1. (5 points) Jose has a toy wind-up car. Inside the toy car is a coiled spring. Jose holds the car on the floor, winds the spring up, and then lets the car go. He notices that the car speeds up quickly, then moves along the floor at a nearly constant speed for a while, then slows down to a stop.

Here are four possible statements that could be made about what was happening, in terms of energy, during various stages of the action described above.

A. Energy was being created.
B. Energy was being destroyed.
C. Energy was being transferred/transformed.
D. None of the above. (In this case, state what you think is happening in terms of energy.)

During each of the following stages circle the letter corresponding to the best statement from those above to describe what you think was happening, in terms of energy. In each case mention the type(s) of energy involved and briefly give your reasons for choosing the answer that you did.

While Jose was winding the spring up: A  B  C  D  (circle one)

Energy cannot be created or destroyed. In this case mechanical energy is being transferred from Jose's hand to the spring. Jose's hand decreases in chemical potential energy, while the spring increases in elastic potential energy.

a) While the car was speeding up: A  B  C  D

Energy cannot be created or destroyed. In this case mechanical energy is being transferred from the spring to the toy car. The spring decreases in elastic potential energy, while the car increases in kinetic energy.

b) While the car was moving along the floor at a constant speed: A  B  C  D
Energy cannot be created or destroyed. If the car is really moving at a constant speed then no energy is being transferred or transformed either, since there is no change in the car's kinetic energy.

Alternate response: It is possible that mechanical energy is still being transferred from the spring to the toy car but this is being balanced by mechanical energy being transformed to thermal energy during a friction-type interaction between the car and the floor. In this case the spring would still be decreasing in stored elastic energy, while the floor and the car increase in thermal energy.

c) While the car was slowing to a stop (but before it actually stopped):  

Energy cannot be created or destroyed. The car is slowing down due to a friction-type contact interaction between the car and the floor. In this interaction mechanical energy is transferred from the car to the floor. The car decreases in kinetic energy while the floor and car increase in thermal energy.

2. (5 points) To the right is a circuit with one battery and one bulb. The bulb glows with a certain brightness.

In the space below, draw two different circuits. One must be a parallel circuit and one must be a series circuit. Each circuit must include two bulbs and any number of batteries that you need. However, all the bulbs in the two circuits must glow with the same brightness as the bulb to the right. Make sure you draw your circuit diagrams carefully so it is clear how bulbs and batteries are connected to each other. For each circuit, briefly explain (in terms of electric circuit ideas) why all the bulbs glow with the same brightness as the one above.

| Series Circuit | In this series circuit there are two identical bulbs in a single loop. This means there is more resistance in the loop than if only one bulb were present and so, with only a single battery a smaller current would flow, making the bulbs dimmer. However, by adding a second battery the push of the batteries is doubled and so the current flowing will be doubled also. This will mean the current flowing will now be the same as in a one- |
batteries, one-bulb circuit, so the two bulbs will glow with the same brightness as the single bulb in the circuit above.

Parallel Circuit

In this parallel circuit there are two identical bulbs connected to a single battery, each in their own loop. In a parallel circuit each loop behaves independently, as if it were the only loop connected to the battery. This means the current flowing in each loop in this parallel circuit will be the same as in a one-battery, one-bulb circuit. Therefore each bulb will glow with the same brightness as the single bulb in the circuit above.

3. (5 points) How did the “blowing-through-straws” analogy help you understand the idea that thinner bulb filaments have more resistance to the flow of electricity than thicker bulb filaments (of the same length)? In answering this question, make sure you refer specifically to what was done in the experiments you did in class and how that helped you change or enhance your own model or idea.

When thinking about resistance of bulb filaments we first thought that they would all be the same, since we thought that the battery supplied the same current to all bulbs and so the resistance to current flow in all circuits would be the same.

We then blew through a thin straw and a thicker straw of the same length and made two observations:

i) It was easier to blow through the thicker straw
ii) For the same strength blow, more air flowed through the thicker straw than the thinner straw

This meant the thinner straw had more resistance to air flow through it than the thicker straw.

This made us think that perhaps in a bulb it is easier to push the charges through a thicker filament than a thinner filament. Therefore, for the same push from a
battery, there would be more current flowing through a thicker filament than a thinner filament. This would then also mean that the thicker filament must have less resistance to the flow of electricity than the thinner filament. Since more current also means a brighter bulb, this would mean that when connected to the same battery (or other power source) a bulb with a thicker filament would glow brighter than a bulb with a thinner filament of the same length.

We confirmed these ideas in two ways. Firstly we used the simulator and saw that as we increased the resistance of the bulb in a circuit the current in then circuit decreased and the brightness of the bulb decreased also.

4. (5 points) In class you performed an experiment to provide evidence of an electromagnetic interaction between an electric current in a wire and a magnet. To the right is a picture of the apparatus you used.

What was the “magnet” in this case?

The compass needle was the permanent magnet

a) When the switch was closed what was the evidence you observed suggesting there was an electric current flowing in the circuit?

The evidence that an electric current was flowing in the circuit was that the light bulb lit up.

b) When the switch was closed what was the evidence you observed suggesting that an electromagnetic interaction was occurring?

The evidence that an electromagnetic interaction was occurring was that the compass needle moved.

c) Why did the magnet move in this case, and not the coil of wire?

The compass needle was support on a pivot in side the magnet and was free to move with very little interference from other interactions. However, the coil of wire was taped tightly to the outside of the compass and so was being held
in place. During the electromagnetic interaction it was prevented from moving by the mechanical interaction with the compass case and the tape.

5. (5 points) A soccer player kicks a ball into the net. When the soccer ball hits the net, it slows to a stop. Below, is a force diagram a student drew to describe the forces acting on the ball as it slowed down.

Is this force diagram complete or is there something missing and/or incorrect? If complete and correct, justify your answer by writing a couple of sentences. If there is one or more things missing or incorrect, re-draw the diagram so it is fully correct, and justify your diagram by writing a couple of sentences.

I think the force diagram is incorrect. The picture shows the ball in the air as it hits the net, not rolling across the ground, so there will be no frictional force of the ground on the ball. Instead, the force that opposes the motion of the ball to slow it down comes from its interaction with the net. I would redraw the diagram like this:

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6. (5 points) Jose has a toy wind-up car. Inside the toy car is a coiled spring. Jose holds the car on the floor, winds the spring up, and then lets the car go. He notices that the car speeds up quickly, then moves along the floor at a nearly constant speed for a while, then slows down to a stop.

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During each of the following stages circle the letter corresponding to the best statement from those above to describe what you think was happening, in terms of energy. In each case mention the type(s) of energy involved and briefly give your reasons for choosing the answer that you did.

While Jose was winding the spring up: A B C D (circle one)

Energy cannot be created or destroyed. In this case mechanical energy is being transferred from Jose's hand to the spring. Jose's hand decreases in chemical potential energy, while the spring increases in elastic potential energy.

d) While the car was speeding up: A B C D

Energy cannot be created or destroyed. In this case mechanical energy is being transferred from the spring to the toy car. The spring decreases in elastic potential energy, while the car increases in kinetic energy.

e) While the car was moving along the floor at a constant speed: A B C D

Energy cannot be created or destroyed. If the car is really moving at a constant speed then no energy is being transferred or transformed either, since there is no change in the car's kinetic energy.

Alternate response: It is possible that mechanical energy is still being transferred from the spring to the toy car but this is being balanced by mechanical energy being transformed to thermal energy during a friction-type
interaction between the car and the floor. In this case the spring would still be decreasing in stored elastic energy, while the floor and the car increase in thermal energy.

f) While the car was slowing to a stop (but before it actually stopped): A B C D

Energy cannot be created or destroyed. The car is slowing down due to a friction-type contact interaction between the car and the floor. In this interaction mechanical energy is transferred from the car to the floor. The car decreases in kinetic energy while the floor and car increase in thermal energy.

7. (5 points) To the right is a circuit with one battery and one bulb. The bulb glows with a certain brightness.

In the space below, draw two different circuits. One must be a parallel circuit and one must be a series circuit. Each circuit must include two bulbs and any number of batteries that you need. However, all the bulbs in the two circuits must glow with the same brightness as the bulb to the right. Make sure you draw your circuit diagrams carefully so it is clear how bulbs and batteries are connected to each other. For each circuit, briefly explain (in terms of electric circuit ideas) why all the bulbs glow with the same brightness as the one above.

| Series Circuit | In this series circuit there are two identical bulbs in a single loop. This means there is more resistance in the loop than if only one bulb were present and so, with only a single battery a smaller current would flow, making the bulbs dimmer. However, by adding a second battery the push of the batteries is doubled and so the |
current flowing will be doubled also. This will mean the current flowing will now be the same as in a one-battery, one-bulb circuit, so the two bulbs will glow with the same brightness as the single bulb in the circuit above.

Parallel Circuit

In this parallel circuit there are two identical bulbs connected to a single battery, each in their own loop. In a parallel circuit each loop behaves independently, as if it were the only loop connected to the battery. This mean the current flowing in each loop in this parallel circuit will be the same as in a one-battery, one-bulb circuit. Therefore each bulb will glow with the same brightness as the single bulb in the circuit above.
8. As the elevator in the previous question passes the 9th floor it begins to slow down (still moving upward), before stopping at the 10th floor. As the elevator is **slowing down**, which one of the following statements best describes the forces acting on it? (Again, assume any frictional forces can be neglected.) Circle your choice.

   a) The upward pull of the cable is stronger than the downward gravitational pull of the Earth.
   b) The upward pull of the cable is equal in strength to the downward gravitational pull of the Earth.
   c) The upward pull of the cable is weaker than the downward gravitational pull of the Earth.

Explain your reasoning

In order for an object to slow down, the force acting in the opposite direction to the motion must be stronger than any force acting in the same direction as the motion. Since the elevator is slowing down as it moves upward, this means the downward force must be stronger than the upward force. The only way for this to happen is if the upward pull of the cable is weaker than the downward gravitational pull of the Earth.

9. The famous chef, Antonio, is making pizza. He shapes the dough for the base into a large round, flat shape, and then tosses it into the air. It rises about three feet before falling back down, where he catches it.

Which of the following diagrams best represents the forces acting on the pizza **after** he has tossed it up, and it is **still rising**. Circle your choice.

A.

- Air resistance
- Direction of motion
- Force of Antonio’s hands
- Gravitational force of the Earth

B.

- Air resistance
- Direction of motion
- Force of Antonio’s hands
- Gravitational force of the Earth
Diagram C is correct.

The gravitational force of the Earth pulls downward on the pizza and all the diagrams show that. However, after the pizza has left Antonio’s hands the force of his hands no longer acts, so both A and B can be eliminated. Like friction, the force of air resistance always opposes the motion of objects and since the pizza is still moving upward, this force must be pushing down on the pizza.

Thus both gravity and air resistance oppose the upward motion, so the correct diagram is C.

10. An archer uses a bow to shoot an arrow straight up into the air on a still, calm day. The arrow rises to a certain height and then falls straight back down, sticking in the ground. The speed time graph for the arrow shown below is for the period starting just after it leaves the bow to just before it sticks in the ground.
d) At what time does the arrow reach its highest point? Briefly justify how you know.

The arrow reaches its highest point at 5 seconds. We can tell this from the graph because it is at this time that it stops slowing down as it rises, stops for an instant at its highest point, and then begins to speed up again as it falls.

e) Were the forces acting on the arrow balanced or unbalanced during the time period shown on the speed-time graph? Briefly justify how you know.

The forces acting on the arrow were unbalanced the whole time. You can tell this because the speed was changing in some way (either slowing down, or speeding up) over the whole time period shown on the graph. (Even when the arrow reached the top and had a speed of zero just for a moment, the speed was still in the process of changing!)

In the remainder of this problem you will explain why the arrow slows down after it leaves the bow and until it reaches its highest point. You will first explain it in terms of energy ideas, and then will explain it again in terms of force ideas. In both cases, ignore the effects of air resistance.
Multiple Choice Questions

1) A rectangular coil, with corners labeled ABCD, of length $L$ and width $w$ is placed in a magnetic field $B$ as shown in Figure below. If there is a current $I$ flowing through this coil, what is the direction of the force acting on section CD of this coil?

A) none  
B) perpendicular to and into the page  
C) perpendicular to and out of the page  
D) in the direction of the magnetic field

Answer: C

2) A 4.0-$\Omega$ resistor is connected in parallel with a 12-$\Omega$ resistor and both of these are connected to a DC power supply with voltage $V$ as shown in Figure 21-9. If the total current in this circuit is 2.0 A, what is the current through the 4.0-$\Omega$ resistor?

![Parallel Circuit Diagram]

A) 2.0 A  
B) 0.5 A  
C) 3.0 A  
D) 1.5 A

Answer: D

3) If $\varepsilon = 9.0$ V, what is the current in the 15-$\Omega$ resistor?
a. 0.20 A
b. 0.30 A
c. 0.10 A
d. 0.26 A
Answer: A

4) When charging two objects by rubbing them together:
a. Neither may be a conductor.
b. They must be made of different material.
c. They will sometimes end up with both being positively charged.
Answer: B

5) At which location will the electric field between the two parallel plates of a charged capacitor be the strongest in magnitude?
a. near the positive plate
b. near the negative plate
c. midway between the two plates at their ends
d. midway between the two plates nearest their center
Answer: D

6) If two parallel, conducting plates have equal positive charge, the electric field lines will:
a. leave one plate and go straight to the other plate.
b. leave both plates and go to infinity.
c. enter both plates from infinity.
d. none of the above.
Answer: B

7) Three equal point charges are placed at the corners of a square of side \(d\) as shown in Figure 19-13. Which of the arrows shown represents the direction of the net electric field at the center of the square?

A) A
8) An electron and a positron are released simultaneously from rest and start to move towards each other because of the attractive Coulomb force between them. (Note: A positron is the antiparticle of the electron, being in all aspects identical to the electron except in the sign of its electrical charge. The charge of the positron is +e, while that of the electron is -e.) They are initially separated by a distance \( d \). The two particles eventually collide. When they collide, 
A) they are closer to the electron’s initial position.
B) they are at the midpoint of their initial separation.
C) they are closer to the positron’s initial position.
D) Not enough data is given to predict where they collide.
Answer: B

9) A charged rod carrying a negative charge is brought near two spheres that are in contact with each other but insulated from the ground. If the two spheres are then separated, what kind of charge will be on the spheres?
A) The sphere near the charged rod becomes positive and the other becomes negative.
B) The sphere near the charged rod becomes negative and the other becomes positive.
C) The spheres do not get any charge.
D) None of the other choices is correct.
Answer: A

10) By what method will a positively charged rod produce a negative charge on a conducting sphere that is placed on an insulating surface?
A) by means of conduction
B) by means of convection
C) by means of induction
D) None of the other choices is correct.
Answer: C

11) A person is lowering a bucket into a well with a constant speed. The force exerted by the rope on the bucket is
A) equal to the bucket’s weight.
B) greater than the bucket’s weight.
C) less than the bucket’s weight, but not zero N.
D) zero N.
Answer: A

12) A car moving encounters a bump that has a circular cross-section. What is the normal force exerted by the seat of the car on a m-kg passenger when the car is at the top of the bump?
A) equal to your true weight, \( mg \).
B) more than your true weight, \( mg \).
C) less than your true weight, \( mg \).
D) could be more or less than your true weight, \( mg \), depending on the value of the speed.
Answer: C

13) Two inclined planes A and B have the same height but different angles of inclination with the horizontal. An object is released at rest from the top of each of the inclined planes. How does the speed of the object at the bottom of inclined plane A compare with that of the speed at the bottom of inclined plane B?
A) It is directly proportional to the angle.
B) It is inversely proportional to the angle.
C) It is same for both planes.
D) There is not enough information to answer the question.
Answer: C

14) A ball with original momentum +4.0 kg·m/s hits a wall and bounces straight back without losing any kinetic energy. The change in momentum of the ball is:
A) 0.
B) −4.0 kg·m/s.
C) 8.0 kg·m/s.
D) −8.0 kg·m/s.
Answer: D

15) Two ice skaters push off against one another starting from a stationary position. The 45-kg skater acquires a speed of 0.375 m/s. What speed does the 60-kg skater acquire?
A) 0.500 m/s
B) 0.281 m/s
C) 0.375 m/s
D) 0 m/s
Answer: B

16) An object rests on an inclined surface. If the inclination of the surface is made steeper, what does the normal force on the object do?
A) increase
B) decrease
C) stays the same
D) The normal force is zero N.
Answer: B

17) In Figure below (a)-(d), a block moves to the right in the positive \( x \)-direction through the displacement \( \Delta x \) while under the influence of a force with the same magnitude \( F \). Which of the following is the correct order of the amount of work done by the force \( F \), from most positive to most negative? (A) d, c, a, b (B) c, a, b, d (C) c, a, d, b
Figure. A force $\vec{F}$ is exerted on an object that undergoes a displacement to the right. Both the magnitude of the force and the displacement are the same in all four cases.

18) A boy throws a ball to another boy who throws it back with half the original speed. What is the ratio of the final kinetic energy to the initial kinetic energy of the ball?
A) 0.25
B) 0.50
C) 2.00
D) 0.75
Answer: A

19) When a parachutist jumps from an airplane, he eventually reaches a constant speed, called the terminal velocity. This means that
A) the acceleration is equal to $g$.
B) the force of air resistance is equal to zero N.
C) the effect of gravity has died down.
D) the force of air resistance is equal to the weight of the parachutist.
Answer: D

20) A rectangular coil lies flat on a horizontal surface. A bar magnet is held above the center of the coil with its south pole pointing down. If the magnet is dropped from this position, what is the direction of the induced current in the coil?
A) clockwise
B) counterclockwise
C) There is no current in the coil.
D) None of the other answers is correct.
Answer: A

21) The primary coil of a transformer has 600 turns and its secondary coil has 150 turns. If the ac current in the primary coil is 2 A, what is the current in its secondary coil?
A) 8 A
B) 1/2 A
C) 2 A
D) 4 A
Answer: A

22) If the number of turns in a rectangular coil of wire that is rotating in a magnetic field is
doubled, what happens to the induced emf, assuming all the other variables remain the same?
A) It stays the same.
B) It is reduced by a factor of 2.
C) It is doubled.
D) It is quadrupled.
Answer: C

23) When a bimetallic strip is heated, the strip will bend toward the side
A) with the larger coefficient of linear expansion.
B) with the smaller coefficient of linear expansion.
C) with the higher temperature.
D) with the lower temperature.
Answer: B