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. (3 points each for full credit)

1. Can an object have increasing speed while its acceleration is decreasing?
   a) No, this is impossible because of the way in which acceleration is defined.
   b) No, because if acceleration is decreasing, the object will be slowing down.
   c) Yes, and an example would be an object falling in the absence of air friction.
   d) Yes, and an example would be an object released from rest and then falling in the presence of air friction.

2. Work is done on an object far out in space where it has negligible gravitational potential energy. If, in this process, there is no net change in its kinetic energy, we can conclude
   a) that friction may have been operative.
   b) that this situation is impossible.
   c) that the energy of the object has decreased.
   d) that the object’s speed decreased.
   e) none of these

3. Planning to elope with her boyfriend, Janice slides down a rope from her fourth story window. As she slides down the rope, she tightens her grip on the rope and this action increases the tension in the rope. When the upward tension in the rope equals Janice’s weight,
   a) Janice will slow down.
   b) Janice will speed up.
   c) Janice will continue at a constant speed.
   d) Janice will come to a stop.
4. The diagram shows a CD rotating clockwise (as seen from above) in the CD-player. After turning it off, the CD slows down. Assuming it has not come to a stop yet, the direction of the acceleration of point P at this instance is

5. Two balls collide head-on elastically. Before the collision, ball-1 (of mass \( m_1 \)) has an initial speed and ball-2 (of mass \( m_2 \)) is at rest. The transfer of energy from ball-1 to ball-2 will be maximum when

- a) \( m_1 > m_2 \)
- b) \( m_2 > m_1 \)
- c) \( m_1/m_2 \approx 0 \)
- d) \( m_1/m_2 = 1 \)
- e) none of these

6. Low-altitude artificial Earth satellites, traversing wisps of atmosphere, are initially slowed down by air-drag so that they cannot remain in their original orbits and inevitably fall back to the planet. Spiraling down ever closer to the Earth, they usually break up and burn up before reaching the ground. The speed of such a satellite

- a) increases as it descends and its angular momentum is not conserved.
- b) decreases as it descends and its angular momentum is conserved.
- c) increases and then decreases, conserving its angular momentum.
- d) must remain constant, conserving its angular momentum.

7. A stone tied to a string is supported from a spring scale that reads 10 N. A pail of water rests on a platform scale that reads 80 N. The stone is lowered into the water, and the spring scale then reads 5 N. It follows that the platform scale

- a) still reads 80 N.
- b) now reads 70 N.
- c) now reads 90 N.
- d) now reads 75 N.
- e) none of these
8. Suppose that the build-up of fatty tissue on the wall of an artery decreased its radius by 10%. Assuming viscous flow and all other variables unchanged, by how much would the flow of blood through that artery be decreased?

a) 10%
b) 20%
c) 30%
d) 34%
e) none of these

9. An adult and a child are sitting on adjacent identical swings. Once they get moving, the adult, by comparison to the child, will necessarily swing with

a) a much greater period
b) a much greater frequency
c) the same period
d) the same amplitude
e) none of these

10. Quite generally, doubling the amplitude of a wave

a) doubles the frequency.
b) halves the period.
c) quadruples the energy.
d) doubles the speed.
e) none of these

11. A clarinet has a single vibrating reed at one end coupled to a cylindrical resonance tube that is flared open at the other end. The coupling of reed and air column produces the interesting spectrum shown. Typically, there is a strong first harmonic, a small second, a strong third, some fourth, a strong fifth, and an appreciable sixth. It appears that the instrument functions as if it were

a) purely closed at both ends
b) purely open at one end
c) a mix of somewhat open at both ends and yet effectively closed at one
d) purely open at both ends
e) none of these
PART II: FREE RESPONSE  Do problem 12 and choose five of the remaining seven problems. Cross out the two problems you have chosen not to do.

12. A stunt pilot, flying an old biplane, climbs in a vertical circular loop. While upside down at the top of the loop, the normal force on the seat is one third of her usual weight.

a) If the plane is traveling at that moment at 300 km/hr, what is the radius of the loop? [8 pts]

b) A World War I pilot did this little trick without fastening his seat belt and — you guessed it — fell out. What can you say about his speed at the top of the loop (in relation to the radius, r)? [4 pts]
13. A fireworks rocket rises straight up to its maximum altitude of 50.0 m. At that point it explodes into two equal-mass pieces; one heads straight down at 20.0 m/s, the other travels straight upward. What is the maximum altitude attained by the second upwardly-moving fragment? [11 pts]
14. At exactly 2 o’clock the hour-hand points at the number two and the minute-hand points at the number twelve. At what time (between 2 and 3 o’clock) is the minute-hand right on top of the hour-hand? Give your answer in minutes and seconds after 2 o’clock. [11 pts]
15. A sphere of mass 10.0 kg rests in a groove, as shown in the diagram. Assuming no friction and taking the weight of the sphere to act at its center, compute the reaction forces exerted by the two surfaces. [11 pts]
16. In 1973, a prominent feature of the Boston skyline was the unoccupied Hancock skyscraper with its windows covered with plywood (because of the unfortunate tendency of the windowpanes to pop out during high winds). After a year-long study of the problem it was reported to the public that “either the wind was too strong for the windows or the windows were not strong enough to handle the wind”! As a physics student, you might rightly guess that Bernoulli’s equation provides a partial explanation of the nature of the problem.

Calculate the net outward force on a window if the wind speed is 22 m/s (about 50 mph). Assume the pressure inside the building is atmospheric, the size of a typical window is 2x4 meters, and the density of air is 1.29 kg/m$^3$, and the flow of air (wind) is laminar. [11 pts]
17. A 3-kg mass (Barney the Bungee-cord jumper) is attached to the end of a 3-meter long spring, the other end of which is attached to the ceiling. The spring constant is 32.5 N/m.

a) By how much does the spring stretch when Barney is just hanging still at equilibrium? [3 pts]
b) The instructor now pulls Barney down, all the way to the floor — an additional 2.5 m. When let go, what is Barney’s period of oscillation? [3 pts]
c) Write an explicit mathematical expression for Barney’s vertical position as a function of time, y(t). Let his equilibrium position be y=0 and let t=0 be when Barney is initially released (from the floor). [5 pts]
18. With one violin playing, the sound level at a certain place is measured to be 50 dB.

a) If three violins play equally loudly, what will the sound level most likely be at the same place? [7 pts]

b) How many violins would have to play (all equally as loud as the first) to make their combined voices sound twice as loud as the first violin? [4 pts]
19. Imagine a hypothetical piano with all strings made of the same material and all under the same tension. The piano extends from 27.5 Hz to 4186 Hz, which is over seven octaves — that is, seven doublings of frequency.

a) If the highest note corresponds to a string 15-cm long, how long will the lowest string have to be? [8 pts]

b) What can you conclude about this approach to piano design? [3 pts]