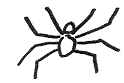
PHYS 2211 Test 2
Fall 2012

Name(print) Key **Lab Section** 

Lab section by day and time: Fenton (N), Greco(N)				
Day	12-3pm	1-4pm	3-6pm	4-7pm
Monday	M01 M02		N01 N02	
Tuesday		M03 N03		M04 N04
Wednesday		M05 N05		M06 N06
Thursday	M07 N07		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."

Peter Parker

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)		

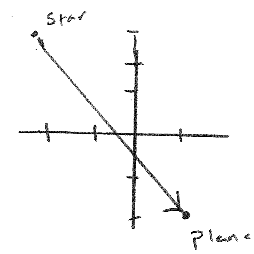
Problem 1 (25 Points)

A planet of mass 2×10^{24} kg is at location $\langle 2 \times 10^{11}, -4 \times 10^{11}, 0 \rangle$ m. A star of mass 6×10^{30} kg is at location $\langle -5 \times 10^{11}, 6 \times 10^{11}, 0 \rangle$ m.

(a 5pts) What is the position vector $\vec{r}$ that points from the star to the planet?

3pts $\left\{ \vec{r} = \vec{r}_{obs} - \vec{r}_{src} = \langle 2\times 10^{11}, -4\times 10^{11}, 0\rangle\, m - \langle -5\times 10^{11}, 6\times 10^{11}, 0\rangle\, m \right.$

2pts $\left\{ \boxed{\vec{r} = \langle 7\times 10^{11}, -10\times 10^{11}, 0\rangle m} \right.$



(b 5pts) What is the unit vector that points in the same direction as the vector $\vec{r}$?

2pts $\left\{ |\vec{r}| = \sqrt{(7\times 10^{11})^2 + (-10\times 10^{11})^2 + 0^2} \right.$

$= \sqrt{1.49 \times 10^{24}} = 1.2 \times 10^{12}\, m$

(1pt)

2pts $\left\{ \hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\langle 7\times 10^{11}, -10\times 10^{11}, 0\rangle}{1.2\times 10^{12}} \right. = \boxed{\langle 0.57, -0.82, 0\rangle}$

(c 5pts) What is the **magnitude** of the gravitational force on the planet due to the star?

$|\vec{F}_g| = \left| -\frac{mMG}{|\vec{r}|^2} \hat{r} \right|$ } 2pts

$|\vec{F}_g| = \frac{mMG}{|\vec{r}|^2} = \frac{(2\times 10^{24})(6\times 10^{30})(6.7\times 10^{-11})}{(1.2\times 10^{12})^2}$ } 2pts

$\boxed{|\vec{F}_g| = 5.4 \times 10^{20}\, N}$ } 1pt (d 5pts) What is the gravitational force **vector** on the planet due to the star?

3pts $\left\{ \vec{F}_g = -|\vec{F}_g|\,\hat{r} \right.$

$$= -5.4\times10^{20}\,\langle 0.57, -0.82, 0\rangle\ N$$

4pts $\left\{ \boxed{\vec{F}_g = \langle -3.1\times10^{20},\ 4.4\times10^{20},\ 0\rangle\ N} \right.$

(e 5pts) What is the gravitational force **vector** on the star due to the planet?

4pts $\left\{ \vec{F}_{star} = -\vec{F}_{planet} = -\langle -3.1\times10^{20},\ 4.4\times10^{20},\ 0\rangle\ N \right.$

1pt $\left\{ \boxed{\vec{F}_{star} = \langle 3.1\times10^{20},\ 4.4\times10^{20},\ 0\rangle\ N} \right.$

Problem 2 (25 Points)

$Y = 5e9$

(a 10pts) One mole of tin has an atomic mass of 118.71 grams and a density of 7.365 $g \cdot cm^{-3}$. A mass of 2.0 kg is attached to a 70 cm long tin wire with a cross sectional area of 8×10^{-7} m^2. How much does the wire stretch?

5% −0.5
15% −1.5
30% −3.0
80% −8.0

$$Y = \frac{F/A}{\Delta L/L}$$

$$\Delta L = \frac{F/A}{Y/L} = \frac{mg/A}{Y/L} = \frac{2 \cdot 9.8 / 8.\times10^{-7}}{5e9/0.7} = 3.43 \times 10^{-3}$$

(b 10pts) A chain is made by linking 2 of these tin wires (see above) end to end (series) and 20 of these chains are bundled side-by-side (parallel). Determine the stiffness of this combination of wires? ***Show all steps in your work.***

$A = 20A_0 \quad L = 2L_0 \quad , A_0 = 8\times10^{-7}\, m^2 \; , L_0 = 0.7\, m$

$$Y = \frac{F/A}{\Delta L/L} = \frac{F/20A_0}{\Delta L/2L_0} = \frac{F \cdot 2L_0}{\Delta L \cdot 20A_0} = \frac{F \cdot L_0}{10 A_0 \Delta L}$$

$$\Delta L = \frac{F \cdot L_0}{10 A_0 Y} \qquad K_{s,wires} = \frac{mg}{\Delta L} = \frac{mg \cdot 10 A_0 Y}{F \cdot L_0} = \frac{\cancel{mg} \cdot 10 A_0 Y}{\cancel{mg}\, L_0}$$

$$K_{s,w} = 10\frac{A_0 Y}{L_0} = \frac{10 \cdot 8\times10^{-7} \cdot 5e9}{0.7}$$

$$\boxed{K_{s,w} = 5.7\times10^{4}\, N/m}$$

(c 5pts) Calculate the speed of sound in tin.

$$\rho = 7.365 \cdot \frac{g}{cm^3} \cdot \frac{kg}{1000g} \cdot \frac{100^3 cm^3}{m^3} = 7.365 \cdot 10^3 \frac{kg}{m^3}$$

(with $1000g = 10^3$, $100^3 = 10^6$)

3pts $\left\{ \begin{aligned} v &= d\sqrt{\frac{k_{si}}{m_a}} \qquad k_{si} = Yd \\ &= d\sqrt{\frac{Yd}{m_a}} \end{aligned} \right.$

$$\text{2pts}\left\{ = \sqrt{\frac{Yd^3}{m_a}} = \sqrt{\frac{5e9}{7.365\times10^3}} = \boxed{823\, m/s = v} \right.$$

$\hookrightarrow \sqrt{\frac{Y}{\rho}}$

Problem 3 (25 Points)

Below is a programming shell to model the interaction of two particles. The force acting on the white particle is directed along the line connecting the two particles and is attractive. Its magnitude is given by $F = kr^5$, where r is the separation between the particles and k is a positive constant. There are no other forces acting on the particles.

Write the necessary statements to compute the force on the white particle and update its momentum. The red particle will remain still.

```
from __future__ import division
from visual import *

## Objects
redParticle = sphere(pos=vector(5,4,0), radius=0.25, color=color.red)
whiteParticle = sphere(pos=vector(-3,-2,0), radius=0.25, color=color.white)
## Constants
k = 0.3
redParticle.m = 1
whiteParticle.m = 5e-3
## Initial conditions
whiteParticle.p = whiteParticle.m*vector(800,800,0)
## Time setup
t = 0
deltat = 5e-6
while t < 1:
    (a 10pts) ## Compute the net force on the white particle
```

5pts
```
r = whiteParticle.pos - redParticle.pos
rmag = mag(r)          # or rmag = sqrt(r.x**2 + r.y**2 + r.z**2)
rhat = r/rmag          # or rhat = norm(r)
```

5pts
```
Fmag = k*rmag**5
F = -Fmag*rhat
```
→ forgot minus sign (-3pts)

```
    (b 10pts) ## Update the momentum of the white particle
```

```
whiteParticle.p = whiteParticle.p + F*deltat
                "               +=
```

All → TA discuss

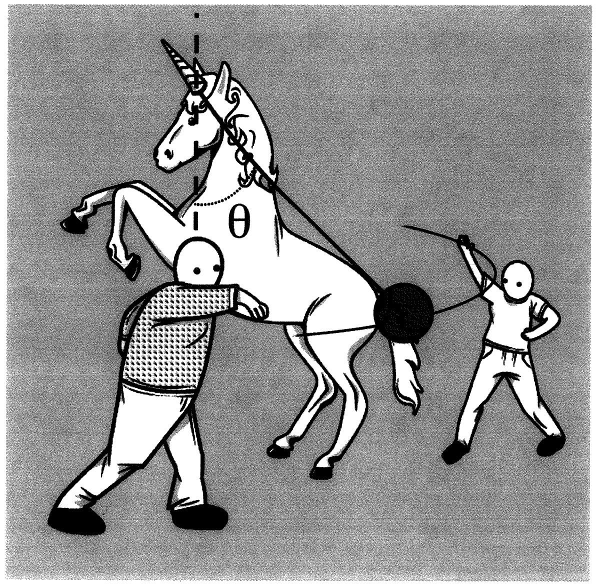
```
    (c 5pts) ## Update the position of the white particle
```

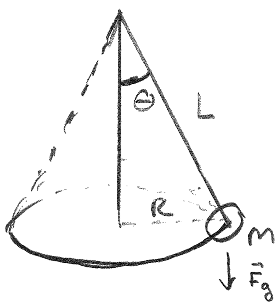
```
whiteParticle.pos = whiteParticle.pos + whiteParticle.p/m*deltat
                  "                  +=
```

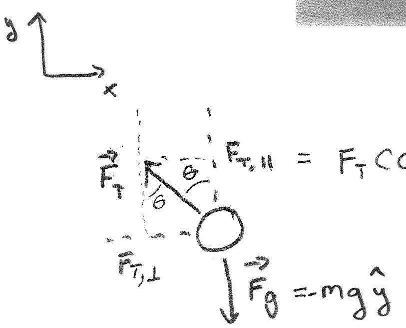
```
    ## Increase time
    t = t + deltat
```

Problem 4 (25 Points)

One day you and Dr. Greco capture a unicorn and decide to include it in a friendly game of tether ball. You tie a tether ball of mass m to a rope of length L. Dr. Greco carefully attaches the other end of the rope onto the horn of the unicorn. As the two of you hit the ball back and forth, you notice that the ball is following a circular path parallel to the ground and that the rope makes an angle θ with the vertical as indicated in the figure. Determine the speed of the tether ball. Please be sure to show all of your work and start from a fundamental principle.







$F_{T,\parallel} = F_T\cos\theta$; $F_{T,\perp} = F_T\sin\theta$

$R = L\sin\theta$

$F_{net,y} = 0 = F_{T,\parallel} + F_g = F_T\cos\theta - mg = 0$

$\Rightarrow \quad F_T\cos\theta = mg$

$F_T = \frac{mg}{\cos\theta}$

$F_{T,\perp} = F_T\sin\theta = mg\frac{\sin\theta}{\cos\theta} = mg\tan\theta$

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

where $\vec F_{net\perp} = \frac{pv}{R}\hat n$

then $mg\tan\theta = \frac{mv^2}{R}$

where $R = L\sin\theta$

then

$\frac{\cancel{m}v^2}{L\sin\theta} = \cancel{m}g\tan\theta$

$$\boxed{v = \sin\theta\sqrt{\frac{gL}{\cos\theta}}}$$

5 % −1.0
15 % −4.0
30 % −7.5
80 % −20

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

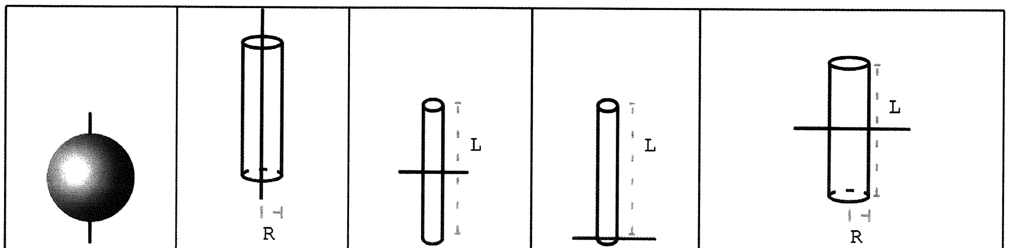
$$\text{prob}(E) \propto \Omega(E)\, e^{-\frac{E}{kT}} \qquad E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1,2,3\ldots$$

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

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 · 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 · 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}