Physical Sciences 2

Exam 2 (Individual)
Thursday, December 1, 2016

Your name: ______________________

Section TF: _____________________________________________________

Do not turn the page until you are told to begin. You will be given 90 minutes to complete this exam. Show all your work on the exam itself; no credit will be given for anything written on other paper. Please box your final answer to each calculation.

You may use a calculator if you have brought one. You may refer to two 8.5”x11” sheets of notes, which must be in your own handwriting. Turn in your notes along with the exam when time is called.

This exam contains 6 sheets of paper (including this one), with 7 problems.

Do not write in the following table; it will be used for grading.

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Problem 1: Multiple Choice [20 points]

For each of the following questions, circle the letter corresponding to the single best answer from the options given. Each question is worth 5 points; no partial credit will be given unless otherwise stated.

a) [4 pts] A heavy box is initially at rest at the top of a ramp. A girl pushes the box down the ramp. At the bottom, she stops pushing and the box comes to a stop due to friction. Fill in the blanks: For the entire process described above, the work done by the girl on the box was _____, and the work done by gravity on the box was _____.

A. positive; positive  
B. positive; negative  
C. positive; zero  
D. zero; positive  
E. zero; negative  
F. zero; zero

b) [4 pts] Two identical springs are attached in series to a mass (as in the first figure), which then oscillates with period $T$. If instead the same two springs are attached to the mass in parallel (as in the second figure), what will be the oscillation period?

A. $\frac{T}{2}$  
B. $\frac{T}{\sqrt{2}}$  
C. $T$  
D. $T\sqrt{2}$  
E. $2T$
c) [4 pts] For a particle undergoing uniform circular motion, which of these quantities is constant? (Circle all that apply; partial credit will be given.)

A. momentum  
B. velocity  
C. acceleration  
D. angular velocity

d) [4 pts] A solid sphere and a hollow ball roll down the same incline. The hollow ball is slower than the solid sphere whenever:

A. $m_{\text{ball}} = m_{\text{sphere}}$, where $m$ is the mass.  
B. $r_{\text{ball}} = r_{\text{sphere}}$, where $r$ is the radius.  
C. Both $m_{\text{ball}} = m_{\text{sphere}}$ and $r_{\text{ball}} = r_{\text{sphere}}$.  
D. The ball is always slower regardless of the relative values of $m$ and $r$.

e) [4 pts] An ice skater performs a fast spin by pulling in her outstretched arms close to her body. What happens to her angular momentum and rotational kinetic energy during this process?

A. They both remain constant.  
B. The angular momentum increases and the kinetic energy decreases.  
C. The angular momentum decreases and the kinetic energy increases.  
D. The angular momentum remains constant and the kinetic energy decreases.  
E. The angular momentum remains constant and the kinetic energy increases.  
F. They both increase.
Problem 2: Tipping the balance [10 pts]

A uniform plank of mass $M = 10$ kg and length $L = 60$ cm is suspended from the ceiling by a pair of ropes positioned as shown. A heavy box of mass $m = 8$ kg rests on the plank at a distance $x$ from the left end. What is the minimum value of $x$ for which the plank will not tip?
Problem 3: Look out below! [15 pts]

A 60.0-kg bungee jumper jumps from a bridge. She is tied to a cylindrical bungee cord that is 12 meters long (unstretched) and has a cross-sectional diameter of 4 cm. In her jump, she falls a total of 31 meters from the bridge until she comes momentarily to rest, and then she begins oscillating up and down. You may treat the bungee cord as an ideal elastic material.

a) [6 pts] Calculate the Young’s modulus $Y$ of the bungee cord.

b) [6 pts] Calculate the maximum acceleration experienced by the jumper.

continued ...
Problem 3 continued

c) [3 pts] As she bounces up and down, what is the period of oscillation?
Problem 4: That sinking feeling [15 pts]

A 3.0-kg piece of wood (density $\rho_{\text{wood}} = 500 \text{ kg} \cdot \text{m}^{-3}$) floats on water ($\rho_{\text{water}} = 1.0 \times 10^3 \text{ kg} \cdot \text{m}^{-3}$).

a) [5 pts] What is the minimum mass of lead ($\rho_{\text{lead}} = 1.1 \times 10^4 \text{ kg} \cdot \text{m}^{-3}$) that you could place on top of the piece of wood that would cause the wood to be completely submerged?

b) [10 pts] What is the minimum mass of lead, hung from the wood by a string, that will cause both blocks to sink?
Problem 5: Abdominal Aortic Aneurysms [15 pts]

The descending branch of the aorta bifurcates into the two common iliac arteries at the bottom of the abdomen, as shown. The blood flows down the aorta from the heart and branches into the two arteries, where it continues towards the legs. The radius of the aorta is $R_1 = 1$ cm, and the radii of the iliac arteries are both $R_2 = 0.5$ cm. Roughly, $h_1 = 40$ cm and $h_2 = 5$ cm.

Doctors are interested in where the blood pressure is highest in this system, because that is where abdominal aortic aneurysms are most likely to occur. Assume the blood pressure $P_0$ at the top of the descending aorta is 16.0 kPa above atmospheric pressure, and the speed of blood flow in the aorta is $v_0 = 1$ m/s. For the purpose of this problem, you may assume steady blood flow, and neglect viscosity. Assume that blood has the same density as water, $\rho_{\text{water}} = 1.0 \times 10^3$ kg·m$^{-3}$.

a) [5 pts] Calculate the pressure $P_1$ at the bifurcation point.

b) [10 pts] Calculate the pressure $P_2$ of the blood at the base of the common iliac arteries.
Problem 6: No bailout required [10 pts]

You are in a boat floating on water. The boat’s hull is \( d = 5 \) cm thick. A tiny circular leak with a radius of \( r = 0.1 \) mm develops in the hull at a distance \( h = 25 \) cm below the surface of the water. As a result, laminar flow of water comes in through the leak. You may need the following information:

\[
\eta_{\text{water}} = 10^{-3} \text{ Pa}\cdot\text{s}, \quad \rho_{\text{water}} = 1000 \text{ kg/m}^3, \quad P_{\text{atm}} = 100 \text{ kPa}.
\]

a) [7 pts] Calculate the flow rate (volume per unit time) of the water as it begins to flow into the boat.

b) [3 pts] Estimate the Reynolds number for the flow of water in the leak.
Problem 6: Squeeze play [15 pts]

The $x$-component of the force exerted by a piece of rubber as a function of the displacement from its equilibrium length is shown in the graph at right. You find that the force is described by the function:

$$F_x = -Ax - Bx^3$$

with $A = 100$ N/m
and $B = 10000$ N/m$^3$

where $x$ is the displacement from the equilibrium length of the piece of rubber (in one dimension).

a) [4 pts] For small displacements, this piece of rubber acts like a spring that obeys Hooke’s law. What is the apparent spring constant $k$ of this piece of rubber? (Hint: consider the dimensions)

b) [6 pts] Derive an expression for the elastic potential energy $U$ of this piece of rubber as a function of $x$, the displacement from its equilibrium length. Take $U$ to be zero at equilibrium.

c) [5 pts] Calculate the work that you must do in order to compress this piece of rubber by a displacement of $-10$ cm from its equilibrium length.