-1.0
-2.0
-4.5
-12

(b 10pts) Suppose you use a spring to launch a payload horizontally from the asteroid so that the payload ends up far from the asteroid, traveling at a speed of 5 m/s. The payload has a mass of 24 kg. If the spring is to be compressed initially an amount 1.3 m, what stiffness k_s must the spring be designed to have?

Initial state: at rest on the spring.
Final state: leaving the spring with velocity found in part (a).

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

$$K_f - \cancel{K_i} + \cancel{U_f} - U_i = 0$$

$$K_f - U_i = 0$$

$$\frac{1}{2}mv_f^2 - \frac{1}{2}k_s s^2 = 0$$

$$k_s s^2 = mv_f^2$$

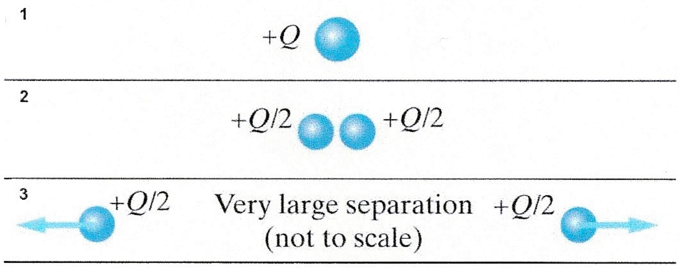
$$k_s = \frac{mv_f^2}{s^2}$$

$$k_s = \frac{(24)(17.08)^2}{(1.3)^2} = \frac{(24)(291.8)}{1.69} \Rightarrow \star \boxed{k_s = 4143.9 \text{ N/m}} \star$$

-0.5
-1.5
-3.0
-8

Problem 2 (25 Points)

In a fission reaction, plutonium-240 (Pu-240) splits to form two silver atoms (Ag-120). Pu-240 has an electric charge $Q = 94e$ and the two silver atoms each have an electric charge $Q/2 = 47e$. The rest mass of Pu-240 is 240.002 u and the rest mass of Ag-120 is 119.893 u, where 1 u = 1.6605e-27 kg.



(a 15pts) Using energy considerations, calculate the distance between centers of the silver atoms just after fission, state (2), when they are momentarily at rest. You should assume that the plutonium atom in state (1) was initial at rest.

Initial state: Plutonium ($E_{rest,Pu}$)

Final state: Two silver ($2E_{rest,Ag} + U$)

$$\Delta E = 0$$

$$E_f - E_i = 0$$

$$2E_{rest,Ag} + U - E_{rest,Pu} = 0$$

$$2m_{Ag}c^2 - m_{Pu}c^2 + \frac{1}{4\pi\epsilon_0}\frac{q_{Ag}q_{Ag}}{r} = 0$$

$$(2m_{Ag} - m_{Pu})c^2 = \frac{-1}{4\pi\epsilon_0}\frac{q_{Ag}^2}{r}$$

$$\left(\frac{-4\pi\epsilon_0}{q_{Ag}^2}\right)(2m_{ag} - m_{pu})c^2 = \frac{1}{r}$$

$$r = \left(\frac{-q_{Ag}^2}{4\pi\epsilon_0}\right)\left(\frac{1}{(2m_{ag} - m_{pu})c^2}\right)$$

$$= \frac{-(9e9)(47^2)(1.6e-19)^2}{(1.6605e-27)[(2)(119.893) - 240.002](9e16)}$$

$$= \frac{-5.089536e-25}{-3.228012e-11}$$

$$\boxed{r = 1.58e-14 \text{ m}}$$

-1.0

-2.0

-4.5

-12

(b 10pts) Calculate the total kinetic energy of the two silver atoms in state (3), when they are far from each other.

Initial state: Two silver atoms (state 2)
Final state: Two silver atoms far away (state 3)

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

$$K_f - \cancel{K_i} + \cancel{U_f} - U_i = 0$$

$$K_f - U_i = 0$$

$$K_f = U_i = \frac{1}{4\pi\epsilon_0} \frac{q_{Ag} q_{Ag}}{r}$$

$$K_f = \frac{(9e9)(47^2)(1.6e-19)^2}{(1.58e-14)}$$

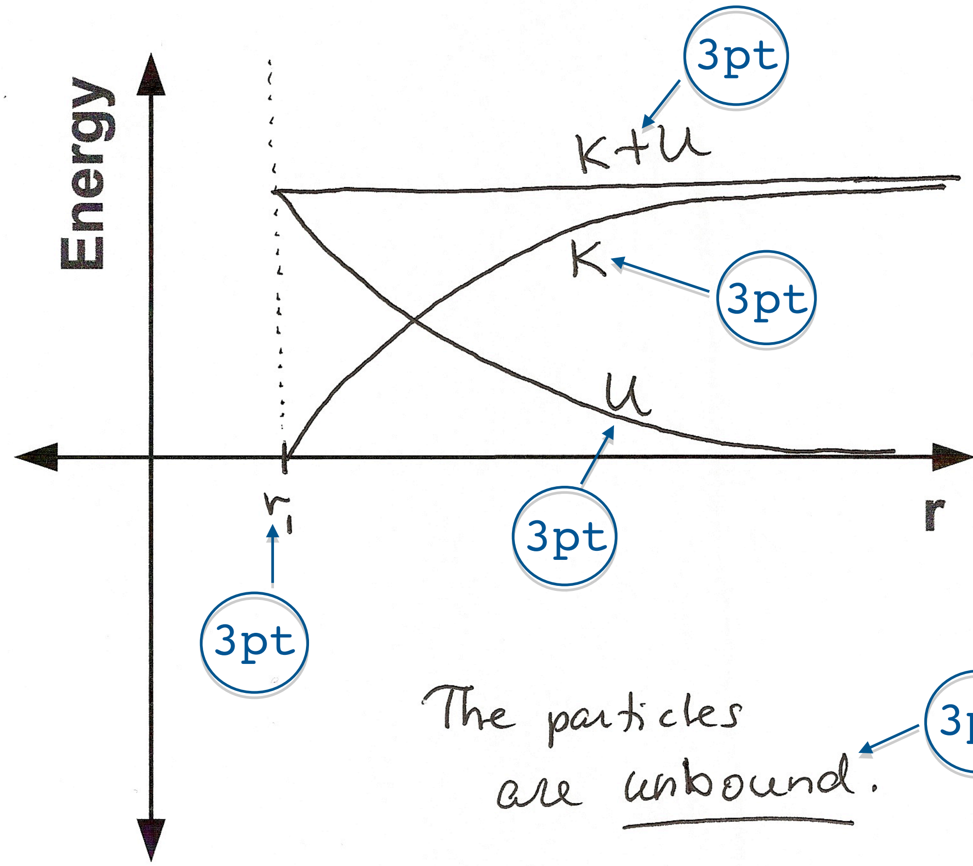
$$\boxed{K_f = 3.22e-11 \text{ Joules}}$$

(or ~201 MeV)

-0.5
-1.5
-3.0
-8

Problem 3 (25 Points)

(a 15pts) Two negatively charged particles are released from rest with an initial separation of r_1. The repulsive force between them then causes them to fly apart. Draw a graph of their potential energy, kinetic energy and total energy K+U versus their separation. Label r_1 on the graph clearly. Are these particles bound or unbound?



The particles are unbound.

3pt

(b 5pts) A child pushes a toy car along a track with a constant force of $\vec{F} =< 5, -15, 0 >$ N, and the car moves from $\vec{r}_i =< 10, 5, 2 >$ m to $\vec{r}_f =< 15, -5, 2 >$. Determine the amount of work done on the car by the child.

$$\Delta\vec{r} = \vec{r}_f - \vec{r}_i = \langle 15, -5, 2\rangle - \langle 10, 5, 2\rangle$$

2pt

$$= \langle 15-10, -5-5, 2-2\rangle$$

$$\Delta\vec{r} = \langle 5, -10, 0\rangle$$

$$W = \vec{F}\cdot\Delta\vec{r} = \langle 5, -15, 0\rangle \cdot \langle 5, -10, 0\rangle$$

2pt

$$= (5)(5) + (-15)(-10) + (0)(0)$$

$$= 25 + 150$$

$$\boxed{W = 175\ \text{J}}$$

1pt

(c 5pts) Determine the angle between the child's force and the displacement of the car.

$$|\vec{F}| = \sqrt{5^2 + (-15)^2 + 0^2} = \sqrt{250} = 15.81$$ 1pt

$$|\Delta\vec{r}| = \sqrt{5^2 + (-10)^2 + 0^2} = \sqrt{125} = 11.18$$ 1pt

$$\vec{F}\cdot\Delta\vec{r} = |\vec{F}|\,|\Delta\vec{r}|\cos\theta \Rightarrow \cos\theta = \frac{\vec{F}\cdot\Delta\vec{r}}{|\vec{F}|\,|\Delta\vec{r}|}$$ 2pt

$$\cos\theta = \frac{175}{(15.81)(11.18)} = \frac{175}{176.76} = 0.99$$

$$\cos\theta = 0.99 \Rightarrow \theta = \cos^{-1}(0.99) \Rightarrow \boxed{\theta = 8.1^\circ}$$

1pt

Problem 4 (25 Points)

Prof. Curtis, Prof. Fenton, and Dr. Greco each purchase a cup of coffee. The cup contains 350 grams of coffee at 93° C. The specific heat of coffee is 4.2 J/(g·C). The cups are well insulated so that no energy is transferred between the coffee and the cup.

(a 10pts) Prof. Curtis prefers to drink her coffee at 82° C. Cream has a specific heat of 3.8 J/(g·C) and an initial temperature of 5° C. How many grams of cream should she add to bring her coffee to the desired temperature?

$$\Delta E_{th} = m C \Delta T$$

Coffee: $\Delta E_1 = m_1 C_1 \Delta T_1$

Cream: $\Delta E_2 = m_2 C_2 \Delta T_2$

$T_f = 82°C$ for both coffee and cream

$$\Delta E_1 + \Delta E_2 = 0$$

$$m_1 C_1 \Delta T_1 + m_2 C_2 \Delta T_2 = 0$$

$$(350)(4.2)(82-93) + (m_2)(3.8)(82-5) = 0$$

$$-16170 + 292.6 m_2 = 0$$

$$292.6 m_2 = 16170$$

$$m_2 = \frac{16170}{292.6}$$

$$\boxed{m_2 = 55.26 g}$$

Professor Curtis should add 55.26 grams of cream to her coffee.

-0.5
-1.5
-3.0
-8

(b 10pts) Dr. Greco likes to add sugar to his coffee. Sugar has a specific heat of 1.2 J/(gr·C) and an initial temperature of 20° C. Dr. Greco adds 16 grams of sugar to his coffee and stirs. By stirring the coffee, Dr. Greco is doing 15 J of work on his coffee. What is the final temperature of the coffee after the liquid comes to rest?

$$\Delta E_c + \Delta E_s = W$$

$$m_c C_c \Delta T_c + m_s C_s \Delta T_s = W$$

$$(350)(4.2)(T_f - 93) + (16)(1.2)(T_f - 20) = 15$$

$$1470(T_f - 93) + 19.2(T_f - 20) = 15$$

$$1470 T_f - 136710 + 19.2 T_f - 384 = 15$$

$$1489.2 T_f - 137094 = 15$$

$$1489.2 T_f = 15 + 137094$$

$$1489.2 T_f = 137109$$

$$T_f = \frac{137109}{1489.2}$$

$$\star \boxed{T_f = 92.07° C} \star$$

$$\boxed{\begin{array}{c} -0.5 \\ -1.5 \\ -3.0 \\ -8 \end{array}}$$

(c 5pts) After purchasing his coffee, Prof. Fenton decides to take a siesta. When he wakes up, he finds that his coffee has reached thermal equilibrium with the air and is at 20° C. Taking the coffee as the system, determine what the thermal transfer of energy Q was between the system and the surroundings.

2pt $\rightarrow \Delta E_{coffee} = Q$

$$m C \Delta T = Q \leftarrow$$ 2pt

$$(350)(4.2)(20 - 93) = Q$$

$$\star \boxed{Q = -107310 \text{ J}} \star$$

1pt

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

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

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

$$\vec{F}_{grav}=-G\frac{m_1m_2}{|\vec{r}|^2}\hat{r} \qquad U_{grav}=-G\frac{m_1m_2}{|\vec{r}|}$$

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

$$\vec{F}_{elec}=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{|\vec{r}|^2}\hat{r} \qquad U_{elec}=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{|\vec{r}|}$$

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

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

$$\vec{r}_{cm}=\frac{m_1\vec{r}_1+m_2\vec{r}_2+\ldots}{m_1+m_2+\ldots} \qquad I=m_1r_{1\perp}^2+m_2r_{2\perp}^2+\ldots$$

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

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

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

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

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

$$\Omega=\frac{(q+N-1)!}{q!\,(N-1)!} \qquad S\equiv k\ln\Omega$$

$$\frac{1}{T}\equiv\frac{\partial S}{\partial E} \qquad \Delta S=\frac{Q}{T}\text{ (small }Q\text{)}$$

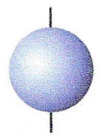
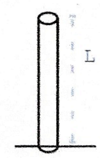
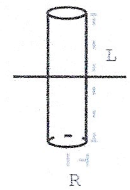
$$\text{prob}(E)\propto\Omega(E)\,e^{-\frac{E}{kT}} \qquad E_N=-\frac{13.6\text{eV}}{N^2}\text{ where }N=1,2,3\ldots$$

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

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 · m²/kg²
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 · 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 · second
hbar $= \frac{h}{2\pi}$	$\hbar$	1.05×10^{-34} joule · 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}