Teacher notes
Topic D

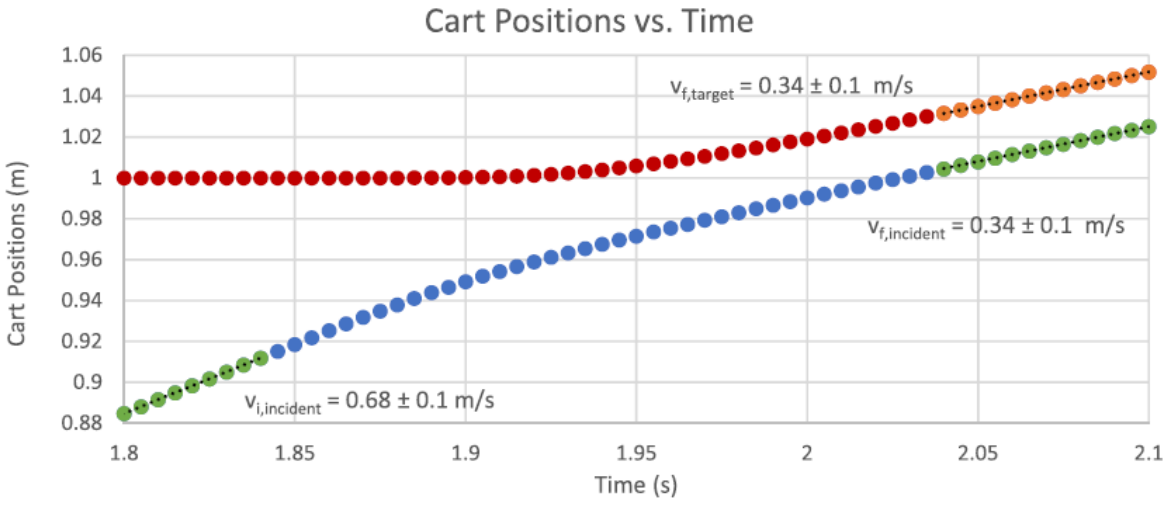
Questions based on an EM induction experiment.

Based on an article by Lane Seeley and Eun-Hee Shin, in *American Journal of Physics*, Vol. 86, No. 9, Sept. 2018.

A great class discussion problem.

A cart attached to a copper tube (blue cart) is approaching a stationary cart attached to bar magnets (red cart). The masses of the two carts and their attachments are the same.

The graph shows the variation with time of the positions of the two carts.



(a) Use the graph to explain
  (i) why the carts never actually touch,
  (ii) why the carts change velocities,
  (iii) how the speeds of the carts were calculated.

(b) Explain why
  (i) the final speeds of the carts are equal,
  (ii) the common final speed of the carts is half of the incoming blue cart speed.

(c) The authors quote the common speed after the interaction as $(0.34 \pm 0.1)\ \text{m s}^{-1}$. State why this would not be considered correct by the standards of this course.

(d) The total initial kinetic energy of the system is *K*. Calculate, in terms of *K*, the final kinetic energy of the two carts.

(e) Suggest why the initial and final kinetic energies are not the same.

Answers

(a)

(i) The graphs for position versus time do not cross.

(ii) There is a force between the carts. As the cart approaches the magnetic flux in the copper tube increases and so an emf is induced in the tube. Therefore, there is an induced current. By Lenz's law, the force is repulsive, so the speed of the red cart increases and that of the blue cart decreases.

(iii) By measuring the gradients of the position versus time graphs for each cart for times greater than 2.05 s when the speeds become constant.

(b)

(i) The force between the two carts will become zero when the flux no longer changes. This happens when both carts have the same speed.

(ii) Applying momentum conservation, we find $mu + 0 = 2mv \Rightarrow v = \frac{u}{2}$.

(c) The uncertainty is given to the first decimal place. The measured value should then have one decimal place only.

(d) $K = \frac{1}{2}mu^2$. $K' = \frac{1}{2}(2m)v^2 = \frac{1}{2}(2m)\frac{u^2}{4} = \frac{1}{2}(\frac{1}{2}mu^2) = \frac{1}{2}K$.

(e) The flux in the copper tube changes and so an emf and a current are induced. The current generates thermal energy in the tube and thus kinetic energy is lost, the collision is inelastic. (This is still a collision even though the carts never touch.)