PY 205-004/005 Practice Test 1, 2004 Feb. 10

Print name____**Lab section**_________

I have neither given nor received unauthorized aid on this test.

Sign ature:____

When you turn in the test (including formula page) ***you must show an NCSU photo ID to identify yourself.***

Do not use other paper. **If you need more space, write on the back of a page and indicate that you did this.**

- **Read all problems carefully before attempting to solve them.**
- **You must show all your work. Use correct vector notation.**
- **Your work must be legible, and the organization must be clear.**
- **Correct answers without adequate explanation will be counted wrong.**
- **Incorrect explanations mixed in with correct explanations will be counted wrong.**
  Cross out anything you don't want us to read!
- **Make explanations complete but brief. Do not write a lot of prose.**
- **Include diagrams where appropriate to explain your work.**
- **Show what goes into a calculation, not just the final number:** $\frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5\times10^{4}$
- **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.

If you cannot do some portion of a problem, invent a symbol for the quantity you can't calculate (explain that you're doing this), and do the rest of the problem.

Problem Score

1 (25 pts):_______

2 (25 pts):_______

3 (25 pts):_______

4 (25 pts):_______

5 (5 pts):_______ (bonus)

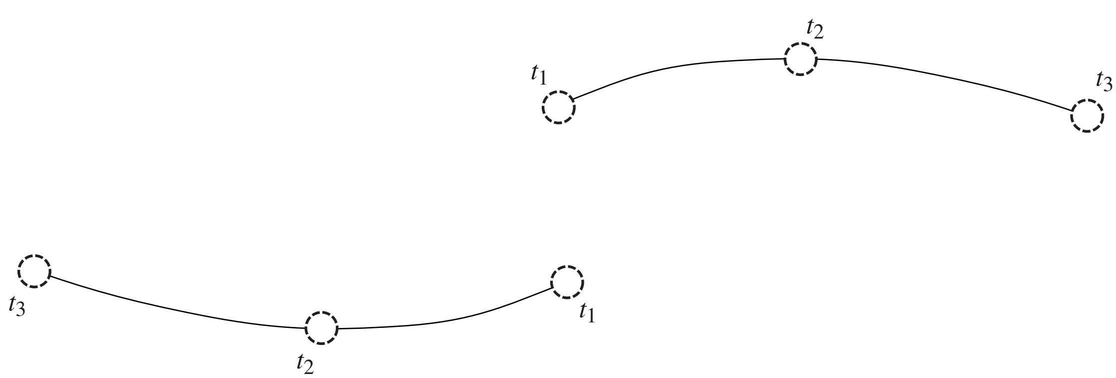
Total (100 pts): _______

Problem 1 (25 pts)

(a) (7 pts) An electron with a speed of $0.95c$ is emitted by a supernova, where c is the speed of light. What is the magnitude of the momentum of this electron?

(b) (6 pts) A thin iron rod is suspended vertically. The dimensions of the rod are 2.3 m by 1.6 mm by 1.3 mm. When you hang a mass of 37 kg from the end of the rod, you find that the rod stretches 2 mm $(2 \times 10^{-3}\ \text{m})$. What is Young's modulus for iron?

(c) (12 pts) Here is a portion of the trajectories of two similar asteroids that are moving away from each other, with positions marked at times t_1, t_2, and t_3. There are no other objects near the asteroids. At each of these positions, draw vectors of appropriate lengths and directions for the forces acting on the asteroids at that location, and label them $\vec{F}$. Then at the same locations draw vectors of appropriate lengths and directions for the momenta of the asteroids at those locations, and label them $\vec{p}$. ("Appropriate lengths" means that larger magnitudes are represented by longer vectors.)



Problem 2 (25 pts) A ping-pong ball is acted upon by the Earth, air resistance, and a strong wind. Here are the positions of the ball at several times.

Early time interval:

At $t = 12.35$ s, the position was $\langle 3.17, 2.54, -9.38 \rangle$ m

At $t = 12.37$ s, the position was $\langle 3.25, 2.50, -9.40 \rangle$ m

Late time interval:

At $t = 14.35$ s, the position was $\langle 11.25, -1.50, -11.40 \rangle$ m

At $t = 14.37$ s, the position was $\langle 11.27, -1.86, -11.42 \rangle$ m

(a) (6 pts) In the early time interval, from $t = 12.35$ s to $t = 12.37$ s, what was the average momentum of the ball? The mass of the ping-pong ball is 2.7 grams (2.7×10^{-3} kg).

(b) (6 pts) In the late time interval, from $t = 14.35$ s to $t = 14.37$ s, what was the average momentum of the ball?

(c) (13 pts) In the time interval from $t = 12.35$ s (the start of the early time interval) to $t = 14.35$ s (the start of the late time interval), what was the average net force acting on the ball?

Problem 3 (25 pts) A ball of unknown mass m is attached to a spring. In outer space, far from other objects, you hold the other end of the spring and swing the ball around in a circle of radius 1.5 m at constant speed.

(a) (3 pts) You time the motion and observe that going around 10 times takes 6.88 seconds. What is the angular speed ω?

(b) (3 pts) What is the speed of the ball?

(c) (4 pts) Is the momentum of the ball changing or not? How can you tell?

(d) (4 pts) If the momentum is changing, what interaction is causing it to change? If the momentum is not changing, why isn't it?

(e) (4 pts) The relaxed length of the spring is 1.2 m, and its stiffness is 1000 N/m. While you are swinging the ball, since the radius of the circle is 1.5 m, the length of the spring is also 1.5 m. What is the magnitude of the force that the spring exerts on the ball?

(f) (7 pts) What is the mass m of the ball?

Problem 4 (25 pts) Here is a portion of a program to calculate and display the orbit of a planet around a star so massive compared to the planet that we can neglect the star's motion. Write or interpret program statements as specified.

```
from visual import *
from __future__ import division

G = 6.7e-11
deltat = 60*60*3
t = 0

star = sphere(pos=vector(0,4e11,0), radius=8e10, color=color.yellow)
star.mass = 1.3e31
planet = sphere(pos=vector(9e11,0,0), radius=5e10, color=color.cyan)
planet.mass = 8e25
planet.trail = curve(color=planet.color)
```

The initial velocity of the planet is < 0, 3.5e4, 0 >. Write a statement to set the initial momentum of the planet:

```
planet.p =

while t < 1e9:
```

(a) (2 pts) *Write a statement to calculate the current vector that points from the planet to the star:*

```
    r =
```

(b) (2 pts) *Write a statement to calculate the magnitude of the vector that points from the planet to the star:*

```
    rmag =

    rhat = r/rmag
```

(c) (2 pts) *Write a statement to calculate the magnitude of the gravitational force acting on the planet:*

```
    Fmag =
```

(d) (2 pts) *Write a statement to calculate the vector gravitational force acting on the planet:*

```
    Fnet =
```

(e) (3 pts) *Write a statement to update the planet's momentum:*

```
    planet.p =
```

(f) (2 pts) *Write a statement to update the planet's position:*

```
    planet.pos =

    planet.trail.append(pos=planet.pos)
    t = t + deltat
```

(continued on next page)

(g) (3 pts) What is the initial momentum of the planet, expressed as a vector? Give numerical values.

$\vec{p}$ = < __________ , ___________ , ___________ > $kg \cdot m/s$

(h) (2 pts) What is the time step (time between position updates), in hours?

(i) (3 pts) The first statement inside the loop calculates a vector `r`. What will the numerical value of this vector be, the first time the computer calculates it? Show your work.

`r` = < __________ , ___________ , ___________ > m

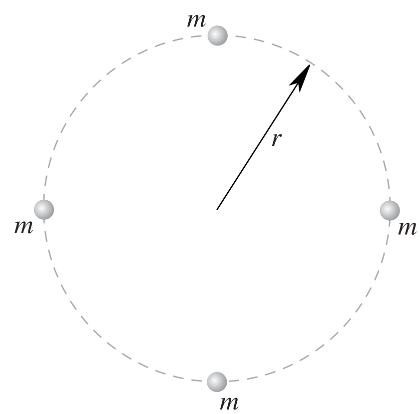
(j) (2 pts) The calculation of the net force contains the quantity `rhat`. Explain briefly why this is needed.

(k) (2 pts) Suppose you change the calculation of the vector `r` so that it represents a vector pointing from the star to the planet. What other change or changes must you make in the program? Why?

Problem 5 (5 pts)

Since this problem is only worth 5 bonus points, don't attempt it unless you have finished all the other problems and checked your work.

There is no general analytical solution for the motion of a gravitational system consisting of more than two bodies. However, there do exist analytical solutions for very special initial conditions. Here are four stars, each of mass m, which move in the plane of the page along a circle of radius r. Calculate how long this system takes to make one complete revolution. You can assume that $v << c$.



FUNDAMENTAL PHYSICAL LAWS AND RELATIONSHIPS

Principle of relativity: Physical laws work in the same way for observers in uniform motion as for observers at rest.

The superposition principle: the effective force on an object is the "net" force, the vector sum of all forces acting on the object, each force unaffected by the presence of other interactions.

The momentum principle, and the definition of momentum. (These must be memorized.)

The relationship among position, velocity, and time. (This must be memorized.)

EVALUATING SPECIFIC PHYSICAL QUANTITIES

$\left|\vec{F}_{\text{gravitational}}\right| = G\dfrac{m_1 m_2}{|\vec{r}|^2}$

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

$\left|\vec{F}_{\text{spring}}\right| = k_s|s|$, opposite the stretch

$Y = \dfrac{F/A}{\Delta L/L} = \dfrac{k_{s,\text{ interatomic}}}{d_{\text{atomic}}}$

Circular motion at constant speed: $\dfrac{d\vec{p}}{dt} = -\dfrac{m\omega^2}{\sqrt{1-|\vec{v}|^2/c^2}}\hat{r}$, or $\dfrac{d\vec{p}}{dt} \approx -m\omega^2\hat{r}$ for $|\vec{v}| << c$

where $\omega = \dfrac{d\theta}{dt} = \dfrac{2\pi}{T}$

$|\vec{v}| = \dfrac{2\pi|\vec{r}|}{T} = \omega|\vec{r}|$

CONSTANTS

$G = 6.7\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$

$g = 9.8$ N/kg

$c = 3\times10^8$ m/s

$M_{\text{Earth}} = 6\times10^{24}$ kg

$M_{\text{Moon}} = 7\times10^{22}$ kg

Radius of the Earth = 6.4×10^6 m

Radius of the Moon = 1.75×10^6 m

Distance from Sun to Earth = 1.5×10^{11} m

Distance from Earth to Moon = 4×10^8 m

Avogadro's number = 6×10^{23}

Typical atomic radius $r \approx 10^{-10}$ m

$m_{\text{electron}} = 9\times10^{-31}$ kg

$m_{\text{proton}} \approx m_{\text{neutron}} \approx m_{\text{hydrogen atom}} = 1.7\times10^{-27}$ kg

CONVERSION FACTORS

1 pound = 0.45 kilogram

1 kilogram = 2.2 pounds

1 mile = 1600 meters

1 inch = 2.54 centimeters

1 hour = (60) (60) s = 3600 s