Classical High School – Physics

Final Exam Review

Newton's Laws of Motion Review

Part A: Mass, Inertia, Weight, and Newton's First Law of Motion

1. Which of the following statements are true of **inertia**? List all that apply.

   a. Inertia is a force.
   b. Inertia is a force which keeps stationary objects at rest and moving objects in motion at constant velocity.
   c. Inertia is a force which brings all objects to a rest position.
   d. All objects have inertia.
   e. A more massive object has more inertia than a less massive object.
   f. Fast-moving objects have more inertia than slow-moving objects.
   g. An object would not have any inertia in a gravity-free environment (if there is such a place).
   h. Inertia is the tendency of all objects to resist motion and ultimately stop.
   i. In a gravity-free environment (should there be one), a person with a lot of inertia would have the same ability to make a turn as a person with a small amount of inertia.

Answer: DE

d. **True** - Bet money on this one. Any object with mass has inertia. (Any object without mass is not an object, but something else like a wave.)

e. **True** - Mass is a measure of an object's inertia. Objects with greater mass have a greater inertia; objects with less mass have less inertia.

2. Which of the following statements are true of the quantity **mass**? List all that apply.

   a. The mass of an object is dependent upon the value of the acceleration of gravity.
   b. The standard metric unit of mass is the kilogram.
   c. Mass depends on how much *stuff* is present in an object.
   d. The mass of an object is variable and dependent upon its location.
   e. An object would have more mass on Mount Everest than the same object in the middle of Lake Michigan.
   f. People in Weight Watcher's are really concerned about their mass (they're mass watchers).
   g. The mass of an object can be measured in pounds.
   h. If all other variables are equal, then an object with a greater mass would have a more difficult time accelerating.
   i. If all other variables are equal, then it would require less exerted force to stop a less massive object than to stop a more massive object.
   j. The mass of an object is mathematically related to the weight of the object.

Answer: BCFHIJ

b. **True** - Know this one. Kilograms is for mass and Newtons is for force.

c. **True** - This is kind of a simple definition of mass but it does do the job (provided *stuff* means *atoms* or *material*).

f. **True** - Weight Watcher's participants only use a measurement of their weight as a reflection of how many atoms of flesh that they have burned from their bodies. Their real interest is in losing mass for reasons related to health, appearance, etc.

h. **True** - Weight and force of gravity are synonymous terms. You should quickly become comfortable with the terms mass, weight and force of gravity; it will save you many headaches as we continue through the course.

i. **True** - A less massive object has less inertia and as such would offer less resistance to changes in their velocity. For this reason, a less massive object requires less force to bring from a state of motion to a state of rest.

j. **True** - The weight of an object is the mass of the object multiplied by the acceleration of gravity of the object. Mass and weight are mathematically related by the equation: Weight (or Fgrav) = m•g

3. Which of the following statements are true of the quantity **weight**? List all that apply.
    a. The weight of an object is dependent upon the value of the acceleration of gravity.
    b. Weight refers to a force experienced by an object.
    c. The weight of an object would be less on the Moon than on the Earth.
    d. A person could reduce their weight significantly by taking an airplane ride to the top of Mount Everest.
    e. Two objects of the same mass can weigh differently.
    f. To gain weight, one must put on more mass.
    g. The weight of an object can be measured in kilograms.
    h. The weight of an object is equal to the force of gravity acting upon the object.
    i. When a chemistry student places a beaker on a balance and determines it to be 84.3 grams, they have weighed the beaker.

Answer: ABCH and possibly EF

a. **True** - The weight of an object is equal to the force of gravity acting upon the object. It is computed by multiplying the object's mass by the acceleration of gravity (**g**) at the given location of the object. If the location of the object is changed, say from the Earth to the moon, then the acceleration of gravity is changed and so is the weight. It is in this sense that the weight of an object is dependent upon the acceleration of gravity.

b. **True** - This statement is true in the sense that the weight of an object refers to a force - it is the force of gravity.

c. **True** - The weight of an object depends upon the mass of the object and the acceleration of gravity value for the location where it is at. The acceleration of gravity on the moon is 1/6-th the value of **g** on Earth. As such, the weight of an object on the moon would be 6 times less than that on Earth.

e. **Mostly True** - Two objects of the same mass can weigh differently if they are located in different locations. For instance, person A and person B can both have a mass of 60 kg. But if person A is on the Earth, he will weigh ~600 N, whereas person B would weight ~100 N on the moon.

f. **Kinda True (Mostly False)** - Weight is the product of mass and the acceleration of gravity (**g**). To gain weight, one must either increase their mass or increase the acceleration of gravity for the environment where they are located. So the statement is true if one disregards the word **MUST** which is found in the statement.

h. **True** - This statement is the precise definition of weight. Weight is the force of gravity.

4. Which of the following statements are true of an object that experiences **balanced forces** (or **unbalanced forces**)? List all that apply.

a. If a person is moving to the right, then the forces acting upon it are NOT balanced.
b. A balance of forces is demonstrated by an object which is slowing to a stop.
c. It would take an unbalanced force to keep an object in motion.
d. If an object is moving with a constant speed in a circle, then the forces acting upon the object are balanced.
e. If an object is accelerating at a constant rate of acceleration, then the forces acting upon the object are balanced.
f. It is NOT possible for just three forces to be acting upon an object and they still balance each other.
g. A free-falling object experiences a balance of forces.
h. Balanced forces cause stationary objects to remain at rest and moving objects to come to rest.
i. Unbalanced forces cause objects to move.

Answer: None of these are true, though one might make a strong argument for I.

i. **False** - Unbalanced forces do more than cause objects to move; unbalanced forces cause objects to accelerate. Though one could make a strong argument that an object that is accelerating must also be moving (albeit with a changing velocity). In this sense, this statement is true.

5. Consider **Newton's first law of motion** to determine which of the following statements are true? List all that apply.

a. Newton's first law of motion is applicable to both moving and nonmoving objects.
b. If a football is moving upwards and rightwards towards the peak of its trajectory, then there are both rightwards and upwards forces acting upon it.
c. It would take an unbalanced force to keep an object in motion.
d. If an object is at rest, then there are no forces acting upon the object.
e. It would take an unbalanced force to keep an object in motion at a constant velocity.
f. It is the natural tendency of all objects to eventually come to a rest position.
g. A pendulum bob is set into its usual back-and-forth periodic motion. After some time (perhaps 10 minutes), the pendulum bob comes to a rest position. This is best explained by the idea of inertia - all objects eventually resist motion.
h. If a 3-kg rock is thrown at a speed of 2 m/s in a gravity-free environment (presuming one could be found), then an unbalanced force of 6 N would be required to keep the rock moving at a constant speed.
i. It would take an unbalanced force to cause an object to accelerate from rest.

Answer: AI

a. **True** - Absolutely true. Like all true scientific laws, they govern all objects. In the case of Newton's first law of motion: An object that is nonmoving remains at rest (unless acted upon by an unbalanced force); and a moving object will continue in its motion at a constant velocity (unless acted upon by an unbalanced force).

i. **True** - Unbalanced forces cause stationary objects to accelerate from rest. In the absence of an unbalanced force, a stationary object would remain at rest.

Part B: Force, Acceleration and Newton's Second Law of Motion

6. Which of the following statements are true of the concept of **force**? List all that apply.

   a. A force is a push or pull exerted upon an object which results from the interaction of that object with its environment.
   b. Bubba approaches Billie and gives him a swift shove. Timid little Billie keeps his hands in his pocket during this interaction. Subsequently, while Bubba places a force upon Billie, Billie does not place a force upon Bubba.
   c. A quarterback throws a football down field. Once thrown, the force from the quarterback persists upon the ball to cause it to continue on its upward trajectory towards its peak.
   d. A sled slides down the hill and reaches the bottom where it gradually slows to a stop. Once on the level ground, the force of the hill persists upon the sled to allow it to continue its forward motion.
   e. Forces always cause objects to move.
   f. An object can experience two or more forces and not accelerate.
   g. A contact force results from the physical contact between two objects.
   h. A field force results from the action of two objects which are positioned some distance away.
   i. Spring and tension forces are examples of field forces.
   j. A force is a vector quantity; there is always a direction associated with it.
   k. Force can be measured in kilograms or Newtons depending upon the system of measurement (metric or otherwise).

Answer: AFGJ and sort of H.

a. **True** - This is a great definition of force.

f. **True** - Certainly! As you sit in your chair, the chair pushes up on your body but your body does not accelerate. This upward force (known as the normal force) is balanced by the downward force of gravity. Many objects experience a force yet do not accelerate.

g. **True** - There are two broad categories of forces - contact forces and field forces. Contact forces, by definition, are those which result from the physical contact of two forces.

h. **True (mostly)** - A field force is a force which can acts between two objects even when they are separated by a distance. Field forces have magnitudes which are dependent upon the distance of separation between the two interacting objects. For instance, the force of gravity between the Sun and the earth is a field force whose value depends upon the distance of separation between the center of the Earth and the center of the Sun. In this sense, the force of gravity is a force which acts when two objects are separated in space from each other. Yet field forces can also occur when the two objects are touching each other. In this sense, one can be skeptical of the wording of the statement.

j. **True** - Forces always have a direction associated with them. As such, force is a vector quantity - a quantity which is fully described by both a magnitude (size, value) and a direction.

7. Consider **Newton's second law of motion** to determine which of the following statements are true? List all that apply.

a. If an object is accelerating to the right, the net force on the object must be directed towards the right.
b. If an object is moving to the right and slowing down, then the net force on the object is directed towards the left.
c. Accelerating objects are either slowing down or speeding up.
d. The acceleration of an object is directly dependent upon its mass and inversely dependent upon its net force.
e. An object has an acceleration of 8 m/s/s. If the net force acting upon the object is increased by a factor of 2, then the new acceleration would be 10 m/s/s.
f. An object has an acceleration of 8 m/s/s. If the net force acting upon the object is increased by a factor of 3, then the new acceleration would be 11 m/s/s.
g. An object has an acceleration of 8 m/s/s. If the mass of the object is increased by a factor of 2, then the new acceleration would be 16 m/s/s.
h. An object has an acceleration of 8 m/s/s. If the mass of the object is increased by a factor of 4, then the new acceleration would be 2 m/s/s.
i. An object has an acceleration of 8 m/s/s. If the net force acting upon the object is increased by a factor of 2 and the mass of the object is decreased by a factor of 2, then the two factors would offset each other and the acceleration would still be 8 m/s/s.
j. An object has an acceleration of 8 m/s/s. If the net force acting upon the object is increased by a factor of 2 and the mass of the object is increased by a factor of 4, then the new acceleration would be 4 m/s/s.
k. An object has an acceleration of 8 m/s/s. If the net force acting upon the object is decreased by a factor of 2 and the mass of the object is increased by a factor of 4, then the new acceleration would be 1 m/s/s.
l. An object has an acceleration of 8 m/s/s. If the net force acting upon the object is increased by a factor of 4 and the mass of the object is increased by a factor of 2, then the new acceleration would be 16 m/s/s.
m. A 2-kg object accelerates from rest to a final velocity of 6 m/s in 3 seconds. The magnitude of the net force acting upon the object is 12 N.
n. A 10-kg object slows down from 24 m/s to a final velocity of 9 m/s in 3 seconds. The magnitude of the net force acting upon the object is 80 N.

Answer: ABHJKL

a. **True** - The acceleration is directly related to the net force and the direction of the acceleration is always the same as the direction of the net force. When it comes to force, objects can be thought of as being in the middle of a tug-of-war between the individual forces. The force that wins the tug-of-war is the force which determines the direction of the acceleration. So if a rightward force wins over a leftward force, the acceleration will be to the right.

b. **True** - An object which is slowing down has an acceleration which is directed opposite the motion of the object. So an object which moves to the right and slows down experiences a leftward acceleration and therefore a leftward net force.

h. **True** - Acceleration is inversely dependent upon the mass. Whatever alteration is made in the mass, the inverse must be made of the acceleration. So if the mass is increased by a factor of 4, then the acceleration is decreased by a factor of 4 from 8 m/s/s to **2 m/s/s**.

j. **True** - Acceleration is inversely dependent upon the mass and directly dependent upon the net force. If the net force is increased by a factor of 2, then the acceleration is increased by a factor of 2. If the mass is decreased by a factor of 4, then the acceleration is decreased by a factor of 4. The overall result of the two changes is to decrease acceleration by a factor of 2 from 8 m/s/s to **4 m/s/s**.

k. **True** - Acceleration is inversely dependent upon the mass and directly dependent upon the net force. If the net force is decreased by a factor of 2, then the acceleration is decreased by a factor of 2. If the mass is decreased by a factor of 4, then the acceleration is decreased by a factor of 4. The overall result of the two changes is to decrease acceleration by a factor of 8 from 8 m/s/s to **1 m/s/s**.

l. **True** - Acceleration is inversely dependent upon the mass and directly dependent upon the net force. If the net force is increased by a factor of 4, then the acceleration is increased by a factor of 4. If the mass is increased by a factor of 2, then the acceleration is decreased by a factor of 2. The overall result of the two changes is to increase acceleration by a factor of 2 from 8 m/s/s to **16 m/s/s**.

Part C: Forced Choice and Short Answer

8a. Big Bubba has a mass of 100 kg on the earth. What is Big Bubba's mass on the moon where the force of gravity is approximately 1/6-th that of Earth's? _________ Explain or show your work.

Answer: 100 kg

Mass is a quantity which is independent of the location of the object. So if Big Bubba has a mass of 100 kg on Earth, then he also has a mass of 100 kg on the moon. Only the weight would change as Big Bubba is moved from the Earth to the moon. He weighs ~1000 N on Earth and 1/6-th this value (~167 N) on the moon.

8b. Little Billie weighs 360 N on Earth. What is Little Billie's mass on the moon where the force of gravity is approximately 1/6-th that of Earth's? _________ Explain or show your work.

Answer: ~36 kg

The mass of an object is related to weight by the equation **W = m•g** where g = ~10 m/s/s on Earth and one-sixth this value (~1.67) on the moon. So if Billy weighs 360 N on Earth, then his mass is approximately ~36 kg. His mass on the moon will be the same as his mass on Earth. Only his weight changes when on the moon; rather than being 360 N, it is 60 N. His weight on the moon could be found by multiplying his mass by the value of g on the moon: (36 kg) • (9.8/6 m/s/s) = ~60 N

9. **TRUE or FALSE:**
An object which is moving rightward has a rightward force acting upon it.

Answer: False

An object which is accelerating rightward must have a rightward force and a rightward net force acting upon it. But an object which is merely moving rightward does not necessarily have a rightward force upon it. A car that is moving rightward and skidding to a stop would not have a rightward force acting upon it.

10. The amount of net force required to keep a 5-kg object moving rightward with constant velocity of 2 m/s is ____.

a. 0 N　　b. 0.4 N　　c. 2 N　　d. 2.5 N

Answer: A

Net force is always m•a. In this case, the velocity is constant so the acceleration is zero and the net force is zero. Constant velocity motion can always be associated with a zero net force.

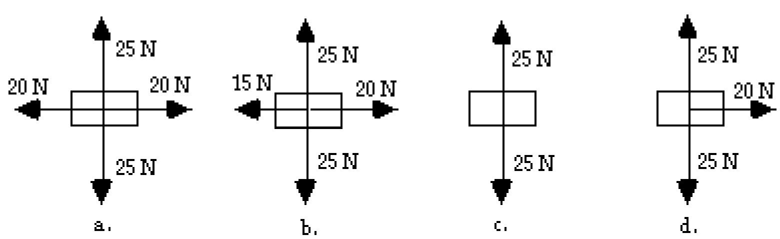
11. **TRUE or FALSE:**

For an object resting upon a non-accelerating surface, the normal force is equal to the weight of the object.

Answer: False

Quite surprisingly to many, the normal force is not necessarily always equal to the weight of an object. Suppose that a person weighs 800 N and sits at rest upon a table. Then suppose another person comes along and pushes downwards upon the persons shoulders, applying a downward force of 200 N. With the additional downward force of 200 N acting upon the person, the total upward force must be 1000 N. The normal force supplies the upward force to support both the force of gravity and the applied force acting upon the person. Its value is equal to 1000 N which is not the same as the force of gravity of the person.

12. Which one(s) of the following force diagrams depict an object moving to the right with a constant speed? List all that apply.



Answer: AC

If an object is moving at a constant speed in a constant rightward direction, then the acceleration is zero and the net force must be zero. Choice B and D show a rightward net force and therefore a rightward acceleration, inconsistent with the described motion.

13. According to Newton's third law, every force is accompanied by an equal and opposite *reaction* force. The reason that these forces do not cancel each other is ____.

a. the action force acts for a longer time period

b. the two forces are not always in the same direction

c. one of the two forces is greater than the other

d. the two forces act upon different objects; only forces on the same object can balance each other.

e. ... nonsense! They do cancel each other. Objects accelerate because of the presence of a third force.

Answer: D

Action and reaction forces always act upon the interacting objects for the same amount of time with the same magnitude. So if object A pushes on object B, then object B simultaneously pushes on object A with the same amount of force. The force on object B will be one of perhaps many forces which will govern its motion. But the reaction force is on object A and cannot contribute to object B's motion since it is not acting upon object B. Action-reaction forces can NEVER cancel each other.

14. As you sit in your chair and study your physics (presuming that you do), the force of gravity acts downward upon your body. The *reaction force* to the force of the Earth pulling you downward is ___.

a. the force of the chair pushing you upward

b. the force of the floor pushing your chair upward

c. the force of the Earth pushing you upward

d. the force of air molecules pushing you upwards

e. the force of your body pulling the Earth upwards

f. ... nonsense! Gravity is a field force and there is no such reaction force.

Answer: E

The most common wrong answer is a - the force of the chair pushing you upward. As you sit in your chair, the chair is indeed pushing you upward but this is not the reaction force to the force of the Earth pulling you downward. The chair pushing you upward is the reaction force to you sitting on it and pushing the chair downward. To determine the action-reaction force pairs if given a statement of the form **object A pulls X-ward on object B**, simply take the subject and the object in the sentence and switch their places and then change the direction to the opposite direction (so the reaction force is object B pulls object A in the opposite direction of X). So if the **Earth** pulls **you down**ward, then the reaction force is **you** pull the **Earth up**ward.

15. A golf pro places a ball at rest on the tee, lines up his shot, draws back his club, and lets one rip. During the contact of the golf club with the golf ball, the force of the club on the ball is ____ the force of the ball on the club and the acceleration of the club is ____ than the acceleration of the ball.

a. greater than, greater than	b. greater than, equal to	c. greater than, less than
d. less than, less than	e. less than, equal to	f. less than, greater than
g. equal to, equal to	h. equal to, greater than	i. equal to, less than

Answer: I

For every action, there is an equal and opposite reaction force. In this case, the force on the club is equal to the force on the ball. The subsequent accelerations of the interacting objects will be inversely dependent upon mass. The more massive club will have less acceleration than the less massive ball.

Each one of Newton's Laws can play a role in any one particular situation. However, one of the laws is often most obviously dominant in governing the motion of a situation. Pick which of Newton's **most** governs the situations described below.

a. First Law (inertia) b. Second Law (F = m•a) c. Third Law (action-reaction)

16. A helicopter must have two sets of blades in order to fly with stability.

17. If you were in an elevator and the cable broke, jumping up just before the elevator hit the ground would not save you. Sorry.

18. You usually jerk a paper towel from a roll in order to tear it instead of pulling it smoothly.

19. A student desk changes the amount of force it puts on other objects throughout a school day.

20. Heavy objects are not easier to move around in a horizontal fashion on the Moon than on the Earth.

21. The stronger, heavier team in a tug-of-war does not create a larger tension in the rope than the weaker, lighter team.

Answers: See answers and explanations below.

16. C - As the helicopter blades spin and push air in one direction, the air pushes the blades in the opposite direction; the result is that the helicopter can begin to rotate about the axis of the blade. To counteract this rotation, a second set of blades is required.

17. A - An object moving downwards will continue to move downwards unless acted upon by an unbalanced force. If you make an effort to supply such a force in an attempt to suddenly alter the direction of your motion, then you are creating a greater velocity change than if you merely hit the ground and stopped. If this greater velocity change occurred suddenly (in the same amount of time as the stopping of you and the elevator), then you would experience a greater acceleration, a greater net force, and a greater ouch mark than if you had merely hit the ground and stopped.

18. A - The paper towel is at rest and resists changes in its at rest state. So if you apply a sudden force to one of the paper towel sheets, the great mass of the remainder of the roll will resist a change in its at rest state and the roll will easily break at the perforation.

19. C - As a student sits in the seat, they are applying a downward force upon the seat. The reaction force is that the seat applies an upward force upon the person.

A *weightier* person will apply more downward force than a lighter person. Thus, the seat will constantly be changing the amount of reaction force throughout the day as students of different weight sit in it.

20. A - All objects have inertia or a tendency to resist changes in their state of motion. This inertia is dependent solely upon mass and is subsequently not altered by changes in the gravitational environment. To move an object horizontally, one must apply a force; this force will be resisted by the mass or inertia of the object. On the moon, the object offers the same amount of inertia as on Earth; it is just as difficult (or easy) to move around.

21. C - A rope encounters tension when pulled on at both ends. The tension in the rope is everywhere the same. If team A were to pull at the left end, then the left end would pull

back with the same amount of force upon team A. This force is the same everywhere in the rope, including at the end where team B is pulling. Thus team B is pulling back on the rope with the same force as team A. So if the forces are the same at each end, then how can a team ever win a tug-of-war. The way a stronger team wins a tug-of-war is with their legs. They push upon the ground with a greater force than the other team. This force upon the ground results in a force back upon the team in order for them to pull the rope and the other team backwards across the line.

Impulse, Momentum and Collisions Review

Part A: Multiple-Multiple Choice

1. Which of the following statements are true about momentum?

a. Momentum is a vector quantity.
b. The standard unit on momentum is the Joule.
c. An object with mass will have momentum.
d. An object which is moving at a constant speed has momentum.
e. An object can be traveling eastward and slowing down; its momentum is westward.
f. Momentum is a conserved quantity; the momentum of an object is never changed.
g. The momentum of an object varies directly with the speed of the object.
h. Two objects of different mass are moving at the same speed; the more massive object will have the greatest momentum.
i. A less massive object can never have more momentum than a more massive object.
j. Two identical objects are moving in opposite directions at the same speed. The forward moving object will have the greatest momentum.
k. An object with a changing speed will have a changing momentum.

Answer: ADGHK

a. **TRUE** - Momentum is a vector quantity. Like all vector quantities, the momentum of an object is not fully described until the direction of the momentum is identified. Momentum, like other vector quantities, is subject to the rules of vector operations.

g. **TRUE** - Momentum is calculated as the product of mass and velocity. As the speed of an object increases, so does its velocity. As a result, an increasing speed leads to an increasing momentum - a direct relationship.

h. **TRUE** - For the same speed (and thus velocity), a more massive object has a greater product of mass and velocity; it therefore has more momentum.

k. **TRUE** - Objects with a changing speed also have a changing velocity. As such, an object with a changing speed also has a changing momentum.

2. Which of the following are true about the relationship between momentum end energy?

a. Momentum is a form of energy.
b. If an object has momentum, then it must also have mechanical energy.

c. If an object does not have momentum, then it definitely does not have mechanical energy either.
d. Object A has more momentum than object B. Therefore, object A will also have more kinetic energy.
e. Two objects of varying mass have the same momentum. The least massive of the two objects will have the greatest kinetic energy.

Answer: BE

b. **TRUE** - If an object has momentum, then it is moving. If it is moving, then it has kinetic energy And if an object has kinetic energy, then it definitely has mechanical energy.

e. **TRUE** - When comparing the momentum of two objects to each other, one must consider both mass and velocity; both are of equal importance when determining the momentum value of an object. When comparing the kinetic energy of two objects, the velocity of an object is of double importance. So if two objects of different mass have the same momentum, then the object with th least mass has a greater velocity. This greater velocity will tip the scales in favor of the least massive object when a kinetic energy comparison is made.

3. Which of the following statements are true about impulse?

a. Impulse is a force.
b. Impulse is a vector quantity.
c. An object which is traveling east would experience a westward directed impulse in a collision.
d. Objects involved in collisions encounter impulses.
e. The Newton is the unit for impulse.
f. The kg•m/s is equivalent to the units on impulse.
g. An object which experiences a net impulse will definitely experience a momentum change.
h. In a collision, the net impulse experienced by an object is equal to its momentum change.
i. A force of 100 N acting for 0.1 seconds would provide an equivalent impulse as a force of 5 N acting for 2.0 seconds.

Answer: BDFGHI

b. **TRUE** - Impulse is a vector quantity Like momentum, impulse is not fully described unless a direction is associated with it.

d. **TRUE** - In a collision, there is a collision force which endures for some amount of time. The combination of force and time is what is referred to as an impulse.

f. **TRUE** - The N•s is the unit of momentum. The Newton can be written as a kg•m/s^2. When substituted into the N•s expression, the result is the kg m/s.

g. **TRUE** - In a collision, there is a collision force which endures for some amount of time to cause an impulse. This impulse acts upon the object to change its velocity and thus its momentum.

h. **TRUE** - Yes!!! This is the impulse-momentum change theorem. The impulse encountered by an object in a collision causes and is equal to the momentum change experienced by that object.

i. **TRUE** - A force of 100 N for 0.10 s results in an impulse of 10 N•s. This 10 N•s impulse is equivalent to the impulse created by a force of 5 N for 2.0 seconds.

4. Which of the following statements are true about collisions?

a. Two colliding objects will exert equal forces upon each other even if their mass is significantly different.
b. During a collision, an object always encounters an impulse and a change in momentum.
c. During a collision, the impulse which an object experiences is equal to its velocity change.
d. The velocity change of two respective objects involved in a collision will always be equal.
e. While individual objects may change their velocity during a collision, the overall or total velocity of the colliding objects is conserved.
f. In a collision, the two colliding objects could have different acceleration values.
g. In a collision between two objects of identical mass, the acceleration values could be different.
h. Total momentum is always conserved between any two objects involved in a collision.
i. When a moving object collides with a stationary object of identical mass, the stationary object encounters the greater collision force.
j. When a moving object collides with a stationary object of identical mass, the stationary object encounters the greater momentum change.
k. A moving object collides with a stationary object; the stationary object has significantly less mass. The stationary object encounters the greater collision force.
l. A moving object collides with a stationary object; the stationary object has significantly less mass. The stationary object encounters the greater momentum change.

Answer: ABF

a. **TRUE** - In any collision between two objects, the colliding objects exert equal and opposite force upon each other. This is simply Newton's law of action-reaction.

b. **TRUE** - In a collision, there is a collision force which endures for some amount of time to cause an impulse. This impulse acts upon the object to change its momentum.

f. **TRUE** - Two colliding objects will exert equal forces upon each other. If the objects have different masses, then these equal forces will produce different accelerations.

Part B: Multiple Choice

6. Which of the following objects have momentum? Include all that apply.

a. An electron is orbiting the nucleus of an atom.

b. A UPS truck is stopped in front of the school building.

c. A Yugo (a compact car) is moving with a constant speed.

d. A small flea walking with constant speed across Fido's back.

e. The high school building rests in the middle of town.

Answer: A, C, and D

Momentum can be thought of as **mass in motion**. An object has momentum if it has its mass in motion. It matters not whether the object is of large mass or small mass, moving with constant speed or accelerating; if the object is MOVING, then it has momentum!

7. A truck driving along a highway road has a large quantity of momentum. If it moves at the same speed but has twice as much mass, its momentum is ________________.

a. zero b. quadrupled c. doubled d. unchanged

Answer: C

Momentum is directly related to the mass of the object. So for the same speed, a doubling of mass leads to a doubling of momentum.

8. **TRUE or FALSE:**

A ball is dropped from the same height upon various flat surfaces. For the same collision time, impulses are smaller when the most bouncing take place.

a. True b. False

Answer: B

Since being dropped from the same height, the balls will be moving with the same pre-collision velocity (assuming negligible air resistance). Upon collision with the ground, the velocity will have to be reduced to zero - that is, the ball will cease moving downwards. This decrease in velocity constitutes the first portion of the velocity change. If the ball bounces, then there is an additional velocity change sending the ball back upwards opposite the original direction. Thus, for the same collision time, bouncing involves a greater velocity change, a greater momentum change, and therefore a greater impulse.

9. Consider a karate expert. During a talent show, she executes a swift blow to a cement block and breaks it with her bare hand. During the collision between her hand and the block, the ___.

a. time of impact on both the block and the expert's hand is the same
b. force on both the block and the expert's hand have the same magnitude
c. impulse on both the block and the expert's hand have the same magnitude

d. all of the above.
e. none of the above.

Answer: D

In any collision, there are always four quantities which are the same for both objects involved in the collision. Each object experiences the same force (Newton's third law) for the same amount of time, leading to the same impulse, and subsequently the same momentum change. Only the acceleration and the velocity change can differ for the two colliding objects. The lower mass object always receives the greater velocity change and acceleration.

10. It is NOT possible for a rocket to accelerate in outer space because ____. List all that apply.

a. there is no air in space
b. there is no friction in space
c. there is no gravity in outer space
d. ... nonsense! Rockets do accelerate in outer space.

Answer: D

Rockets accelerate in outer space by means of Newton's third law of motion. It does not matter that there is no air outside of the rocket. Rockets produce their own gas by burning fuels. The combustion of rocket fuels produces gaseous products. The rocket's thrusters push these gases backwards (or rightwards, or leftwards, or ...) and the gases push the rocket forwards (or leftwards, or rightwards, or ...). Thus, rockets indeed can and do accelerate in outer space.

11. In order to catch a ball, a baseball player naturally moves his or her hand backward in the direction of the ball's motion once the ball contacts the hand. This habit causes the force of impact on the players hand to be reduced in size principally because ___.

a. the resulting impact velocity is lessened
b. the momentum change is decreased
c. the time of impact is increased
d. the time of impact is decreased
e. none of these

Answer: C

Increasing the time over which the ball's momentum is brought to 0 will decrease the force required to stop it. Suppose a ball is coming at you with 100-units of momentum. An impulse of 100-units would be required to stop the ball. Regardless of how the impulse is accomplished (big F, little t or little F, big t), there must be 100-units of it. Imparting such an impulse over a long time results in a small force.

12. Suppose that Paul D. Trigger fires a bullet from a gun. The speed of the bullet leaving the muzzle will be the same as the speed of the recoiling gun ____.

a. because momentum is conserved
b. because velocity is conserved
c. because both velocity and momentum are conserved
d. only if the mass of the bullet equals the mass of the gun
e. none of these

Answer: D

In any collision or explosion involving two objects, the momentum change for each object is the same. So both the bullet and the gun encounter the same momentum change. The momentum change is simply the mass multiplied by the velocity change. Thus, the velocity change would only be the same if their masses were the same. Otherwise, the smaller-mass object receives a greater velocity change.

13. Suppose that you're driving down the highway and a moth crashes into the windshield of your car. Which undergoes the greater change is momentum?

a. the moth b. your car c. both the same

Answer: C

In any collision, there are always four quantities which are the same for both objects involved in the collision. Each object experiences the same force (Newton's third law) for the same amount of time, leading to the same impulse, and subsequently the same momentum change. Only the acceleration and the velocity change can differ for the two objects. The object with the least mass always receives the greatest velocity change and acceleration.

14. Suppose that you're driving down the highway and a moth crashes into the windshield of your car. Which undergoes the greater force?

a. the moth b. your car c. both the same

Answer: C

In any collision, there are always four quantities which are the same for both objects involved in the collision. Each object experiences the same force (Newton's third law) for the same amount of time, leading to the same impulse, and subsequently the same momentum change. Only the acceleration and the velocity change can differ for the two objects. The object with the least mass always receives the greatest velocity change and acceleration.

15. Suppose that you're driving down the highway and a moth crashes into the windshield of your car. Which undergoes the greater impulse?

a. the moth b. your car c. both the same

Answer: C

In any collision, there are always four quantities which are the same for both objects involved in the collision. Each object experiences the same force (Newton's third law) for the same amount of time, leading to the same impulse, and subsequently the same momentum change. Only the acceleration and the velocity change can differ for the two objects. The object with the least mass always receives the greatest velocity change and acceleration.

16. Suppose that you're driving down the highway and a moth crashes into the windshield of your car. Which undergoes the greater acceleration?

a. the moth   b. your car   c. both the same

Answer: A

In any collision, there are always four quantities which are the same for both objects involved in the collision. Each object experiences the same force (Newton's third law) for the same amount of time, leading to the same impulse, and subsequently the same momentum change. Only the acceleration and the velocity change can differ for the two objects. The object with the least mass always receives the greatest velocity change and acceleration.

18. In a physics experiment, two equal-mass carts roll towards each other on a level, low-friction track. One cart rolls rightward at 2 m/s and the other cart rolls leftward at 1 m/s. After the carts collide, they couple (attach together) and roll together with a speed of ______________. Ignore resistive forces.

a. 0.5 m/s   b. 0.33 m/s   c. 0.67 m/s   d. 1.0 m/s   e. none of these

Answer: A

Use 1 kg as the mass of the carts (or any number you wish) and then set the expression for initial final total momentum:

(1 kg)*(2) + (1 kg) *(-1) = (1 kg) *v + (1 kg) *v
Now solve for v using the proper algebraic steps.

(2 kg•m/s) - (1 kg•m/s) = (2 kg) v
1 kg•m/s = (2 kg)v

(1 kg•m/s) / (2 kg) = v

0.5 m/s = v

19. A physics cart rolls along a low-friction track with considerable momentum. If it rolls at the same speed but has twice as much mass, its momentum is ____.

a. zero   b. four times as large   c. twice as large   d. unchanged

Answer: C

The momentum of an object is calculated as the product of mass and velocity. Thus, the momentu object. If the mass of an object is somehow doubled, the momentum is doubled as well.

20. The firing of a bullet by a rifle causes the rifle to recoil backwards. The speed of the rifle's recoil is smaller than the bullet's forward speed because the ___.

a. force against the rifle is relatively small   b. speed is mainly concentrated in the bullet

c. rifle has lots of mass   d. momentum of the rifle is unchanged

e. none of these

Answer: C

Please don't answer A (for it will make Newton roll over in his grave and he's getting quite tired of that). Perhaps you've heard that "for every action, there is an equal and opposite ...". Choice B is invalid; speed is not something that becomes concentrated or squeezed into an object. Choice D is invalid; ask anyone who's fired a rifle if the rifle is set into motion by the firing of the bullet. (Of course, since it is set in motion, its momentum is not unchanged.) Because of the large mass of the rifle, the acceleration and the recoil speed of the rifle is small.

21. Two objects, A and B, have the same size and shape. Object A is twice as massive as B. The objects are simultaneously dropped from a high window on a tall building. (Neglect the effect air resistance.) The objects will reach the ground at the same time but object A will have a greater ___. Choose all that apply.

a. speed b. acceleration c. momentum

d. none of the above quantities will be greater

Answer: C

The two objects free-fall at the same rate of acceleration, thus giving them the same speed when they hit the ground. The heavier object however has more momentum since momentum takes into account both the speed and the mass of the object (p=m*v).

22. Cars are equipped with padded dashboards. In collisions, the padded dashboards would be safer than non-padded ones because they ____. List all that apply.

a. increase the impact time b. decrease an occupant's impulse

c. decrease the impact force d. none of the above

Answer: AC

Both A and C are correct. Padded dashboard serve to increase the time over which the momentum of a passenger is reduced to zero. With this increase in time, there is a decrease in force (big T, little f).

The impulse acting upon the passenger is not changed. The passenger still must have his/her mass slowed down from the pre-impact velocity to zero velocity. This means the velocity change is the same whether the collision occurs with a padded dashboard, an air bag or a glass windshield. Since the velocity change is independent of the collision time, the momentum change and the required impulse are also independent of the collision time.

23. A 4 kg object has a momentum of 12 kg•m/s. The object's speed is ___ m/s.

a. 3 b. 4 c. 12 d. 48 e. none of these.

Answer: A

This is a relatively simple plug-and-chug into the equation p=m*v with m=4 kg and p=12 kg•m/s.

24. A wad of chewed bubble gum is moving with 1 unit of momentum when it collides with a heavy box that is initially at rest. The gum sticks to the box and both are set in motion with a combined momentum that is ___.

a. less than 1 unit   b. 1 unit   c. more than 1 unit   d. not enough information

Answer: B

Before the collision, the total system momentum is 1 unit - all due to the motion of the wad of gun total momentum of the box and gum after the collision must also be 1 unit.

25. A relatively large force acting for a relatively long amount of time on a relatively small mass will produce a relatively ______. List all that apply.

a. small velocity change   b. large velocity change

c. small momentum change   d. small acceleration

Answer: B

A large force acting upon a small mass will result in a large acceleration (a=F/m) and subsequently a large velocity change (Delta v = a*t). This rules out choices A and D. A large force and for a long time will result in a large impulse and therefore a large momentum change. This rules out choice C.

26. Consider the concepts of work and energy (presuming you have already studied it) and those of impuse and momentum. Force and time is related to momentum change in the same manner as force and displacement pertains to ___________.

a. impulse   b. work   c. energy change   d. velocity   e. none of these.

Answer: C

A force multiplied by a time gives an impulse which will cause (and be equal to) a momentum change. In the same manner, a force multiplied by a displacement gives work which will cause (and be equal to) an energy change. Take the time to reread those two sentences because it relates two big concepts.

27. A 5-N force is applied to a 3-kg ball to change its velocity from +9 m/s to +3 m/s. This impulse causes the momentum change of the ball to be ____ kg•m/s.

a. -2.5   b. -10   c. -18   d. -45   e. none of these

Answer: C

Don't make this harder than it is; the momentum change of an object can be found if the mass and the velocity change are known. In this equation, m=3 kg and the velocity change is -6 m/s. When finding the velocity change, always subtract the initial velocity from the final velocity (v_f - v_i).

There is a second means of determining the momentum change of an object (though it does not need to be used in this problem). The momentum change can also be found if the force and the time are known. Multiplying force*time yields the impulse and the impulse equals the momentum change.

28. A 5-N force is applied to a 3-kg ball to change its velocity from +9 m/s to +3 m/s. The impulse experienced by the ball is ____ N•s.

a. -2.5 b. -10 c. -18 d. -45 e. none of these

Answer: C

Impulse is defined as a force acting upon and object for a given amount of time. Impulse can be computed by multiplying force*time. But in this problem, the time is not known. Never fear - the impulse equals the momentum change. The momentum change in this problem is -18 kg•m/s (see question #27). Thus, the impulse is -18 N•s.

29. A 5-N force is applied to a 3-kg ball to change its velocity from +9 m/s to +3 m/s. The impulse is encountered by the ball for a time of ____ seconds.

a. 1.8 b. 2.5 c. 3.6 d. 10 e. none of these

Answer: C

Use the impulse momentum change theorem with F=5 N, m=3 kg and Delta v=-6 m/s. Solving for time involves the following steps.

t = m*(delta v)/F = (3 kg)*(-6 m/s) / (5 N)
t = 3.6 s

34. A 0.5-kg ball moving at 5 m/s strikes a wall and rebounds in the opposite direction with a speed of 2 m/s. If the impulse occurs for a time duration of 0.01 s, then the average force (magnitude only) acting upon the ball is ____ Newtons.

a. 0.14 b. 150 c. 350 d. 500 e. none of these

Answer: C

This is a relatively simple plug-and-chug into the equation

F*t = m*(Delta vel.)

with m=0.5 kg, t=0.01 s and Delta vel.=-7 m/s. (The change in velocity is -7 m/s since the ball must first slow down from 5 m/s to 0 m/s and then be *thrown back* in the opposite direction at 2 m/s.) Using these numbers and solving for force yields -350 N. The magnitude of the force is 350 N and the "-" sign indicates the direction of the force.

35. If mass and collision time are equal, then impulses are greater on objects which rebound (or bounce).

a. TRUE b. FALSE

Answer: A

The impulse is equal to the momentum change. And when there is a rebound, the momentum change is larger since there is a larger velocity change. For instance, a ball thrown at a wall at 5 m/s may rebound at -3 m/s yielding a velocity change of -8 m/s. An egg thrown at the same wall at the same speed of 5 m/s hits and stops, thus yielding a velocity change of -5 m/s. More velocity change means more momentum change and thus more impulse.

36. Consider the head-on collision between a lady bug and the windshield of a high speed bus. Which of the following statements are true? List all that apply.

a. The magnitude of the force encountered by the bug is greater than that of the bus.
b. The magnitude of the impulse encountered by the bug is greater than that of the bus.
c. The magnitude of the momentum change encountered by the bug is greater than that of the bus.
d. The magnitude of the velocity change encountered by the bug is greater than that of the bus.
e. The magnitude of the acceleration encountered by the bug is greater than that of the bus.

Answer: D and E

In any collision between two objects, the force, impulse, and momentum change are the same for each object. (This makes statements A, B, and C false.) However, the smaller mass object encounters a greater acceleration and velocity change. (This makes statements D and E true).

Part E: Problem-Solving

57. A 0.530-kg basketball hits a wall head-on with a forward speed of 18.0 m/s. It rebounds with a speed of 13.5 m/s. The contact time is 0.100 seconds. (a) determine the impulse with the wall, (b) determine the force of the wall on the ball.

Answer: Answer: (a) -16.7 N s; (b) -167 N

Given: m = 0.530 kg; v_i = 18.0 m/s; v_f = 13.5 m/s; t = 0.100 s

Find: (a) Impulse, (b) Force

(a) Impulse = Momentum Change = m•Delta v = m•(v_f - v_i)= (0.530 kg)•(-13.5 m/s - 18.0 m/s)

Impulse = -16.7 kg•m/s = **-16.7 N•s**

where the "-" indicates that the impulse was opposite the original direction of motion.

(Note that a kg•m/s is equivalent to a N•s)

(b) The impulse is the product of force and time. So if impulse is known and time is known, force can be easily determined.

Impulse = F•t

F = Impulse/t = (-16.7 N s) / (0.100 s) = **-167 N**

where the "-" indicates that the impulse was opposite the original direction of motion.

58. A 4.0-kg object has a forward momentum of 20. kg•m/s. A 60. N•s impulse acts upon it in the direction of motion for 5.0 seconds. A resistive force of 6.0 N then impedes its motion for 8.0 seconds. Determine the final velocity of the object.

Answer: v_f = 8.0 m/s

This question is best thought about conceptually using the principle that an objects momentum is changed when it encounters an impulse and the amount of change in momentum is equal to the impulse which it encounters.

Here an object starts with 20 units (kg•m/s) of momentum. It then encounters an impulse of 60 units (N•s) in the direction of motion. A 60-unit impulse will change the momentum by 60 units, either increasing or decreasing it. If the impulse is in the direction of an object's motion, then it will increase the momentum. So now the object has 80 units (kg•m/s) of momentum. The object then encounters a resistive force of 6.0 N for 8.0 s. This is equivalent to an impulse of 48 units (N•s). Since this impulse is "resistive" in nature, it will decrease the object's momentum by 48 units. The object now has 32 units of momentum. The question asks for the object's velocity after encountering these two impulses. Since momentum is the product of mass and velocity, the velocity can be easily determined.

$$p = m \cdot v$$

$$v_{final} = p_{final} / m = (32 \text{ kg m/s}) / (4.0 \text{ kg}) = \mathbf{8.0\ m/s}$$

59. A 3.0-kg object is moving forward with a speed of 6.0 m/s. The object then encounters a force of 2.5 N for 8.0 seconds in the direction of its motion. The object then collides head-on with a wall and heads in the opposite direction with a speed of 5.0 m/s. Determine the impulse delivered by the wall to the object.

Answer: 53 N•s

Like the previous problem, this problem is best solved by thinking through it conceptually using the impulse-momentum change principle.

Here the object begins with a momentum of 18 units (kg•m/s). The object encounters a force of 2.5 N for 8.0 seconds. This is equivalent to an impulse of 20 units (N•s). Since this impulse acts in the direction of motion, it changes the object's momentum from 18 units to 38 units. A final impulse is encountered when colliding with a wall. Upon rebounding, the object has a momentum of -15 units (kg•m/s). The -15 is the product of mass (3 kg) and velocity (-5 m/s). The "-" sign is used since the object is now moving in the opposite direction as the original motion. The collision with the wall changed the object's momentum from +38 units to -15 units. Thus, the collision must have resulted in a 53-unit impulse since it altered the object's momentum by 53 units.

60. A 46-gram tennis ball is launched from a 1.35-kg homemade cannon. If the cannon recoils with a speed of 2.1 m/s, determine the muzzle speed of the tennis ball.

Answer: 62 m/s

Given: m_{ball} = 46 g = 0.046 kg; m_{cannon} = 1.35 kg; v_{cannon} = -2.1 m/s

Find: v_{ball} = ???

The ball is in the cannon and both objects are initially at rest. The total system momentum is initia After the explosion, the total system momentum must also be 0. Thus, the cannon's backward momentum must be equal to the ball's forward momentum.

$$m_{cannon} \bullet v_{cannon} = -m_{ball} \bullet v_{ball}$$

$$(1.35 \text{ kg}) \bullet (-2.1 \text{ m/s}) = (0.046 \text{ kg}) \bullet v_{ball}$$

$$v_{ball} = (1.35 \text{ kg}) \bullet (2.1 \text{ m/s}) / (0.046 \text{ kg}) = 61.63 \text{ m/s} = \mathbf{\sim 62 \text{ m/s}}$$

Work-Energy and Energy Conservation Review

Part A: Forced Choice Questions

1. Which of the following statements are true about work? Include all that apply.

a. Work is a form of energy.
b. A Watt is the standard metric unit of work.
c. Units of work would be equivalent to a Newton times a meter.
d. A $kg \bullet m^2/s^2$ would be a unit of work.
e. Work is a time-based quantity; it is dependent upon how fast a force displaces an object.
f. Superman applies a force on a truck to prevent it from moving down a hill. This is an example of work being done.
g. An upward force is applied to a bucket as it is carried 20 m across the yard. This is an example of work being done.
h. A force is applied by a chain to a roller coaster car to carry it up the hill of the first drop of the Shockwave ride. This is an example of work being done.
i. The force of friction acts upon a softball player as she makes a headfirst dive into third base. This is an example of work being done.
j. An eraser is tied to a string; a person holds the string and applies a tension force as the eraser is moved in a circle at constant speed. This is an example of work being done.
k. A force acts upon an object to push the object along a surface at constant speed. By itself, this force must NOT be doing any work upon the object.
l. A force acts upon an object at a 90-degree angle to the direction that it is moving. This force is doing negative work upon the object.
m. An individual force does NOT do positive work upon an object if the object is moving at constant speed.
n. An object is moving to the right. A force acts leftward upon it. This force is doing negative work.
o. A non-conservative force is doing work on an object; it is the only force doing work. Therefore, the object will either gain or lose mechanical energy.

Answer: ACDHIKNO

a. **TRUE** - Work is a form of energy, and in fact it has units of energy.

c. **TRUE** - A $N \bullet m$ is equal to a Joule.

d. **TRUE** - A $kg \bullet m^2/s^2$ is a mass unit times a speed squared unit, making it a kinetic energy unit and equivalent to a Joule.

h. **TRUE** - There is a component of force in the direction of displacement and so this is an example of work.

i. **TRUE** - There is a force and a displacement; the force acts in the opposite direction as the displacement and so this force does negative work.

n. **TRUE** - A force which acts in a direction opposite the motion of an object will do negative work.

o. **TRUE** - When non-conservative forces do work upon an object, the object will either gain or lose mechanical energy. Mechanical energy is conserved (neither gained nor lost) only when conservative forces do work upon objects.

2. Which of the following statements are true about power? Include all that apply.

a. Power is a time-based quantity.
b. Power refers to how fast work is done upon an object.
c. Powerful people or powerful machines are simply people or machines which always do a lot of work.
d. A force is exerted on an object to move it at a constant speed. The power delivered by this force is the magnitude of the force multiplied by the speed of the object.
e. The standard metric unit of power is the Watt.
f. If person A and person B do the same job but person B does it faster, then person A does more work but person B has more power.
g. The Newton•meter is a unit of power.
h. A 60-kg boy runs up a 2.0 meter staircase in 1.5 seconds. His power is approximately 80 Watt.
i. A 300-Newton force is applied to a skier to drag her up a ski hill at a constant speed of 1.5 m/s. The power delivered by the toe rope is 450 Watts.

Answer: ABDEI

a. **TRUE** - Power is a rate quantity and thus time-based.

b. **TRUE** - This is the definition of power.

d. **TRUE** - An equation for computing work in constant speed situations is P=F•v.

e. **TRUE** - Watt is the unit of power? Yes!!

i. **TRUE** - Since force and speed are given, use Power = F•v. The calculation yields 450 W.

3. Consider the following physical situations. For each case, determine the angle between the indicated force (in **boldface type**) and the displacement ("theta" in the work equation).

a. 0 degrees b. 180 degrees c. 90 degrees d. 30 degrees e. 60 degrees

a. A rightward **applied force** is used to displace a television set to the right.
- **Answer: A - 0 degrees**

b. The **force of friction** acts upon a rightward-moving car to bring it to a stop.
- **Answer: B - 180 degrees**

c. A waiter uses an **applied force** to balance the weight of a tray of plates as he carries the tray across the room. - **Answer: C - 90 degrees**

d. The force of **air resistance** acts upon a vertically-falling skydiver. - **Answer: B - 180 degrees**
e. The **force of friction** acts upon a baseball player as he slides into third base. - **Answer: B - 180 degrees**
f. An **applied force** is used by a freshman to lift a World Civilization book to the top shelf of his locker. - **Answer: A - 0 degrees**
g. A bucket of water is tied to a string and **tension** supplies the centripetal force to keep it moving in a circle at constant speed. - **Answer: C - 90 degrees**
h. An **applied force** acting at 30-degrees to the horizontal is used to displace an object to the right. - **Answer: D - 30 degrees**
i. A group of football players use an **applied force** to push a sled across the grass. - **Answer: A - 0 degrees**
j. The **tension** in the elevator cable causes the elevator to rise at a constant speed. - **Answer: A - 0 degrees**
k. In a physics lab, an **applied force** is exerted parallel to a plane inclined at 30-degrees in order to displace a cart up the incline. - **Answer: A - 0 degrees**
l. An **applied force** is exerted upwards and rightwards at an angle of 30-degrees to the vertical in order to displace an object to the right. - **Answer: E - 60 degrees**
m. A child rests on the seat of a swing which is supported by the **tension** in its cables; he swings from the highest position to its lowest position. - **Answer: C - 90 degrees**

Answer: See questions above; explanations given below.

a. The forward motion is do to the forward pushing; if the force and motion are in the same direction, then the angle is 0 degrees.

b. Friction opposes motion and as such does negative work; the angle is 180 degrees.

c. The force is vertical and the displacement if horizontal; they make a 90 degree angle.

d. Air resistance opposes motion and as such does negative work; the angle is 180 degrees.

e. Friction opposes motion and as such does negative work; the angle is 180 degrees.

f. The frosh applies an upward force to cause an upward displacement; the angle is 0 degrees.

g. For uniform circular motion, the force is inwards and the displacement at each instant is tangent to the circle; these two vectors make a 90 degree angle.

h. This is a straightforward question; no tricks here.

i. The forward motion is do to the forward pushing; if the force and motion are in the same direction, then the angle is 0 degrees.

j. The cable pulls up on the elevator and the elevator is displaced upward; if the force and motion are in the same direction, then the angle is 0 degrees.

k. The 30-degree angle is the incline angle, not necessarily the angle between F and d. The force is parallel to the incline and the cart is displaced along the direction of the incline; so the two vectors are in the same direction and the angle between them is 0 degrees.

l. Compare the wording of this to part h. This one is tricky because the angle between F and d is 60-degrees. If you missed it, reread the question, paying careful attention to the "with the vertical" part.

m. As the child swings, she traces out a circular arc and as such the tension (centripetal) is perpendicular to the direction of motion (tangent).

4. Consider the following physical situations. Identify whether the indicated force (in **boldface type**) does positive work, negative work or no work.

a. Positive Work   b. Negative Work   c. No Work

Description of Physical Situation	+, -, or no Work
a. A cable is attached to a bucket and the **force of tension** is used to pull the bucket out of a well.	A. Positive Work
b. Rusty Nales uses a hammer to exert an **applied force** upon a stubborn nail to drive it into the wall.	A. Positive Work
c. Near the end of the Shockwave ride, a braking system exerts an **applied force** upon the coaster car to bring it to a stop.	B. Negative Work
d. The **force of friction** acts upon a baseball player as he slides into third base.	B. Negative Work
e. A busy spider hangs motionless from a silk thread, supported by the **tension** in the thread.	C. No Work
f. In baseball, the catcher exerts an abrupt **applied force** upon the ball to stop it in the catcher's mitt.	B. Negative Work
g. In a physics lab, an **applied force** is exerted parallel to a plane inclined at 30-degrees in order to displace a cart up the incline.	A. Positive Work
h. A pendulum bob swings from its highest position to its lowest position under the influence of the **force of gravity**.	A. Positive Work

Answer: See table above; explanations provided below.

a. The force is upwards and the displacement is upwards. When the force and the displacement act in the same direction, positive work is done.

b. The force is horizontal and the displacement is horizontal. When the force and the displacement act in the same direction, positive work is done. (It is true that the wall is doing negative work upon the nail but this statement is about the hammer's force on the nail.)

c. The force is backwards and the displacement is forwards. When the force and the displacement act in the opposite direction, negative work is done.

d. The force is backwards and the displacement is forwards. When the force and the displacement act in the opposite direction, negative work is done.

e. If the force does not cause the object to be displaced (the object hangs motionless), then no work is done.

f. The force is backwards and the displacement is forwards. When the force and the displacement act in the opposite direction, negative work is done.

g. The force is upwards and parallel to the incline and the displacement is in the same direction parallel to the incline. When the force and the displacement act in the same direction, positive work is done.

h. As the bob swings downwards from its highest position, the motion is downwards (and rightwards); the force is also downwards and as such there is a component of force in the direction of motion. When the force and the displacement act in the same direction, positive work is done. (Note that if the bob was swinging upwards from its lowest position to its highest position, then **gravity** would be doing negative work.)

5. Which of the following statements are true about conservative and non-conservative forces? Include all that apply.

a. A force is regarded as a conservative force if it does work but does not remove mechanical energy from a system of objects.
b. A force is regarded as a non-conservative force if it does not add mechanical energy to a system of objects.
c. The force of gravity and elastic (spring) force are both examples of a conservative forces.
d. Applied forces, air resistance, friction forces, and tension are common examples of non-conservative forces.
e. Physicists envy biologists' ability to instill order on the world of animal species through their taxonomic system. So physicists have made a habit of identifying forces as conservative and non-conservative forces in order to instill order on the world of forces.
f. If a non-conservative force acts upon an object, then the object will either gain or lose mechanical energy.
g. If the only forces which do work upon an object are conservative forces, then the object will conserve its mechanical energy.
h. If the sum of an object's KE and PE is remaining constant, then non-conservative forces are NOT doing work.
i. If work is NOT done on an object by a non-conservative force, then the object will experience a transformation of energy from kinetic to potential energy (or vice versa).
j. An object starts from an elevated position with 50 J of potential energy and begins its fall towards the ground. If non-conservative forces can be assumed to NOT do work, then at some point during the fall the object will have 20 J of potential energy and 30 J of kinetic energy.

Answer: A(sort of) CDGH I(sort of) J

a. **TRUE (sort of)** - If a force does work, yet does not remove mechanical energy from an object, then it is definitely a conservative force. The *sort of* indicates that a force is also considered a conservative force if it does work and does not *add* mechanical energy to an object.

c. **TRUE** - You must know this!

d. **TRUE** - These are all non-conservative forces. You can add normal force to the list as well.

g. **TRUE** - This is a big principle. You must know this one!

h. **TRUE** - Non conservative forces would alter the total mechanical energy; that is, the PE + KE would not be a constant value.

i. **TRUE (sort of)** - This statement is true (sort of); when only conservative forces are doing work, an object has its kinetic energy transformed into potential energy (or vice versa) without the total amount of the two being altered. It would however be possible that work is not done by a non-conservative force and there be no transformation of energy at all; i.e., the object remains at rest. A conservative force must be doing work in order for there to be a transformation of energy.

j. **TRUE** - One would notice that the PE would begin to drop from 50 J to 0 J and that the KE would increase from 0 J to 50 J. And of course there would be a point at which the PE/KE would be distributed with 20 J to PE and 30 J to KE.

6. Which of the following statements are true about kinetic energy? Include all that apply.

   a. Kinetic energy is the form of mechanical energy which depends upon the position of an object.
   b. If an object is at rest, then it does not have any kinetic energy.
   c. If an object is on the ground, then it does not have any kinetic energy.
   d. The kinetic energy of an object is dependent upon the weight and the speed of an object.
   e. Faster moving objects always have a greater kinetic energy.
   f. More massive objects always have a greater kinetic energy.
   g. Kinetic energy is a scalar quantity.
   h. An object has a kinetic energy of 40 J. If its mass were twice as much, then its kinetic energy would be 80 J.
   i. An object has a kinetic energy of 40 J. If its speed were twice as much, then its kinetic energy would be 80 J.
   j. Object A has a mass of 1 kg and a speed of 2 m/s. Object B has a mass of 2 kg and a speed of 1 m/s. Objects A and B have the same kinetic energy.
   k. An object can never have a negative kinetic energy.
   l. A falling object always gains kinetic energy as it falls.
   m. A 1-kg object is accelerated from rest to a speed of 2.0 m/s. This object gains 4.0 Joules of kinetic energy.
   n. If work is done on an object by a non-conservative force, then the object will either gain or lose kinetic energy.

Answer: BGHK

b. **TRUE** - Kinetic energy depends upon speed. If there is no speed (the object is at rest), then there is no kinetic energy.

g. **TRUE** - Kinetic energy does not have a direction associated with it; it is a scalar quantity.

h. **TRUE** - Kinetic energy is directly related to the mass of an object.

i

k. **TRUE** - Kinetic energy is determined by the equation $0.5 \cdot m \cdot v^2$. the quantity **m** is always positive. And even if **v** is negative, $\mathbf{v}^2$ will always be positive. Therefore, kinetic energy can never be a negative value.

7. Which of the following statements are true about potential energy? Include all that apply.

   a. Moving objects cannot have potential energy.
   b. Potential energy is the energy stored in an object due to its position.
   c. Both gravitational and elastic potential energy are dependent upon the mass of an object.
   d. The gravitational potential energy of an object is dependent upon the mass of the object.

e. If the mass of an elevated object is doubled, then its gravitational potential energy will be doubled as well.
f. Gravitational potential energy is lost as objects free-fall to the ground.
g. The higher that an object is, the more potential energy which it will have.
h. The unit of measurement for potential energy is the Joule.
i. A 1-kg mass at a height of 1 meter has a potential energy of 1 Joule.
j. A 1-kg object falls from a height of 10 m to a height of 6 m. The final potential energy of the object is approximately 40 J.
k. If work is done on an object by a non-conservative force, then the object will either gain or lose potential energy.

Answer: BDEFGH

b. **TRUE** - This is the definition of potential energy.

d. **TRUE** - The equation states that PE_{grav} = **m**•g•h; PE is dependent upon mass.

e. **TRUE** - The equation states that PE_{grav} = m•g•**h**; if the **h** is doubled, then the **PE** will be doubled as well.

f. **TRUE** - As objects free-fall, the height (**h**) decreases; subsequently, the PE decreases.

g. **TRUE** - The equation states that PE_{grav} = m•g•**h**; PE is directly related to height.

h. **TRUE** - The Joule (abbrev. J) is the standard metric unit of energy - all forms of energy.

8. Which of the following statements are true about mechanical energy? Include all that apply.

a. The total amount of mechanical energy of an object is the sum of its potential energy and the kinetic energy.
b. Heat is a form of mechanical energy.
c. The mechanical energy of an object is always conserved.
d. When non-conservative forces do work, energy is transformed from kinetic to potential (or vice versa), but the total mechanical energy is conserved.
e. A bowling ball is mounted from a ceiling by way of a strong cable. It is drawn back and released, allowed to swing as a pendulum. As it swings from its highest position to its lowest position, the total mechanical energy is mostly conserved.
f. When a friction force does work on an object , the total mechanical energy of that object is changed.
g. The total mechanical energy of an object remains constant if the only forces doing work on the object are conservative forces.
h. If an object gains mechanical energy, then one can be certain that a non-conservative force is doing work.

Answer: AEFGH

a. **TRUE** - This is the definition of mechanical energy.

e. **TRUE** - Tension does not do work upon the object and so the total mechanical energy is conserved. The presence of air resistance (a non-conservative force) does a little work and so one might notice a very slight change in mechanical energy.

f. **TRUE -** Friction is a non-conservative force and thus alters the total mechanical energy of an object.

g. **TRUE** - This is the conservation of energy principle and one that you need to firmly understand.

h. **TRUE** - If there is any change in the total mechanical energy of an object (whether a gain or a loss), then you know for certain that there is a non-conservative force doing work.

9. Rank these four objects in increasing order of kinetic energy, beginning with the smallest.

Object A	**Object B**	**Object C**	**Object D**
m = 5.0 kg v = 4.0 m/s h = 2.0 m	m = 10.0 kg v = 2.0 m/s h = 3.00 m	m = 1.0 kg v = 5.0 m/s h = 5.0 m	m = 5.0 kg v = 2.0 m/s h = 4.0 m

Answer: D < C < B < A

This is probably best done by performing a calculation of KE and comparing the results:

Object A: KE = 0.5•(5.0 kg)•(4.0 m/s)^2 = 40. J
Object B: KE = 0.5•(10.0 kg)•(2.0 m/s)^2 = 20. J

Object C: KE = 0.5•(1.0 kg)•(5.0 m/s)^2 = ~13 J (12.5 J)

Object D: KE = 0.5•(5.0 kg)•(2.0 m/s)^2 = 10. J

The order is evident once the calculations are performed.

10. Rank these four objects in increasing order of potential energy, beginning with the smallest.

Object A	**Object B**	**Object C**	**Object D**
m = 5.0 kg v = 4.0 m/s h = 2.0 m	m = 10.0 kg v = 2.0 m/s h = 3.00 m	m = 1.0 kg v = 5.0 m/s h = 5.0 m	m = 5.0 kg v = 2.0 m/s h = 4.0 m

Answer: C < A < D < B

This is probably best done by performing a calculation of PE and comparing the results. Using the approximation that g = ~10 m/s/s gives much quicker results.

Object A: PE = (5.0 kg)•(~10 m/s^2)•(2.0 m) = ~100 J
Object B: PE = (10.0 kg)•(~10 m/s^2)•(3.00 m) = ~300 J

Object C: PE = (1.0 kg)•(~10 m/s^2)•(5.0 m) = ~50 J

Object D: PE = (5.0 kg)•(~10 m/s^2)•(4.0 m) = ~200 J

The order is evident once the calculations are performed.

NOTE: The next 15 questions presume that the value of **g** is ~10 m/s/s.

11. A 1200 kg car and a 2400 kg car are lifted to the same height at a constant speed in a auto service station. Lifting the more massive car requires ____ work.

a. less b. the same c. twice as much

d. four times as much e. more than 4 times as much

Answer: C

The amount of work done by a force to displace an object is found from the equation

W = F*d*cos(Theta)

The force required to raise the car at constant speed is equivalent to the weight (m*g) of the car. Since the 2400-kg car weighs 2X as much as the 1200-kg car, it would require twice as much work to lift it the same distance.

12. An arrow is drawn back so that 50 Joules of potential energy is stored in the stretched bow and string. When released, the arrow will have a kinetic energy of ____ Joules.

a. 50 b. more than 50 c. less than 50

Answer: A

A drawn arrow has 50 J of stored energy due to the stretch of the bow and string. When released, such that the arrow will have 50 J of kinetic energy upon being fired. Of course, this assumes no e other non-conservative forces and that the arrow is shot horizontally.

13. A child lifts a box up from the floor. The child then carries the box with constant speed to the other side of the room and puts the box down. How much work does he do on the box while walking across the floor at constant speed?

a. zero J b. more than zero J

c. more information needed to determine

Answer: A

For any given situation, the work done by a force can be calculated using the equation

W = F*d*cos(Theta)

where F is the force doing the work, d is the displacement of the object, and Theta is the angle between the force and the displacement. In this specific situation, the child is applying an upward force on the box (he is *carrying* it) and the displacement of the box is horizontal. The angle between the force (vertical) and the displacement (upward) vectors is 90 degrees. Since the cosine of 90-degrees is 0, the child does not do any work upon the box. A detailed discussion of a similar situation (the waiter and the tray of food) can be found at The Physics Classroom.

14. A 1000-kg car is moving at 40.0 km/hr when the driver slams on the brakes and skids to a stop (with locked brakes) over a distance of 20.0 meters. How far will the car skid with locked brakes if it is traveling at 120. km/hr?

a. 20.0 m b. 60.0 m c. 90.0 m d. 120. m e. 180. m

Answer: E

When a car skids to a stop, the work done by friction upon the car is equal to the change in kinetic energy of the car. Work is directly proportional to the displacement of the car (skidding distance) and the kinetic energy is directly related to the square of the speed ($KE=0.5*m*v^2$). For this reason, the skidding distance is directly proportional to the square of the speed. So if the speed is tripled from 40 km/hr to 120 km/hr, then the stopping distance is increased by a factor of 9 (from 20 m to 9*20 m; or 180 m). A detailed discussion of the distance-speed squared relationship can be found at The Physics Classroom.

15. A platform diver weighs 500 N. She steps off a diving board that is elevated to a height of 10 meters above the water. The diver will possess ___ Joules of kinetic energy when she hits the water.

a. 10 b. 500 c. 510 d. 5000 e. more than 5000 .

Answer: D

The use of the work-energy theorem and a simple analysis will yield the solution to this problem. Initially, there is only PE; finally, there is only KE. Assuming negligible air resistance, the kinetic energy of the diver upon hitting the water is equal to the potential energy of the diver on top of the board.

$$PE_i = KE_f$$
$$m*g*h_i = KE_f$$

Substituting 500 N for m*g (500 N is the weight of the diver, not the mass) and 10 m for h will yield the answer of 5000 J.

16. A ball is projected into the air with 100 J of kinetic energy. The kinetic energy is transformed into gravitational potential energy on the path towards the peak of its trajectory. When the ball returns to its original height, its kinetic energy is ____ Joules. Do consider the effects of air resistance

a. less than 100 b. 100 c. more than 100

d. not enough information given

Answer: A

During any given motion, if non-conservative forces do work upon the object, then the total mechanical energy will be changed. If non-conservative forces do negative work (i.e., F_{nc}*d*cos(Theta) is a negative number), then the final TME is less than the initial TME. In this case, air resistance does negative work to remove energy from the system. Thus, when the ball returns to its original height, their is less TME than immediately after it was thrown. At this same starting height, the PE is the same as before. The reduction in TME is made up for by the fact that the kinetic energy has been reduced; the final KE is less than the initial KE.

17. During a construction project, a 2500 N object is lifted high above the ground. It is released and falls 10.0 meters and drives a post 0.100 m into the ground. The average impact force on the object is ____ Newtons.

a. 2500 b. 25000 c. 250,000 d. 2,500,000

Answer: C

The use of the work-energy theorem and a simple analysis will yield the solution to this problem. Initially, there is only PE; finally, there is neither PE nor KE; non-conservative work has been done by an applied force upon the falling object. The work-energy equation can be written as follows.

$$PE_i + W_{nc} = 0$$
$$PE_i = - W_{nc}$$

$$m*g*h_i = - F*d*\cos(Theta)$$

Substituting 2500 N for m*g (2500 N is the weight of the driver, not the mass); 10.0 m for h; 0.100 m for the displacement of the falling object as caused by the upward applied force exerted by the post; and 90 degrees for Theta (the angle between the applied force and the displacement of the falling object) will yield the answer of 250000 N for F.

18. A 10-Newton object moves to the left at 1 m/s. Its kinetic energy is approximately ____ Joules.

a. 0.5 b. 1 c. 10 d. more than 10

Answer: A

The KE of any object can be computed if the mass (m) and speed (v) are known. Simply use the equation

$$KE=0.5*m*v^2$$

In this case, the 10-N object has a mass of approximately 1 kg (use F_{grav} = m*g). The speed is 1 m/s. Now plug and chug to yield KE of approximately 0.5 J.

19. Luke Autbeloe stands on the edge of a roof throws a ball downward. It strikes the ground with 100 J of kinetic energy. Luke now throws another identical ball upward with the same initial speed, and this too falls to the ground. Neglecting air resistance, the second ball hits the ground with a kinetic energy of ____ J.

a. less than 100 b. 100 c. 200 d. more than 200 e. none of these

Answer: B

Quite surprisingly to many, each ball would hit the ground with the same speed. In each case, the PE+KE of the balls immediately after being thrown is the same (they are thrown with the same speed from the same height). Upon hitting the ground, they must also have the same PE+KE. Since the PE is zero (on the ground) for each ball, it stands to reason that their KE is also the same. That's a little physics and a lot of logic - and try not to avoid the logic part by trying to memorize the answer.

20. An object at rest may have ___________.

a. speed b. velocity c. acceleration d. energy e. all of these

Answer: D

An object at rest absolutely cannot have speed or velocity or acceleration. However, an object at rest could have energy if there is energy stored due to its position; for example, there could be gravitational or elastic potential energy.

21. A 50-kg platform diver hits the water below with a kinetic energy of 5000 Joules. The height (relative to the water) from which the diver dove was approximately ____ meters.

a. 5 b. 10 c. 50 d. 100

Answer: B

The kinetic energy of the diver upon striking the water must be equal to the original potential ener

$$\mathbf{m*g*h_i = KE_f}$$

$$\mathbf{(50\ kg)*(\sim 10\ m/s/s)*h = 5000\ J}$$

So, **h = ~10 m**

22. A job is done slowly, and an identical job is done quickly. Both jobs require the same amount of _____, but different amounts of _____. Pick the two words which fill in the blanks in their respective order.

a. energy, work b. power, work c. work, energy d. work, power

e. power, energy f. force, work g. power, force h. none of these

Answer: D

Power refers to the rate at which work is done. Thus, doing two jobs - one slowly and one quickly - involves doing the same job (i.e., the same work and same force) at different rates or with different power.

23. Which requires more work: lifting a 50.0 kg crate a vertical distance of 2.0 meters or lifting a 25.0 kg crate a vertical distance of 4.0 meters?

a. lifting the 50 kg crate b. lifting the 25 kg crate

c. both require the same amount of work

Answer: C

Work involves a force acting upon an object to cause a displacement. The amount of work done is found by multiplying F*d*cos(Theta). The equation can be used for these two motions to find the work.

Lifting a 50 kg crate vertically 2 meters	Lifting a 25 kg crate vertically 4 meters
W = (~500 N)*(2 m)*cos(0)	W = (~250 N)*(4 m)*cos(0)
W = ~1000 N	**W = ~1000 N**
(Note: The weight of a 50-kg object is approximately 500 N; it takes 500 N to lift the object up.)	(Note: The weight of a 25-kg object is approximately 250 N; it takes 250 N to lift the object up.)

24. A 50.0 kg crate is lifted to a height of 2.0 meters in the same time as a 25.0 kg crate is lifted to a height of 4 meters. The rate at which energy is used (i.e., power) in raising the 50.0 kg crate is ____ as the rate at which energy is used to lift the 25.0 kg crate.

a. twice as much   b. half as much   c. the same

Answer: C

The power is the rate at which work is done (or energy is used). Power is found by dividing work by time. It requires the same amount of work to do these two jobs (see question #23) and the same amount of time. Thus, the power is the same for both tasks.

25. Using 1000. J of work, a small object is lifted from the ground floor to the third floor of a tall building in 20.0 seconds. What power was required in this task?

a. 20 W   b. 50 W   c. 100 W   d. 1000 W   e. 20000 W

Answer: B

This is a relatively simple plug-and-chug into the equation P=W/t with W=1000. J and t=20.0 s.

Part B: Straightforward Computational Problems

26. Approximate the work required lift a 2.5-kg object to a height of 6.0 meters. **PSYW**

Answer: ~150 J

The work done upon an object is found with the equation

W = F*d*cos(Theta)

In this case, the d=6.0 m; the F=24.5 N (it takes 24.5 N of force to lift a 2.5-kg object; that's the weight of the object), and the angle between F and d (Theta) is 0 degrees. Substituting these values into the above equation yields

W = F*d*cos(Theta) = (24.5 N)*(6 m)*cos(0) = **~150 J (147 J)**

27. A student applies a force to a cart to pull it up an inclined plane at a constant speed during a physics lab. A force of 20.8 N is applied parallel to the incline to lift a 3.00-kg loaded cart to a height of 0.450 m along an incline which is 0.636-m long. Determine the work done upon the cart and the subsequent potential energy change of the cart. **PSYW**

Answer: 13.2 J

There are two methods of solving this problem. The first method involves using the equation

W = F*d*cos(Theta)

where F=20.8 N, d=0.636 m, and Theta=0 degrees. (The angle theta represents the angle betwee the force and the displacement vector; since the force is applied parallel to the incline, the angle is zero.) Substituting and solving yields

W = F*d*cos(Theta) = (20.8 N)*(0.636 m)*cos(0) = **13.2 J**.

The second method is to recognize that the work done in pulling the cart along the incline at constant speed changes the potential energy of the cart. The work done equals the potential energy change. Thus,

W=Delta PE = m*g*(delta h) = (3.00 kg)*(9.8 m/s/s)*(0.45 m) = **13.2 J**

28. Eddy, whose mass is 65.0-kg, climbs up the 1.60-meter high stairs in 1.20 s. Approximate Eddy's power rating. **PSYW**

Answer: P = 849 Watts

Eddy's power is found by dividing the work which he does by the time in which he does it. The work done in elevating his 65.0-kg mass up the stairs is determined using the equation

W = F*d*cos(Theta)

where F = m*g = 637 N (the weight of the 65.0 kg object), d =1.60 m and Theta = 0 degrees (the angle between the upward force and the upward displacement). Solving for W yields 1019.2 Joules. Now divide the work by the time to determine the power:

P = W/t = (1019.2 J)/(1.20 s) = **849 Watts**

29. A 51.7-kg hiker ascends a 43.2-meter high hill at a constant speed of 1.20 m/s. If it takes 384 s to climb the hill, then determine ... . **PSYW**

a. kinetic energy change of the hiker.
b. the potential energy change of the hiker.
c. the work done upon the hiker.
d. the power delivered by the hiker.

Answers:

a. **Delta KE = 0 J**
b. **Delta PE = +21900 J**
c. **W = +21900 J**
d. **P = 57.0 Watts**

a. The speed of the hiker is constant so there is no change in kinetic energy - **0 J.**

b. The potential energy change can be found by subtracting the initial PE (0 J) from the final PE (m [from (51.7 kg)*(9.8 m/s/s)*(43.2 m)] and the initial potential energy is 0 J. So Delta PE = **+219**

c. The work done upon the hiker can be found using the work-energy theorem. The equation redu

$W_{nc} = PE_f$

(PE_i = 0 J since the hiker starts on the ground; and $KE_i = KE_f$ since the speed is constant; these tw they are equal). The final potential energy is 21888 J [from (51.7 kg)*(9.8 m/s/s)*(43.2 m)]. So W

d. The power of the hiker can be found by dividing the work by the time.

P=W/t=(21888 J)/(384 s) = **57.0 Watts**

30. An 878-kg car skids to a stop across a horizontal surface over a distance of 45.2 m. The average force acting upon the car is 7160 N. Determine ... . **PSYW**

a. the work done upon the car.
b. the initial kinetic energy of the car.
c. the acceleration of the car.
d. the initial velocity of the car.

Answers:

a. **W = -324000 J**
b. **KE_i = +324000 J**
c. **a = -8.16 m/s/s**
d. **v_i = 27.2 m/s**

a. The work done upon the car can be found using the equation

W = F*d*cos(Theta)

where F=7160 N, d=45.2 m, and Theta=180 degrees (the force is in the opposite direction as the displacement). Substituting and solving yields **-323632 J (rounded to -324000 J)**.

b. The initial kinetic energy can be found using the work-energy theorem. The equation reduces to

$KE_i + W_{nc} = 0$

(PE_i and PE_f = 0 J since the car is on the ground; and KE_f = 0 J since the car is finally stopped). Rearrange the equation and it takes the form $KE_i = -W_{nc}$. So KE_i = **+324000 J (rounded from +323632 J)**.

c. The acceleration of the car can be found using Newton's second law of motion: F_{net} = m*a

The friction force is the net force (since the up and down forces balance) and the mass is 878 kg. Substituting and solving yields a = **-8.16 m/s/s**.

d. The initial velocity of the car can be found using the KE equation: KE = 0.5*m*v^2 where m=878 kg and KE_i=323632 J. Substituting and solving for velocity (v) yields v = **27.2 m/s**. (A kinematic equation could be also used to find the initial velocity.)

31. A 510-kg roller coaster car starts at a height of 32.0 m. Assuming negligible energy losses to friction and air resistance, determine the PE, KE, and speed of the car at the various locations (A, B, C, D, and E) along the track.

Location	**Height (m)**	**PE* (J)**	**KE* (J)**	**velocity (m/s)**
Start	32.0	**160 000 J**	**0 J**	0
A	28.0	**140 000 J**	**20 000 J**	**8.9 m/s**
B	11.0	**55 000 J**	**105 000 J**	**20.5 m/s**
C	20.0	**100 000 J**	**60 000 J**	**15.5 m/s**
D	5.0	**25 000 J**	**135 000 J**	**23.2 m/s**
E	15.0	**75 000 J**	**85 000 J**	**18.4 m/s**
F	0	**0 J**	**160 000 J**	**25.3 m/s**

*rounded to the second significant digit

Answers: See above table (answers in red)

The potential energy for every row can be found using the equation PE = m*g*h where m=510 kg and g = 9.8 m/s/s. In the first row, the total mechanical energy (KE + PE) equals 160 000 J (rounded). Since no work is done by non-conservative forces, the total mechanical energy must be

160 000 J in all the other rows. So the KE can be computed by subtracting the PE from 160 000 J. The velocity can be found using the equation:

$$KE = 0.5*m*v^2$$

where m=510 kg. The algebraic rearrangement of this equation results in v = SQRT(2*KE/m).

32. A 65.8-kg skier accelerates down an icy hill from an original height of 521 meters. Use the work-energy theorem to determine the speed at the bottom of the hill if...

a. ... no energy is lost or gained due to friction, air resistance and other non-conservative forces. **PSYW**

b. ... $1.40*10^5$ J of energy are lost due to external forces. **PSYW**

Answers: (a) **v = 101 m/s; (b) v = 77.2 m/s**

a. Use the work energy theorem:

$$KE_i + PE_i + W_{nc} = KE_f + PE_f$$

The PE_f can be dropped from the equation since the skier finishes on the ground at zero height. The KE_i can also be dropped since the skier starts from rest. The W_{nc} term is dropped since it is said that no work is done by non-conservative (external) forces. The equation simplifies to

$$PE_i = KE_f$$

The expressions for KE ($0.5*m*v^2$) and PE (m*g*h) can be substituted into the equation:

$$m*g*h = 0.5*m*v_f^2$$

where m=65.8 kg, h=521 m, g=9.8 m/s/s. Substituting and solving for v_f yields **101 m/s**.

b. This equation can be solved in a similar manner, except that now the W_{ext} term is -140000 J. So the equation becomes

$$m*g*h - 140000\text{ J} = 0.5*m*v_f^2$$

Now substituting and solving for v_f yields **77.2 m/s**.

33. Use the work-energy theorem to determine the force required to stop a 988-kg car moving at a speed of 21.2 m/s if there is a distance of 45.7 m in which to stop it. **PSYW**

Answer: F = $4.86*10^3$ N

The work energy theorem can be written as

$$KE_i + PE_i + W_{nc} = KE_f + PE_f$$

The PE_i and PE_f can be dropped from the equation since they are both 0 (the height of the car is 0 m). The KE_f can also be dropped for the same reason (the car is finally stopped). The equation simplifies to

$$KE_i + W_{nc} = 0$$

The expressions for KE ($0.5*m*v^2$) and W_{nc} (F*d*cos[Theta]) can be substituted into the equation:

$$0.5*m*v_i^2 + F*d*\cos[Theta] = 0$$

where m=988 kg, v_i=21.2 m/s, d=45.7 m, and Theta = 180 degrees. Substituting and solving for F yields **$4.86*10^3$ N**.

Newton's Law of Universal Gravitation Review

Part A: Multiple Choice

1. Which of the following statements are true of an object moving in a circle at a constant speed? Include all that apply.

   a. The object experiences a force which has a component directed parallel to the direction of motion.
   b. Inertia causes objects to move in a circle.
   c. There can be a force pushing outwards on the object as long as the net force in inwards.
   d. Because the speed is constant, the acceleration is zero.
   e. The acceleration and the net force vector are directed perpendicular to each other.
   f. If the net force acting upon the object is suddenly reduced to zero, then the object would suddenly depart from its circular path and travel tangent to the circle.
   g. The acceleration of the object is directed tangent to the circle.

Answer: CF

C is true; an object which moves in a circle must have a net inward force. There are many instances of individual outwards forces which are exceeded by an individual inward force (e.g., see #5 below).

F is true; if the net force is 0 N, then the moving object will maintain its state of motion. At the instant that F_{net} becomes 0 N, the object is moving tangent to the circle.

For **Questions #2-#5**, identify the type of force which causes the following **bold-faced** objects to travel along a circular path.

2. An **eraser** is tied to a string swung in a horizontal circle.

a. gravity	b. normal	c. tension	d. applied
e. friction	f. spring	g. electrical	h. magnetic

3. The **moon** orbits the earth.

a. gravity	b. normal	c. tension	d. applied
e. friction	f. spring	g. electrical	h. magnetic

4. A **car** makes a sharp right-hand turn along a level roadway.

a. gravity	b. normal	c. tension	d. applied
e. friction	f. spring	g. electrical	h. magnetic

5. A **roller coaster car** passes through a loop. Consider the car at the bottom of the loop.

a. gravity b. normal c. tension d. applied

e. friction f. spring g. electrical h. magnetic

Answers:

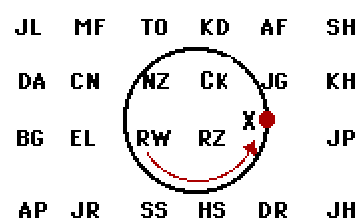
2. C - Tension (A string is attached to the eraser and pulls it towards the center point of the circle.)

3. A - Gravity (All masses attract with a force of gravity. In the case of the moon and the earth, gravity pulls on the moon in a direction which is roughly perpendicular to its path.)

4. E - Friction (Once the wheels are turned, friction can push perpendicular to the wheels' direction, pushing the car towards the center of the circle.)

5. B - Normal (There are two forces at the bottom of the loop; gravity pulls outwards from the center; but the normal force exceeds the magnitude of gravity, pushing inwards with sufficient force to supply the needed centripetal force.)

6. A physics teacher ties an eraser to the end of a string and then whirls it in a counter-clockwise circle. If the teacher lets go of the string, then the eraser hits a student (or several students) in the classroom. If the string is let go when the eraser is at point X on the diagram at the right, then which student(s) in the class will the eraser hit? Write the initials in this space: ________________



Answer: JG and AF

Once the centripetal force is no longer present, the eraser will follow its straight-line, inertial path. This path would be directed tangent to the circle and would pass through the locations where JG and AF are sitting. View a reasonably cool animation.

7. Which of the following statements are true about gravitational force? Identify all that apply.

a. The gravitational force only acts between very, very massive objects.
b. The gravitational force between an object and the earth is inversely related to the distance between the object's and the earth's center.
c. The gravitational force can ALWAYS be accurately calculated by multiplying the object mass by the acceleration of gravity (m•g).
d. The gravitational force acting upon an object is the same as the weight of the object.
e. The gravitational force between two objects is independent of the mass of the smaller of the two objects.
f. If object A gravitationally attracts object B with a force of X Newtons, then object B will also gravitationally attract object A with the same force of X Newtons.
g. The doubling of the separation distance (measured from the center) between two objects will halve the gravitational force between the objects.

h. It an object is placed two earth-radii above the surface of the earth, then the force of gravitational attraction between the object and the earth will be one-fourth the magnitude as on earth's surface.
i. Orbiting astronauts do not experience a force of gravity; this explains why they feel weightless.

Answer: BCDF

B is true; if the distance is increased, then the force is decreased.

C is true; this is always the case. It is not true however to say that the gravitational force is equal to mass•9.8 m/s/s. The value of g varies with location and so at distances significantly further from the earth's surface, g is reduced and the gravitational force must be computed using a different value of g.

D is true; weight and gravitational force are synonymous.

F is true; for every action there is an equal and opposite reaction. This is Newton's third law, an inescapable reality about forces.

G is false; doubling the separation distance will make the force one-fourth the size.

8. Which of the following statements are true about the acceleration of gravity? Identify all that apply.

a. The acceleration of gravity experienced by objects located near to (and far from) from the earth depends upon the mass of the object.
b. The acceleration of gravity experienced by objects located near to (and far from) from the earth depends upon the mass of the Earth.
c. The acceleration of gravity experienced by objects located near to (and far from) the earth is inversely related to the distance between the center of the object and the center of the earth.
d. Increasing the mass of an object will increase the acceleration of gravity experienced by the object.
e. Doubling the distance between an object and the earth's center will decrease the acceleration of gravity by a factor of four.
f. The acceleration of an orbiting satellite is equal to the acceleration of gravity at that particular location.
g. If the mass of the Earth were doubled (without an alteration in its radius), then the acceleration of gravity on its surface would be approximately 20 m/s^2.
h. If the mass of the Earth were doubled and the radius of the earth were doubled, then the two changes would offset each other and the acceleration of gravity on its surface would still be approximately 10 m/s^2.

Answer: BCEFG

B is true; check out the equation again. The acceleration of gravity created by the earth depends upon the earth's mass.

C is true; check out the equation one more time. The separation distance is located in the denominator of the equation, indicating an inverse relationship.

E is true; **g** is inversely proportional to the square of the distance; a doubling of the distance means that you must divide the force of gravity value by 4 (2^2) to obtain the new force of gravity value.

F is true; the acceleration of gravity is the acceleration which is caused by gravity when it is the only force. For an orbiting satellite, gravity is the only force.

G is true; according to the equation, the **g** value is directly proportional to the mass of the earth. An increase in **M** results in a proportional increase in **g**.

10. Which of the following statements are true about the motion of planets about the sun? Identify all that apply.

a. The force of gravity is the only force which acts upon the planets.
b. Their trajectories are highly elliptical.
c. The planets which are furthest from the sun have the greatest period.
d. For any given planet, the speed is greatest when the planet is closest to the sun.
e. The velocity vector is directed tangent to the elliptical path.
f. The net force vector is at all times directed perpendicular to the velocity vector.
g. To keep the planet from escaping the sun's gravitational field, the net force vector is greatest when the planet is furthest from the sun.

Part B: Short Answer

11. Explain how something can be moving at a constant speed yet be accelerating at the same time.

Answer:

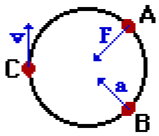
The object would have to be traveling in a curved path since it is accelerating. Acceleration is defined as a change in velocity over a change in time. If the speed is staying the same, then the velocity must be changing by altering the direction in which the object is heading. A force is required to do this. See an informative animation and further explanation.

12. How did Newton come up with the idea that the moon is actually "falling" toward the Earth.

Answer:

Newton made the connection between objects falling (accelerating) towards the earth and objects in space which are accelerating towards the earth while they are in circular motion around the earth. Both are being pulled by the earth due to the gravitational force. The moon stays in orbit due to it having the appropriate tangential velocity that keeps it from coming closer to the earth's surface. The moon, however, is still accelerating at the rate any object would have at that distance from the earth. In a sense, the moon is falling around the earth rather than into the earth.

Part C: Diagramming and Analysis



15. In the diagram at the right, draw vector arrows (straight lines with arrowheads) which indicate the following for an object which is moving in a clockwise circle.

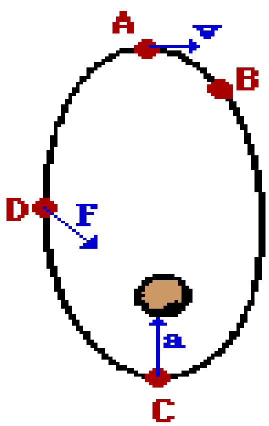
- the net force at point A.
- the acceleration at point B.
- the velocity at point C.

Answer:

See diagram for answers. The force and acceleration vectors are directed inwards towards the center of the circle and the velocity vector is directed tangent to the circle.

16. The diagram at the right shows a satellite orbiting the Earth in an elliptical path in a clockwise direction.

a. Draw a vector representing the velocity of the object at position A.



b. raw a vector representing the force on the object at position D.
c. Draw a vector representing the acceleration of the object at position C.
d. At which of the four positions is the satellite moving fastest?

Answer:

See diagram for answers. The force and acceleration vectors are directed towards the planet being orbited (which is at a foci of the ellipse) and the velocity vector is directed tangent to the path.

Part D: Short Computations

21. Two objects attract each other with a force of gravity (F_{grav}) of 36 N. If the distance separating the objects is doubled, then what is the new force of gravitational attraction? **PSYW**

22. Two objects attract each other with a force of gravity (F_{grav}) of 36 N. If the distance separating the objects is doubled and the masses one of the objects is tripled, then what is the new force of gravitational attraction? **PSYW**

23. Two objects attract each other with a force of gravity (F_{grav}) of 36 N. If the distance separating the objects is increased by a factor of 4 and the masses of both objects are tripled, then what is the new force of gravitational attraction? **PSYW**

Answers:

For **Questions #21-#23**, Newton's universal gravitation equation must be used as a guide to thinking about how an alteration in one variable would effect another variable. From the equation, it can be deduced that a change in either one of the masses would produce a proportional change in the force of gravity. However, a change in the separation distance will produce the inverse square effect upon the force of gravity. So increasing separation distance by a factor of x, will decrease the force of gravity by a factor of x^2. This reasoning leads to the following solutions.

21. New force = 36 N / 4 = **9.0 N**

22. New force = 36 N • 3 / 4 = **27.0 N**

23. New force = 36 N •3 •3 / 16 = **20.3 N**

25. Suppose that a planet was located 12.0 times further from the sun than the earth's distance from the sun. Determine the period of the planet. **PSYW**

Answer: 41.6 yr

This question explores the R-T relationship. As such, Kepler's third law - that the T^2/R^3 ratio is the same for all the planets - must be utilized.

$$T_{earth}^2/R_{earth}^3 = T_{planet}^2/R_{planet}^3$$
$$(1\ \text{year})^2/R_{earth}^3 = T_{planet}^2/(12.0 \bullet R_{earth})^3$$

Rearranging this equation to solve for the period of the planet yields the equation:

$$T_{planet}^2 = (1\ \text{year})^2 \bullet (12.0 \bullet R_{earth})^3/R_{earth}^3 = (1\ \text{year})^2 \bullet (12.0)^3 = 1728\ \text{year}^2$$
$$T_{planet} = \text{SQRT}(1728\ \text{year}^2) = \mathbf{41.6\ years}$$

26. The acceleration of gravity on the moon is approximately one-sixth the value on earth's surface. If a person weighs 60.0 N on the moon's surface, what is his/her approximate mass on Earth? **PSYW**

Answer: 36.7 kg

If the **g** value on the moon is 1/6-th of the value of earth (g_{earth} = 9.8 m/s^2), then g_{moon} = 1.63 m/s/s. The mass of a 60.0-N person (on the moon) can then be found:

$$m = F_{grav}/g = (60.0\ N) / (1.63\ m/s/s) = \mathbf{36.7\ kg}$$

Since mass is unaffected by location (moon or earth or *free space*), the mass of the person on earth is the same as the mass on the moon - 36.7 kg.

27. Determine the force of gravitational attraction between a 52.0-kg mother and a 3.0-kg child if their separation distance is 0.50 meters. **PSYW**

Answer: $4.2 \cdot 10^{-8}$ N

Use Newton's universal gravitation equation:

$$F_{grav} = G \cdot m_1 \cdot m_2 / R^2 = (6.67 \cdot 10^{-11}\ N \cdot m^2/kg^2) \cdot (52.0\ kg) \cdot (3.0\ kg) / (0.50\ m)^2 = \mathbf{4.2 \cdot 10^{-8}\ N}$$

28. Use the following information to determine the orbital velocity at *treetop level* on the surface of the moon. **PSYW**

Mass of moon = 7.36×10^{22} kg
Radius of Moon = 1.74×10^{6} m

Answer: 1680 m/s

The orbital velocity equation is

$$v = SQRT(G \cdot M_{central}/R) = SQRT[\ (6.67 \cdot 10^{-11}\ N \cdot m^2/kg^2) \cdot (7.36 \cdot 10^{22}\ kg) / (1.74 \cdot 10^{6}\ m)\ ]$$

$$v = SQRT\ (2.82 \cdot 10^{6}\ m^2/s^2) = \mathbf{1680\ m/s}$$