Name	Section	Date	Score
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Phys 20.01 Long exam 3

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2025 W46

Instructions: For comprehension and conceptual questions, choose the best answer. For problem-solving questions, choose the best answer and show your solution and reasoning. Comprehension is 1 pt each, conceptual is 2 pt each, and problem-solving is 3 pt each.

1. Comprehension

1. The work-energy theorem states that the change in the kinetic energy of an object is equal to what?
   a. The work done on the object
   b. The force applied to the object
   c. The loss of the object's potential energy
   d. The object's total mechanical energy minus its kinetic energy

2. Can a lighter object have more momentum than a heavier one? How?
   a. No, as momentum is independent of mass
   b. No, as momentum is independent of velocity
   c. Yes, if lighter object's velocity is considerably high
   d. Yes, if lighter object's velocity is considerably low

3. Consider two objects of same mass. If a force of 100 N acts on the first for a duration of 1 s and on the other for a duration of 2 s, which statement is true?
   a. The first object acquires more momentum
   b. The second object acquires more momentum
   c. Both objects acquires the same momentum
   d. Neither object experiences a change in momentum

4. Why do we use average force when solving momentum?
   a. Forces are usually constant over a period of time
   b. Forces are usually not constant over a period of time
   c. Forces are always constant over a period of time
   d. Forces are always not constant over a period of time

5. Which of these systems are isolated?
   a. While slipping on patch of ice, a car collides totally inelastically with another car. System: both cars
   b. Same situation as in A. System: slipping car
   c. A car does emergency stop on a road. System: car
   d. A billiard ball collides elastically with another ball on a pool table. System: both balls and the table

6. Which of the following is not a conservative force?
   a. the force exerted by a spring on an object in 1D
   b. the force of friction
   c. the force of gravity

7. A car slows down as a result of air friction. Which is true?
   a. The car's kinetic energy decreases
   b. Heat is generated
   c. The energy of the car/road/air system is constant
   d. all of the above
   e. none of the above

8. How does a simple machine make work easier?
   a. It reduces input force and output force
   b. It reduces input force and increases output force
   c. It increases input force and reduces output force
   d. It increases input force and output force

9. Which is true? Conservation of the total momentum of a system
   a. holds only when mechanical energy is conserved
   b. holds for any system
   c. follows from Newton's second law
   d. is equivalent to Newton's third law

10. A woman holds a bowling ball in a fixed position. The work she does on the ball
    a. depends on the weight of the ball
    b. cannot be calculated without more information
    c. is equal to zero

11. When you do positive work on an object, its kinetic energy
    a. increases
    b. decreases
    c. remains the same
    d. need more information about the way the work was done

12. The impulse delivered to a body by a force is
    a. defined only for interactions of short duration
    b. equal to the change in momentum of the body
    c. equal to the area under an F vs. x graph
    d. defined only for elastic collisions

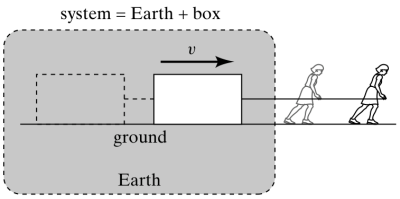
13. In an inelastic collision
    a. both energy and momentum are conserved
    b. energy is conserved
    c. momentum is conserved
    d. neither is conserved

14. Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. Just before hitting the ground, the heavier marble has
    a. as much kinetic energy as the lighter one
    b. twice as much kinetic energy as the lighter one
    c. half as much kinetic energy as the lighter one
    d. four times as much kinetic energy as the lighter one
    e. impossible to determine

15. A person pulls a box along the ground at a constant speed. If we consider Earth and the box as our system,

what can we say about the net external force on the system?

a. It is zero because the system is isolated
b. It is nonzero because the system is not isolated
c. It is zero even though the system is not isolated
d. It is nonzero even though the system is isolated
e. none of the above

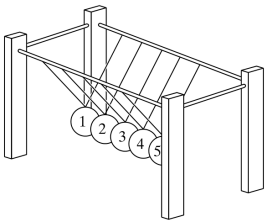


2. Conceptual

1. Cars these days have parts that can crumple or collapse in the event of an accident. How does this help protect the passengers?
   a. Reduces injury by increasing time of impact
   b. Reduces injury by decreasing time of impact
   c. Reduces injury by increasing change in momentum
   d. Reduces injury by decreasing change in momentum

2. A car accelerates from rest. In doing so the car gains a certain amount of momentum and Earth gains
   a. more momentum
   b. the same amount of momentum
   c. less momentum
   d. The answer depends on interaction between the two

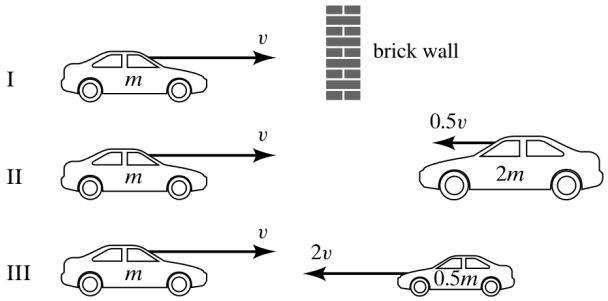
3. If ball 1 in the arrangement shown here is pulled back and then let go, ball 5 bounces forward. If balls 1 and 2 are pulled back and released, balls 4 and 5 bounce forward, and so on. The number of balls bouncing on each side is equal because
   a. of conservation of momentum
   b. the collisions are all elastic
   c. neither of the above



4. Suppose the entire population of the world gathers in one spot and, at the sounding of a prearranged signal, everyone jumps up. While all the people are in the air, does Earth gain momentum in the opposite direction?
   a. No, the inertial mass of Earth is so large that the planet's change in motion is imperceptible
   b. Yes, because of its much larger inertial mass, however, the change in momentum of Earth is much less than that of all the jumping people
   c. Yes, Earth recoils, like a rifle firing a bullet, with a change in momentum equal to and opposite that of the people
   d. It depends

5. About a second later, 5 billion people land back on the ground. After the people have landed, Earth's momentum is
   a. the same as what it was before the people jumped
   b. different from what it was before the people jumped

6. If all three collisions in the figure shown here are totally inelastic, which bring/s the car on the left to a halt?
   a. I
   b. II
   c. III
   d. I, II
   e. I, III
   f. II, III
   g. all three



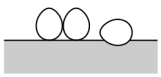
7. Which collisions cause the most damage?
   a. I
   b. II
   c. III
   d. I, II
   e. I, III
   f. II, III
   g. all three

8. A compact car and a large truck collide head on and stick together. Which undergoes the larger momentum change?
   a. car
   b. truck
   c. The momentum change is the same for both vehicles
   d. Can't tell without knowing the final velocity of combined mass

9. Two people on rollerblades throw a ball back and forth. After a couple of throws, they are (ignore friction)
   a. standing where they were initially
   b. standing farther away from each other
   c. standing closer together
   d. moving away from each other
   e. moving toward each other

10. Two cars, one twice as heavy as the other, are at rest on a horizontal track. A person pushes each car for 5 s. Igrnoring friction and assuming equal force exerted on both cars, the kinetic energy of the light car after the push … the kinetic energy of the heavy car.
    a. is smaller than
    b. is equal to
    c. is larger than
    d. cannot be determined relative to

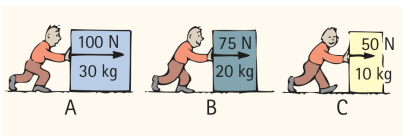
11. In the following figure, a 10-kg weight is suspended from the ceiling by a spring. The weight-spring system is at equilibrium with the bottom of the weight about 1 m above the floor. The spring is then stretched until the weight is just above the eggs. When the spring is released, the weight is pulled up by the contracting spring and then falls back down under the influence of gravity. On the way down, it
    a. reverses its direction of travel well above the eggs
    b. reverses its direction of travel precisely as it reaches the eggs
    c. makes a mess as it crashes into the eggs



12. **How high can we jump?** The maximum height a typical human can jump from a crouched start is about 60 cm. By how much does the gravitational potential energy increase for a 72 kg person in such a jump?
    a. 423 J
    b. 42,336 J
    c. 43.2 J
    d. 706 J

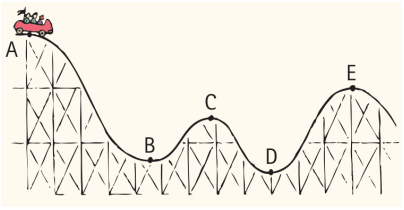
13. Where does this energy come from?
    a. The chemical potential energy stored within the muscle cells (specifically ATP)
    b. The kinetic energy generated as the jumper pushes off the ground
    c. The elastic potential energy stored in the jumper's tendons and ligaments
    d. The reaction force exerted by the ground pushing the person upwards

14. Marshall pushes crates starting from rest across the floor of his classroom for 3 s with a net force as shown. For each crate, rank the impulses delivered from greatest to least.
    a. A, B, C
    b. C, B, A
    c. B, A, C
    d. No ranking as A = B = C



15. Rank the changes in momentum.
    a. A, B, C
    b. C, B, A
    c. B, C, A
    d. No ranking as A = B = C

16. The roller coaster ride starts from rest at point A. Rank the speeds from greatest to least at each point.
    a. A, E, C, B, D
    b. E, C, A, B, D
    c. D, B, C, E, A
    d. D, B, A, C, E



17. Rank the potential energies.
    a. A, E, C, B, D
    b. E, C, A, B, D
    c. D, B, C, E, A
    d. D, B, A, C, E

3. Problem solving

Momentum and the archerfish. Archerfish are tropical fish that hunt by shooting drops of water from their mouths at insects above the water's surface to knock them into the water, where the fish can eat them. A 65 g fish at rest just at the surface of the water can expel a 0.30 g drop of water in a short burst of 5.0 ms. High-speed measurements show that the water has a speed of 2.5 m/s just after the archerfish expels it.

1. What is the average force the fish exerts on the drop of water?
    a. 0.00015 N
    b. 0.00075 N
    c. 0.075 N
    d. 0.15 N.

Rearranging the impulse-momentum theorem, we get the average force F_{avg} exerted on the drop of water

$$\Delta p = F_{\text{avg}} \cdot \Delta t$$

$$\implies F_{\text{avg}} = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} = m\frac{v_f - v_0}{\Delta t}$$

$$= (0.3 \times 10^{-3}\ \text{kg})\frac{(2.5 - 0)\ \text{m/s}}{5.0 \times 10^{-3}\ \text{s}}$$

$$F_{\text{avg}} = 0.15\ \text{N}$$

Car crashin'. Suppose you are in an automobile accident.

1. All other things being equal, are you better off in a more massive car or a lighter one? Why? Write down your reasoning.
    a. more massive is better
    b. lighter is better
    c. the mass of the car does not matter

A more massive car is better because, in a collision, its greater inertia means it changes velocity less drastically. This results in less severe deceleration for the occupants, reducing the forces they experience and thus the risk of injury.

2. Is it better to be in a car that crumples on impact rather than one that holds together stiffly? Why? Write down your reasoning.
   a. crumply is better
   b. stiffer is better
   c. it does not matter as long as the car has an airbag

   A crumply car is better because crumple zones extend the time it takes for the car to stop during an impact. By increasing the crash duration, the impact force on the passengers is significantly reduced, which greatly lowers the risk and severity of injuries. The concept of impulse saves the day.

Spotify recap! This year's *[insert your favorite music streaming app here]* recap is almost here. Whatchu think will be your top 1 song? 🎵 _____