Physical Sciences 2

Practice Exam 2

Your name: _____________________________________________________

Section TF: _____________________________________________________

**Do not** turn the page until you are told to begin. Take 90 minutes to complete this exam (your exam will be shorter and 75 minutes). 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 one 8.5”x11” sheet of notes, which must be in your own handwriting. Turn in your notes along with the exam when time is called.

This exam contains 5 sheets of paper (including this one), consisting of 6 problems.

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

<table>
<thead>
<tr>
<th>Problem</th>
<th>___ / ___</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem 1</td>
<td>20</td>
</tr>
<tr>
<td>Problem 2</td>
<td>15</td>
</tr>
<tr>
<td>Problem 3</td>
<td>10</td>
</tr>
<tr>
<td>Problem 4</td>
<td>25</td>
</tr>
<tr>
<td>Problem 5</td>
<td>15</td>
</tr>
<tr>
<td>Problem 6</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>
Problem 1: Multiple Choice [20 pts]

For each of the following questions, circle the letter corresponding to the best answer from the options given. Each question is worth 4 points; no partial credit will be given unless otherwise stated. You may, but do not need to, show your work.

a) A mass-spring system submerged in a viscous syrup solution is critically damped. Which of the following changes could cause the system to become underdamped? Circle all that apply; partial credit will be awarded.

A) increase the initial displacement of the mass from equilibrium
B) use a stiffer spring
C) dilute the syrup solution with water
D) replace the mass with a denser material of the same size

b) The three containers shown below all have the same area at the base, and are filled to the same height with water. In which container is the force exerted by the water on the base of the container greatest?

A. Container A  B. Container B  C. Container C  D. The force is the same in all three containers

c) You may have noticed that the bubbles in a glass of champagne are smaller than the bubbles in a bottle of soda. Fill in the blank: If the pressure of the CO₂ inside the bubble is the same in both cases, then the surface tension of the air-champagne interface must be _____ the surface tension of the air-soda interface.

A) lower than  B) the same as  C) higher than
Problem 1 continued

d) Three forces, each with the same magnitude, are exerted on a door as shown. $F_1$ acts at the middle of the door, and the other two act at the end of the door. If counterclockwise torques (calculated about the hinge) are considered positive, which of the following statements correctly orders the torques exerted by the three forces?

A) torque 1 < torque 2 < torque 3
B) torque 1 < torque 3 < torque 2
C) torque 2 < torque 3 < torque 1
D) torque 3 < torque 1 < torque 2
E) torque 3 < torque 2 < torque 1

e) When a block of mass $m$ is hung from the bottom end of a vertical cylindrical rod, the rod stretches a distance $d$. If the same block is hung from another rod made of the same material but with twice the length and twice the radius, by how much will the rod stretch?

A) The rod will stretch a distance $4d$
B) The rod will stretch a distance $2d$
C) The rod will stretch a distance $d$
D) The rod will stretch a distance $0.5 \ d$
E) The rod will stretch a distance $0.25 \ d$
Problem 2: Trust Fall [15 pts]

Standing rigidly with your arms by your sides and your feet planted to the floor, you begin to fall backwards. How fast is your head moving right before it hits the ground? You may approximate your body as a uniform rigid rod of length $L$. The moment of inertia for a rod rotating about one end is $I = \frac{mL^2}{3}$.

Then, once you have found an algebraic expression, please estimate a numerical answer.
Problem 3: Oil and water [10 pts]

A block of wood with a density of $\rho_b = 900 \text{ kg/m}^3$ is initially floating at the surface of water ($\rho_w = 1000 \text{ kg/m}^3$), as in the figure (which is not to scale).

a) [5 pts] At equilibrium, what percentage of the volume of the block lies below the water level?

b) [5 pts] Now you pour oil, with density $\rho_o = 800 \text{ kg/m}^3$, on top of the water. (Oil and water do not mix.) When the system comes to a new equilibrium, what percentage of the block’s volume lies below the water level?
Problem 4: Aquatic Therapy [25 pts]

A physical therapist is testing the strength of a patient’s biceps muscle. She has the patient hold a ball of mass $M$ and radius $R_{\text{ball}} = 10$ cm in his hand (see figure). She increases the mass of the ball until the patient can just barely hold his arm at an angle of $105^\circ$, which occurs at $M = 35$ kg. The center of mass of the patient’s arm is located 15 cm from the elbow, and the arm has a mass of $m_{\text{arm}} = 2.0$ kg. The patient’s biceps muscle connects to the arm 5 cm from the elbow joint.

a) [15 pts] What is the magnitude of the maximum force the biceps can withstand, $F_{\text{biceps}}$?
Problem 4 continued

b) [10 pts] The therapist then has the patient perform the same test while his arm and the mass are fully submerged in a swimming pool. Given your answer from part a), what is the maximum mass \( M \) the patient can now hold in place? You can model the arm as a cylinder of length \( L_{\text{arm}} = 30 \text{ cm} \) and radius \( R_{\text{arm}} = 4 \text{ cm} \); the mass has a constant volume of a sphere with radius \( R_{\text{ball}} = 10 \text{ cm} \). Assume that the buoyant force on a submerged object acts at its center of mass; recall that water has a density of \( \rho_w = 1000 \text{ kg/m}^3 \).
Problem 5: Bumper cars [15 pts]

A 25-kg child is riding a bumper car of mass $m_{\text{car}} = 300$ kg at the amusement park. The child then drives the car straight into a wall. The walls of the bumper car ride are lined with spring-loaded guard rails, as shown in the figure to the right, each with an effective spring constant of $k_{\text{eff}} = 520$ kN/m, so that the cars bounce back (that’s what makes it fun!). Assume that the car and child have a speed $v = 4$ m/s just before crashing into the wall, and the same speed $v$ just after the collision.

For how long was the car in contact with the wall? You may treat this part of the motion as simple harmonic motion.
Problem 6: Let it slide [15 pts]

A mass $m$ is placed on a spring $k$ on a horizontal surface with friction, as shown. Let $x = 0$ be the equilibrium position of the mass. The spring is then compressed a distance $d$ by the mass, and the mass is released. It travels to the right (detaching from the spring as it passes $x = 0$), finally coming to rest at $x = L$.

Determine the coefficient of kinetic friction $\mu_k$ between the mass and the floor, in terms of $m$, $k$, $d$, $L$, and $g$. 

\[ x = 0 \]
\[ x = -d \]
\[ x \]