PART I: MULTIPLE CHOICE

Each multiple choice question has one best answer -- circle the letter of the best answer. **Partial credit will be given on the multiple choice questions.** If you circle two answers, one of which is correct, you will receive half credit for the question. No credit will be given for more than two answers, even if one of them is correct. (4 points each for full credit)

1. A ball falls from the top of a building, through the air (air friction is present), to the ground below. How does the kinetic energy (K.E.) just before striking the ground compare to the potential energy (P.E.) at the top of the building?
   a) K.E. is equal to P.E.
   b) K.E. is greater than P.E.
   c) K.E. is less than P.E.
   d) It is impossible to tell from the information given.

2. An archer draws her bow and shoots an arrow straight up into the air. If she had drawn the bow string three times as far back, the arrow would have traveled
   a) three times as high.
   b) four times as high.
   c) six times as high.
   d) nine times as high.

3. Two identical freight cars freely roll toward each other on a level track, one at 2 m/s to the right and the other at 1 m/s to the left. The cars collide and couple together and roll toward the right with a speed of
   a) 1/2 m/s
   b) 1/3 m/s
   c) 2/3 m/s
   d) 1 m/s
   e) none of these

4. A popular swinging-balls apparatus (demonstrated in lecture) consists of an aligned row of six identical elastic balls that are suspended by strings so they barely touch each other. If two balls are lifted from one end of the row and released, they strike the row and two balls from the other end pop out. If instead, one ball popped out with twice the velocity of the two, there would be a violation in the conservation of
   a) momentum
   b) energy
   c) both momentum and energy
   d) neither momentum and energy
5. A freight car of mass $m$, travelling with a velocity $v$, strikes a stationary freight car whose mass is $2m$. The bumpers lock together in this inelastic collision. What fraction of the initial kinetic energy is lost in this collision?

a) $\frac{1}{2}$
b) $\frac{1}{3}$
c) $\frac{1}{4}$
d) $\frac{2}{3}$

6. In analyzing the condition of rotational equilibrium, one takes the sum of the torques about an axis

a) which must pass through the body’s center-of-mass.
b) through which the line-of-action of all the forces must pass.
c) passing through the center of the body.
d) located anywhere.
e) none of the above

7. A concrete block supported horizontally at its two ends can be broken with a downward karate chop to the middle because

a) the bottom of the block will be in tension and concrete is weak in tension, so it will crack on the bottom face.
b) the top will be in compression and concrete is weak in compression, so it will crack at the top.
c) the bottom will be in compression, so it will crack on the bottom.
d) the top will be in tension, so it will crack on top
e) none of these

8. You are in a boat floating in a small pond. A large log is floating nearby, which you grab and take onto the boat. With respect to the shore, the water level of the pond

a) will rise.
b) will fall.
c) will remain the same.
d) will depend on the mass of the log.
PART II: FREE RESPONSE

9. A 3250-kilogram aircraft takes 12.5 min to achieve its cruising altitude of 10.0 km and cruising speed of 850 km/h. If the plane’s engines deliver, on the average, 1500 hp of power during this time, what is the efficiency of the engines? (1 hp = 746 W) [17 pts]
10. A 10-gram bullet is fired horizontally into, and becomes embedded in, a suspended block of wood with a mass of 0.890 kg (like the ballistic pendulum experiment).

a) How does the speed of the block with the embedded bullet immediately after the collision compare with the initial speed, \( v_0 \), of the bullet? [7 pts]

b) If the block with the embedded bullet swings upward, and its center-of-mass is raised 0.40 m, what was the initial speed of the bullet? [7 pts]

c) Was the collision elastic? If not, what percentage of the initial kinetic energy was lost? [3 pts]
11. It is common for a figure skater to finish her free skating routine with a spin. Figures A, B, and C depict the skater in three positions. In A she initiates her spin about a vertical axis with both arms and one leg extended. As she makes the transition from A to B to C, her spin rate increases dramatically, giving an eye-catching climax to her skating routine.

a) If her initial rotational velocity (in A) is $\omega$, calculate her final angular velocity (in C) in terms of the initial $\omega$; i.e., how much faster is she spinning in figure C compared to A? [12 pts]

b) How much greater is her rotational kinetic energy in C compared to A? [3 pts]

c) If there is a change in her rotational kinetic energy, why is there not a change in her rotational (angular) momentum; or is there? [2 pts]

To simplify this problem, treat the head, neck, trunk, and standing leg in fig A as if they were a disk of mass (0.7)M and radius R. Let the two outstretched arms be treated like one uniform rod of length 6R and mass (0.12)M, spinning about its center axis. Let the outstretched leg be treated like a uniform rod of length 3R and mass (0.17)M, spinning about its end axis. In figure C, treat the entire figure skater as a spinning disk of mass M and radius R.
12. An ice cube, being just a little less dense than water, floats in water with much of the ice submerged. If olive oil is poured on top, the ice cube floats at the interface between the olive oil and water (in the same manner as the block of polyethylene did between Crisco oil and water in the lecture demonstration). If the olive oil has a specific gravity of 0.91 and the specific gravity of ice is 0.92, what fraction of the ice cube is submerged below the level of the oil-water interface (i.e., what is \( h/H \))? Assume the ice cube is truly a cube and its cross-sectional area is equal to \( A \). \[17 \text{ pts}\]