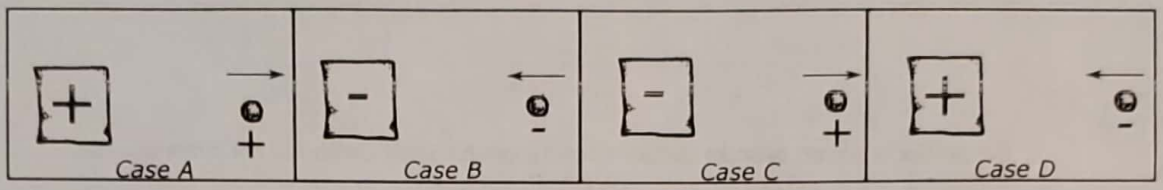
NAME Vignesh Rangarajan DATE 3/30/21

Scenario

Consider a charged box and a charged sphere somewhere in space far from other objects. The box is very massive so that it can be assumed to remain at rest, but the sphere is light and able to freely move. The four cases below show different combinations of signs of charge on the box and sphere as well as the initial direction of the sphere's velocity. Assume that all cases have the same initial speed of the sphere, initial distance from sphere to box, magnitude of charge on sphere, and magnitude of charge on box.



Data Analysis

PART A: In which case or cases above is the speed (magnitude of velocity) increasing at the moment shown? Mark all correct answers.

✓ Case A ____ Case B ____ Case C ✓ Case D

Justify your answer.

In case A, the charged box and sphere are both positively charged, causing the block to repel the sphere. Since the sphere is already moving to the right, its velocity and acceleration are in the same direction, causing speed to increase. In case D, the charged box is positive, but the sphere is negative, causing the box to attract the sphere. Since the sphere is moving left and is attracted, velocity and acceleration are in the same direction, causing an increase in speed.

PART B: In which case or cases above is the magnitude of acceleration increasing at the moment shown? Mark all correct answers.

____ Case A ✓ Case B ____ Case C ✓ Case D

Justify your answer.

In cases B and D, the sphere is approaching the block. Since $F \propto \frac{1}{r^2}$, as the sphere get closer, acceleration increases in magnitude. $F \propto a$ so an increase in the force also causes an increase in the magnitude of acceleration.

Argumentation

PART C: Carlos and Dominique are asked to rank the net force exerted on the sphere in each of the cases. (For Part C, consider ALL forces acting on the sphere.) Carlos incorrectly says that all four net forces are equal. Dominique correctly says $F_C = F_D > F_A = F_B$.

i. Even though Carlos is incorrect, he was considering a correct physical principle. Explain the correct idea(s) that could have led to Carlos's conclusion.

Carlos could have been thinking that since $F = \frac{kq_1q_2}{r^2}$, and all charges of the box and sphere are identical, the force in each case would be equal.

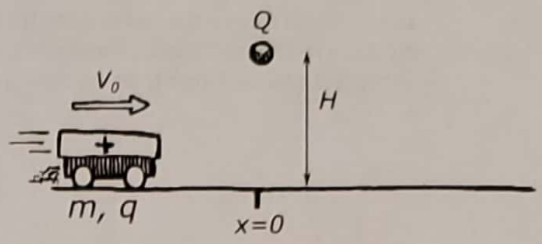
ii. Dominique is correct because she considered something that Carlos did not. State what this additional idea is and explain how it leads to Dominique's correct answer.

Dominique also is considering the gravitational forces in each of the cases. In cases C and D, we are able to see that the gravitational force has identical direction to the electrostatic force, but opposite direction in cases A and B, causing $F_C = F_D > F_A = F_B$.

NAME Vignesh Rangarajan DATE 3/30/31

Scenario

A cart having a positive charge q and mass m rolls on a track. Friction in the bearings may be neglected. The cart is initially to the left of position $x = 0$ and has a rightward velocity v_0. A fixed positive charge Q is located directly above position $x = 0$, a height H above the track. The cart itself is very small compared to the distance H.

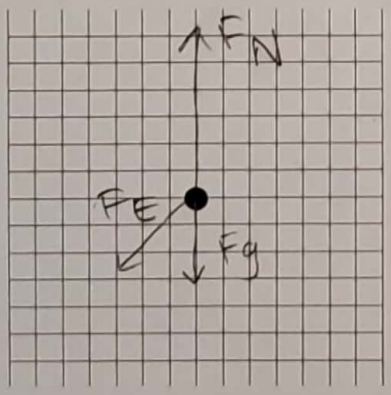


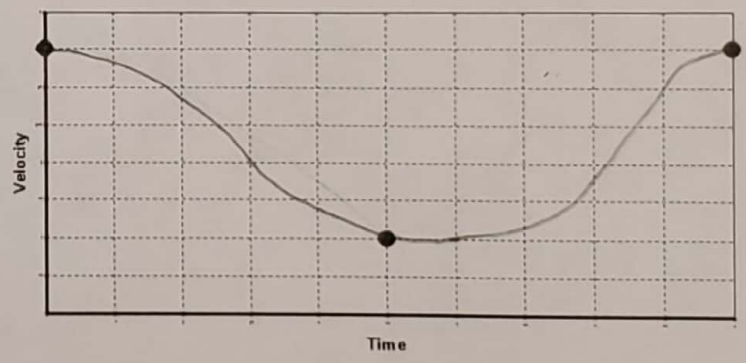
The graph of the acceleration of the cart (where the rightward direction is positive) is shown. The two other grids show three points on the graphs of the cart's velocity and position as functions of time.

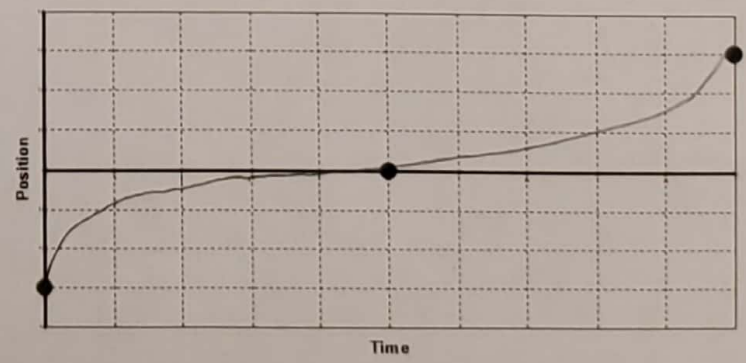
Using Representations

PART A: On the grids labeled "velocity" and "position," connect the three dots with appropriate lines or curves to make graphs of the cart's velocity and position as functions of time during the same interval shown in the acceleration vs. time graph.

PART B: The dot below represents the cart. Draw a free-body diagram showing and labeling all the forces (not components) exerted on the cart when the cart is located at position $x = -H$. Indicate relative lengths of the forces that balance.







Argumentation

PART C: The graph shows the magnitude of acceleration increasing as the cart approaches the origin, then decreasing to zero as the cart reaches the origin. In a clear, coherent, paragraph-length response, explain why the magnitude of acceleration increases and then decreases as the cart approaches the origin. Refer to the forces that you drew on Part B and/or their components as necessary.

The magnitude of the acceleration initially increases as the cart reaches the origin since the force increases as distance decreases; and, since $F \propto a$, the acceleration increases. However, the magnitude of acceleration also decreases since the horizontal component of force becomes smaller due to the angle to the horizontal approaching 90°. Therefore, the force from the charge at height H is vertical, which simply causes the normal force to be greater and does not change the vertical component of acceleration.