AP Exam: Conservation Laws

Full Name, Period, AP/Honors:

Remember to budget your time. You will only have about 2 minutes for each MC, 8 for each FRQ.

1 Multiple choice

1. You have a car that is loaded with blocks. How could you decrease the stopping distance of the car?
   - A. Swap the tires for ones with higher static friction coefficient
   - B. Increase the mass of the car
   - C. Decrease the mass of the car
   - D. Ensure that the tires are fully locked when stopping
   - E. None of the above.

2. After rolling without sliding down a ramp of height h, some object has a speed of $v = \sqrt{\frac{7}{10}gh}$. What is the constant, ϵ, in $I = \epsilon MR^2$ where I is the object's moment of inertia?
   - A. $\frac{13}{7}$
   - B. $\frac{4}{5}$
   - C. $\frac{7}{10}$
   - D. $\frac{8}{9}$
   - E. $\frac{2}{5}$

3. Consider the case of a bead with mass m that is placed on an infinite, frictionless rod oriented horizontally. The bead can move along the rod, but cannot leave the rod. The bead initially has momentum $\vec{p}$ in the positive direction. At the end of the rod is a spring. By how much will the spring be compressed when the bead hits it?
   - A. $\frac{p}{k}$
   - B. $\frac{p}{\sqrt{mk}}$
   - C. $\frac{p^2}{mk}$
   - D. $\frac{mk}{p}$
   - E. $\frac{pk}{2m}$

4. In some reference frame, not necessarily on Earth, an object has a kinetic energy $KE > 0$. Which of these must be true about the object?
   - A. The momentum is in the positive direction.
   - B. The potential energy of the object is negative.
   - C. The object is rotating around its center of mass.
   - D. The angular momentum is nonzero with respect to at least one axis.
   - E. None of the above

5. An object travels in a circle horizontally with constant ω, but changing $\vec{v}$. Friction exists. Take the system to consist of only the object. Which of these correctly describes the change in the kinetic energy of the object as it moves, and a correct reasoning?
   A. $\Delta KE = 0$ because all objects moving in a circle maintain constant angular momentum
   B. $\Delta KE = 0$ because $\vec{F}_{net}$ and $\vec{v}$ are always perpendicular
   C. $\Delta KE = 0$ because potential energy did not increase and the net force was always 0
   D. $\Delta KE \neq 0$ because the system experienced a constant non-zero net force
   E. $\Delta KE \neq 0$ because friction extracted energy from the system

6. (**Honors**) An object with mass M and momentum $\vec{p}$ collides with an object with mass $3M$ that is initially at rest. No external forces act. What will be the final momentum of the resulting object?
   A. $\vec{p}$
   B. $3\vec{p}$
   C. $\frac{1}{4}\vec{p}$
   D. $\frac{1}{3}\vec{p}$
   E. $4\vec{p}$

7. (**Honors**) A roller coaster starts at a height of h with a speed v. After descending to 0, it returns to the same height with the same speed. Neglect friction and air resistance. Which of these is true about the net work done by gravity?
   A. 0, no matter how our system was defined
   B. 0, if we included Earth, positive otherwise
   C. 0, if we included Earth, negative otherwise
   D. Non-zero, no matter how our system was defined

8. (**AP**) A truck with mass 1500 kg is initially traveling with a momentum $\vec{p}$. It collides with a car of mass 500 kg traveling with a momentum of $-\frac{\vec{p}}{2}$. A time Δt later the objects are stuck together, forming a pile of steel. The momentum of the pile is $-\frac{\vec{p}}{2}$. What was the average net force on the system consisting of both objects during the time interval?
   A. $\frac{\vec{p}}{2\Delta t}$
   B. $\frac{\vec{2}p}{\Delta t}$
   C. $\frac{-\vec{4}p}{\Delta t}$
   D. $\frac{-\vec{p}}{\Delta t}$
   E. $\frac{-\vec{p}}{2\Delta t}$
   F. We need to know the velocity of the car and truck to answer.

9. (**AP**) You have a way to launch bouncy balls with mass m_b so that they have exactly the same kinetic energy as a specific car with mass M_c traveling at 60 mph. You shoot them at the back of the car mentioned earlier, and they bounce back with almost the same speed they had before. How many do you need to shoot before the car travels at 60mph? Assume that you are firing them from a second car that always keeps pace with the car you are shooting.

   A. ∞, the car will only asymptotically approach 60mph.

   B. $\frac{M_c}{m_b}$

   C. $\sqrt{\frac{M_c}{2m_b}}$

   D. $\frac{2M_c}{m_b}$

   E. $\frac{1}{2}\sqrt{\frac{M_c}{m_b}}$

2 Short Answer

1. An object with mass π kg is sliding around a circular track with a radius of 1 m and friction coefficient $\mu_k = \frac{1}{\pi}$. It start at a position of $+1\ \mathrm{m}\hat{\mathrm{x}}$ and moves clockwise. Gravity is $g = \pi\ \frac{\mathrm{m}}{\mathrm{s}^2}$.

   (a) (3 pt, **All**) The first time it reaches a position of $-1\ \mathrm{m}\hat{\mathrm{x}}$, how much work has been done by Friction?

   (b) (3 pt, **Honors**) If the object's initial kinetic energy is $2\pi^2$, what will be its energy when it completes one lap around the circle?

   (c) (3 pt, **AP**) If the objects initial speed is $v = \sqrt{51\pi}\ \frac{\mathrm{m}}{\mathrm{s}}$, where will it be when it stops?

2. (5 pt) A bullet of mass m_b is fired horizontally with a kinetic energy E_b into a cube of mass M_c that is attached to the ceiling with an initially vertical, massless, rod. The rod pivots without friction around the end on the ceiling. How high will the cube swing if the bullet sticks inside the cube? You may assume that $M_c >> m_b$ and call the initial height of the cube 0.

3. You have two disks with the same density. The first disk has a mass of M and a thickness of T. The second disk has a mass of $2M$ and a thickness of $\frac{T}{2}$. Recall that the volume of a cylinder is $\pi R^2 T$.

   (a) (3 pt) If the first disk has moment of inertia I, what is the moment of inertia of the second disk?

   (b) (3 pt) If the first disk is spinning with ω ccw and the second disk was spinning with ω cw, what will be the final angular speed of the second disk after the two disks come together? Assume that each disk remains intact, but that they are stuck together at the end. Also assume that the disks were aligned vertically at the beginning. Express your answer in terms of I_1 and I_2.

   (c) (Extra Credit, 1 pt): Assume that the first disk was initially traveling at $v\hat{z}$ and the second was traveling at $-v\hat{z}$. What are the linear velocity and linear speed of a point on the edge of the second disk after the collision? It may help to express your answer in cylindrical polar coordinates.

4. (5 pt) The amount of radiation given off by a hot object is given by $L = 4\pi R^2 \sigma T^4$. In this equation, R is the radius of the object, T is the object's temperature, and σ is a constant. You have access to an accurate thermometer, a sphere of known radius, a means of heating the sphere, and a device that measures the amount of radiation an object gives off. Provide a brief procedure to determine the constant σ. A diagram is optional, and do not worry about details of how the thermometer or heating work.