1. (24 points) In the table below is shown three physical situations in which two objects move and interact. The assumptions you are to make about the objects and the system are given in the second column of the table. For each case select: during the time described, whether the momentum of the pair is conserved during the interaction and whether the mechanical energy of the pair is conserved during the interaction. For each of these cases, choose the letters corresponding to one or more of the reasons that the conservation holds or does not from the list below the table.

<table>
<thead>
<tr>
<th>Objects</th>
<th>Assumptions</th>
<th>Is momentum conserved?</th>
<th>Is mechanical energy conserved?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A toy train and a bumper (spring)</td>
<td>The train rolls down a hill and bounces off the bumper. Friction with the ground and in the bumper can be neglected.</td>
<td>___ Yes ___ No</td>
<td>___ Yes ___ No</td>
</tr>
<tr>
<td></td>
<td>Reason:</td>
<td></td>
<td>Reason:</td>
</tr>
<tr>
<td>Two cylinders, A and B</td>
<td>The heavy cylinder (A) has frictionless wheels and is rolling along on a horizontal tabletop when a lighter cylinder (B) is lightly dropped onto it. There is friction between the two cylinders.</td>
<td>___ Yes ___ No</td>
<td>___ Yes ___ No</td>
</tr>
<tr>
<td></td>
<td>Reason:</td>
<td></td>
<td>Reason:</td>
</tr>
<tr>
<td>Two gliders on an air track</td>
<td>The light glider approaches the heavier and bounces off. The heavier glider has a compressed spring that is released when the gliders meet, driving them apart. Friction can be ignored between the gliders and the track and internally in the spring.</td>
<td>___ Yes ___ No</td>
<td>___ Yes ___ No</td>
</tr>
<tr>
<td></td>
<td>Reason:</td>
<td></td>
<td>Reason:</td>
</tr>
</tbody>
</table>

Possible reasons:

A. There are unbalanced external forces acting on the pair of objects.
B. There are no unbalanced external forces acting on the pair of objects.
C. There are non-conservative forces involved in the interaction.
D. There are no non-conservative forces involved in the interaction.
E. Momentum is always conserved.
F. Energy is always conserved.
3. (15 points) The photo at the right shows a six-year old child bouncing on a trampoline. The trampoline basically acts like a spring, catching the child, storing its energy, and returning it. The photo shows the child at the top of her jump. If we assume when the trampoline catches her it stretches halfway to the ground, estimate the spring constant of the trampoline. Be sure to clearly state your assumptions and how you came to the numbers you estimated, since grading on this problem will be mostly based on your reasoning, not on your answer.
1. (30 points) A superball is dropped from a height of 1 m and bounces a number of times before it is caught. Below are shown graphs of some of the physical variables of the problem. Match the graphs that best show the time dependence of the variables in the list below the graphs. (Assume for these first few bounces the superball can be treated as a “perfect bouncer.”)

You may use a graph more than once or not at all. If none of the graphs work well for a variable, put N. Note: the time axes are to the same scale, but the ordinates {"y axes"} are not.

The time $t = 0$ is taken to be the instant when the ball leaves the hand. Use a coordinate system in which the positive direction is taken as up and the origin is at the floor. (No explanations are required for this problem.)

_____  a. The velocity of the ball
_____  b. The kinetic energy of the ball
_____  c. The potential energy of the ball
_____  d. The momentum of the ball
_____  e. The total mechanical energy of the ball.
_____  f. The position (y coordinate) of the ball
2. (20 points) Two gliders are set up to collide on an air track as shown in the figure below. The glider on the right is at rest and has a spring connected to it. Before the collision, as shown in the figure at the left, the smaller glider (mass $m$) is on the left approaching the larger glider (mass $M$). The spring on the larger glider is compressed and stores a spring potential energy of $\Delta E$. When the two carts collide, the spring is released, giving all its potential energy up to the kinetic energy of the two carts. (The mass of the spring and latch is included in $M$; the friction internal to the spring and between the carts and the air track may be ignored.)

a. Is the momentum of the two carts conserved in this collision? If it is, write the equation that the variables of this collision satisfy as a result using the symbols given in the description of the problem. If it is not, explain why not. (10 pts)

b. Is mechanical energy conserved in this collision? If it is, write the equation that the variables of this collision satisfy as a result using the symbols given in the description of the problem. If it is not, explain why not. (10 pts)
1. (20 points) Two fan carts labeled A and B are placed on opposite sides of a table with their fans pointed in the same direction as shown in the figure at the right. Cart A is weighted with iron bars so it is twice as heavy as cart B. When the fans are turned on, they provide a constant force on the cart independent of its mass. Assume that friction is small enough to be neglected. The fans are rigged so that they go off when the carts cross the finish line (shown by the checkered flag). Put your answers to items a-d in the boxes at the right. (Explanations are not required for this problem.)

a. Which cart will reach the finish line first? (5 pts)
   (1) Cart A.
   (2) Cart B
   (3) They will reach at the same time.

b. After both fans have gone off, which of the following statements are true about the kinetic energies of the two carts? (5 pts)
   (1) \(K_A > K_B\)
   (2) \(K_A = K_B\)
   (3) \(K_A < K_B\)

c. After both fans have gone off, which of the following statements are true about the momenta of the two carts? (5 pts)
   (1) \(p_A > p_B\)
   (2) \(p_A = p_B\)
   (3) \(p_A < p_B\)

d. Which of the following statements are true? You may choose as many as you like, or none. If you choose none, write N. (5 pts)
   (1) After the fans are turned on, each cart moves at a constant velocity, but the two velocities are different from each other.
   (2) During the entire race the kinetic energy of each cart is conserved.
   (3) During the entire race the momentum of each cart is conserved.
2. (25 points) On a visit to New Zealand, I watched a woman bungee jumping from a high bridge. In this activity, an operator attaches an elastic rope to the jumper. The jumper then jumps off the bridge. She falls freely until she reaches the unstretched length of the rope. Then, the rope begins to stretch and slow her to a stop. It yanks her back up and she oscillates up and down for a while. When she is nearly stopped, the operator of the jump pulls on the elastic rope and hauls her back up to the bridge.

In order to use common symbols, let’s call the jumper’s mass, $m$, the unstretched length of the rope, $L_0$, the height of the bridge above the water, $H$, the elastic constant of the rope, $k$, and the gravitational field strength, $g$. The approximate values of these symbols for this case are: $m = 50 \text{ kg}$, $L_0 = 8 \text{ m}$, $H = 150 \text{ m}$, and $g = 10 \text{ N/kg}$.

a) Write an expression for the energy of the jumper-rope system in terms of symbols that can be used to describe her descent. (10 pts)

b) How fast is she falling when she reaches the length of the unstretched rope? (5 pts)

c) If the elastic rope stretches an extra 4 m to bring her to a stop, what is its spring constant, $k$? (10 pts)
4. (10 points) In class we considered a demonstration in which we let a superball and a clay ball (of equal masses) swing down to hit a wooden block. To the surprise of almost half the class, the superball knocked the block over but the clay ball did not. Tell whether you were surprised by this result or not and explain how you might help someone who finds the result strange make sense of it. Note: This is an essay question. Your answer will be judged not solely on its correctness, but for its depth, coherence, and clarity.
1. **(30 points)** In lecture we observed two billiard balls that were driven down parallel tracks by a spring gun. One ball traveled along a flat track, the other along a track with a dip. The apparatus is shown in the figure below.

Below are shown 6 graphs and 10 physical quantities. Identify which of the graphs could match each physical quantity if the vertical axis were given the correct scale. The time $t = 0$ occurs just after the balls have been pushed by the spring. Choose the graphs that match each quantity a.-j. If none works, write N. Each graph may be chosen as many times as you like. You may assume friction can be neglected. *No explanations are required on this problem.* (3 pts each)

- a. ___ The kinetic energy of ball A
- b. ___ The potential energy of ball A
- c. ___ The kinetic energy of ball B
- d. ___ The potential energy of ball B
- e. ___ The total energy of ball A
- f. ___ The total energy of ball B
- g. ___ The velocity of ball A
- h. ___ The velocity of ball B
- i. ___ The position of ball A
- j. ___ The position of ball B.

If you need more space, continue on the back and check here.
4. (10 points) In the middle part of the class we have studied momentum conservation and energy conservation. Pick one of these topics and explain briefly what it means, when it holds, and how it relates to the material studied in the first part of the class (Newton’s laws). Note: This is an essay question. Your answer will be judged not solely on its correctness, but for its depth, coherence, and clarity.
2. (20 points) Two carts of equal mass are floating on a level air track so that they move horizontally with essentially no friction.

(a) Cart B is stationary and cart A approaches it from the left with a velocity $v$. It collides elastically (there are metal springs on the ends of the carts) so that no mechanical energy is lost in the collision. Will the momentum of each cart be conserved or not? Explain. (5 pts)

(b) Will the total momentum of the system (the two carts taken together) be conserved or not? Explain the reasons for your answer. (5 pts)

(c) The metal springs on the carts are replaced by Velcro so the carts will stick together when they hit. Will the mechanical energy of the system (the two carts) be conserved or not? Explain the reasons for your answer. (5 pts)

(d) Cart B is replaced by cart C, which has twice the mass of cart A. If cart A has a mass of 1 kg and approaches cart C with a speed of 30 cm/s, with what speed will they travel after they have hit and stuck together? (5 pts)
3. (15 points). One of the activities for the annual high school Physics Olympics competition is the “egg drop.” Students create packaging that allows them to drop a raw egg off the top of the physics building to land on the ground undamaged. Some packages involve parachutes to slow the fall of the egg, but some don’t. In one version, the packaging can have a mass equal to no more than the mass of the egg. For a packing that does NOT involve slowing the fall using air resistance, estimate how much energy the packing has to absorb when it hits the ground so that the egg does not break. Be sure to clearly state your assumptions and how you came to the numbers you estimated, since grading on this problem will be mostly based on your reasoning, not on your answer.

If you need more space, continue on the back and check here.