Name__________________________________Period __________ Date_______________

2:29 Colliding Steel Balls (D-7)

1. Think about an elastic collision between two steel balls:
   a. How does the final momentum of the pair compare with the original momentum?

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   b. How does the final kinetic energy of the pair compare with the original KE? ____________

2. The target ball is stationary before impact. The projectile ball moves toward the target with velocity "V_o". The mass of the projectile is "M". The target mass differs from the projectile mass by a factor of "R", so that the target mass is "RM". ("R" is a *ratio*.) Just after impact the projectile ball has velocity "V_1" and the target has velocity "V_2". Use #1 to see what happens if all three velocities are parallel:
   a. Show how V_2 can be calculated from V_o and R. _________________________________
   b. Show how V_1 can be calculated from V_o and R. Simplify if possible.

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3. The kinetic energy transferred to the second ball is a certain fraction of the original KE.
   a. Let "A" represent that fraction. Use 2a to show how that "energy transmission efficiency" can be calculated from R. (Remember that the mass of the second ball is RM, not M.) ________________
   b. Let "B" represent the "energy retention efficiency", i.e. the ratio of the energy remaining in the first ball after impact to its original KE. Show how that ratio can be calculated from R. __________________________

4. Imagine a long series of steel balls suspended as in a "swinging wonder" toy. This set differs from the toy in one important way: These balls do not have equal masses but instead have equal mass *ratios*. The first ball has mass "M" and the last one has mass "ρM". Let the ratio of any two consecutive masses be "R", as in #1. Let "N + 1" represent the number of balls in the set. Show how R can be calculated from N and the mass ratio, ρ. Check carefully!

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5. Suppose the first ball in the series is given a velocity toward the remaining balls, which hang in a neat, straight row. Show how the KE transmitted to the last ball can be calculated from N, A, and the original KE. ______________________

6. We want to find the limit of that "overall energy transmission efficiency" as N goes to infinity.
   a. First, use 3a to eliminate "A" from equation 5. That gives us the overall efficiency in terms of R: ______________________________
   b. Is the limit obvious in equation 6a? ________________

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7. Here's a trick that may be helpful for #6: Notice that when N becomes great, R grows closer and closer to ___________. (Give the limiting numerical value of R.)
   a. Therefore we should choose a letter such as "δ" (delta) to represent the *difference* between R and its limiting value. Thus we shall replace R in 6a with ______– ______.
   b. For example, if R = 0.98 then each mass is___% less than the previous mass, so δ = ______.
   c. The squared binomial in our revised version of eq. 6a then has a big term and a very small term. After squaring it, you have a big term, a small term, and an insignificant term which can be dropped. Then a miracle happens during routine simplification. Try it! Then make a conclusion answering question 6. (Remember that "efficiency" is a *dimensionless ratio*.)

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8. Suppose the first ball in the series is a 5-kg cannonball with a speed of 1 m/s, and the last one is a 30-gram ball bearing. How fast will the ball bearing go just after impact? Explain your answer clearly enough so that *even a physics teacher* can understand it.

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