Practice Test 2 PY205-004/005 Tuesday March 2, 2004

Name______________________________________________________________________Lab section________

• Read all problems carefully before attempting to solve them.

• 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.

• Make explanations complete but brief. Do not write a lot of prose.

• Include diagrams!

• Show what goes into a calculation, not just the final number: \( \frac{(8 \times 10^{-3})(5 \times 10^6)}{(2 \times 10^{-5})(4 \times 10^4)} = 5 \times 10^4 \)

• Give physical units with your results.

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 (15 pts):_______

2 (20 pts):_______

3 (15 pts):_______

4 (15 pts):_______

5 (10 pts):_______

6 (25 pts):_______

7 (5 pt bonus):_____

Total: _________
Problem 1 (15 pts) A proton moving in the x direction is speeded up by a constant electric force in the x direction, of magnitude $3.4 \times 10^{-12}$ N. When the proton passes the location $x = 5$ m, its speed is $2.95 \times 10^3$ m/s.

(a) (7 pts) What is the kinetic energy of the proton at this point?

(b) (8 pts) When the proton passes the location $x = 9$ m, what is its kinetic energy? If you could not do part a, call the answer to part a “$K_a$” and express your answer to part b in terms of $K_a$. 
Problem 2 (20 pts) In the lab you observe a mass of 0.74 kg oscillating up and down at the end of a spring. You time the oscillations and record that the mass makes 15 round trips in 4.50 seconds. You remove the mass and measure the length of the spring, which is 0.430 m. Next you hang the mass from the spring, so that the mass hangs motionless. Now what is the length of the spring?
**Problem 3 (15 pts)** A load of 190 kg is supported motionless above the ground by two ropes. Rope 1 exerts a force of \((-300, 500, 0) \text{ N}\) on the load.

(a) (10 pts) What is the force exerted by rope 2? Explain carefully and completely, starting from a fundamental principle.

(b) (5 pts) Draw a diagram showing all the forces acting on the load. All vectors should be drawn to the same scale, so that longer arrows correspond to larger magnitudes. Clearly label each force to identify it.
**Problem 4 (15 pts)** In outer space, a piece of space junk whose mass is 60 kg is subject to a constant net force \((13, -9, 12)\) \(\text{N}\). When the space junk is at location \((10, 6, -4)\) \(\text{m}\), its speed is 0.8 m/s. When the space junk has moved to location \((13, 8, -2)\) \(\text{m}\), what is its speed?

**Problem 5 (10 pts)** Here is a version of a program to model a mass oscillating on a spring.

```python
from visual import *
from __future__ import division # makes 1/2 be 0.5, not 0
L0 = 0.3
ks = 1.1
spring = cylinder(pos=vector(0,0,0), axis=vector(L0,0,0), radius=0.01)
track = box(pos=vector(0,-.075,0), size=(1.0,0.05,0.10))
bball = sphere(pos=vector(L0+0.15,0,0), radius=0.05, color=color.green)
bball.m = 0.03
bball.p = bball.m*vector(0,0,0)
deltat = 0.01
t = 0
while t<3.0:
    rate(100)
    Fnet = vector(-ks*(bball.pos.x-L0),0,0)
bball.p = bball.p + Fnet*deltat
bball.pos = bball.pos + (bball.p/ball.m)*deltat
spring.axis = bball.pos
t = t + deltat
```

(a) (3 pts) What is the angular frequency \(\omega\) of this oscillator?

(b) (4 pts) What is the amplitude of this oscillator? How do you know this?

(c) (3 pts) What statement would you need to change to study an oscillator with a spring-like force that is proportional to the cube of the stretch (the 3rd power of the stretch)? Write the modified statement:
Problem 6 (25 pts) You blast off from Mars, and you turn off the rockets when you are 3500 km (3.5×10^6 m) from the center of Mars, well above its thin atmosphere and headed away from the planet. You intend to leave Mars for good, and by the time you get very far away you want to be coasting at a speed of 1800 m/s. Mars has a mass of 6.4×10^{23} kg.

(a) (5 pts) Draw a graph of kinetic energy, of potential energy, and of kinetic plus potential energy for this process. Label each of the three curves. The center-to-center distance is marked for the place where you turn off the rockets; start your drawing at that place.  

*Be sure you label the curves to identify them!*

(b) (16 pts) Calculate the speed you must have when you are 3500 km (3.5×10^6 m) from the center of Mars in order that your speed when you are very far from Mars is 1800 m/s. Explain carefully and completely, starting from a fundamental principle.

(c) (4 pts) What approximations or idealizations did you need to make to calculate the speed?
Problem 7 (5 pt bonus question)

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.

Three stars, each with mass $M$, are initially at rest in the xy plane at the corners of an equilateral triangle, very far from each other. They come together due to their mutual attractions. At a later time they are at the corners of an equilateral triangle whose sides are of length $d$. What is the kinetic energy of each star at this time?
FUNDAMENTAL PHYSICAL LAWS

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 energy principle, and the definitions of work and energy. (These must be memorized.)
The relationship among position, velocity, and time. (This must be memorized.)

EVALUATING SPECIFIC PHYSICAL QUANTITIES

\[ |\vec{F}_{\text{gravitational}}| = \frac{G m_1 m_2}{|\vec{r}|^2}, \quad U_{\text{grav}} = -\frac{G m_1 m_2}{|\vec{r}|} \]

Near the Earth’s surface \[ |\vec{F}_{\text{gravitational}}| = mg, \quad \text{and} \quad \Delta U_{\text{grav}} = \Delta (mg y) \]

\[ |\vec{F}_{\text{spring}}| = k_s |\vec{\delta}|, \quad \text{opposite the stretch} \quad \omega = \frac{k_s}{m} \quad \omega = 2\pi / T \]

\[ Y = \frac{F/A}{\Delta L/L} = \frac{k_s, \text{interatomic}}{d_{\text{atomic}}} \quad \nu_{\text{sound}} = \frac{k_s, \text{interatomic}}{N m} \quad F_s = -\frac{dU}{dx} \]

Circular motion at constant speed:
\[ \frac{d\theta}{dt} = \frac{-m\omega^2}{\sqrt{1 - |\vec{v}|^2/c^2}} \quad \frac{d\vec{v}}{dt} = -m\omega^2 \hat{r} \quad \text{for} \quad |\vec{v}| << c \]

where \( \omega = \frac{d\theta}{dt} = \frac{2\pi}{T} \quad |\vec{v}| = \frac{2\pi |\vec{r}|}{T} = \omega |\vec{r}| \)

CONSTANTS

\[ G = 6.7 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \quad g = 9.8 \text{ N/kg} \quad c = 3 \times 10^8 \text{ m/s} \]

\[ \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \quad \text{Avogadro's number} = 6 \times 10^{23} \text{ molecules/mole} \]

\[ m_{\text{electron}} = 9 \times 10^{-31} \text{ kg} \quad m_{\text{proton}} = m_{\text{neutron}} = m_{\text{hydrogen atom}} = 1.7 \times 10^{-27} \text{ kg} \]

\[ M_{\text{Earth}} = 6 \times 10^{24} \text{ kg} \quad M_{\text{Moon}} = 7 \times 10^{22} \text{ kg} \]

Radius of the Earth = 6.4 \times 10^6 \text{ m} \quad \text{Radius of the Moon} = 1.75 \times 10^6 \text{ m} \]

Distance from Sun to Earth = 1.5 \times 10^{11} \text{ m} \quad \text{Distance from Earth to Moon} = 4 \times 10^8 \text{ m} \]

Typical atomic radius \( r = 10^{-10} \text{ m} \quad \text{Proton radius} \quad r = 10^{-15} \text{ m} \)

Effective stiffness of interatomic bond in aluminum is 16 N/m, lead is 5 N/m