Interactions

1. Change in velocity
2. Change of identity
3. Change of shape
4. Change of temp

Lack of change when one is expected

Vectors and scalars

Take magnitude of vector \( \sqrt{x^2 + y^2 + z^2} = |\vec{r}| \)

Adding and subtracting multiply by scalar

Unit vectors \( \hat{r} = \frac{\vec{r}}{|\vec{r}|} \), \( \vec{r} = |\vec{r}| \hat{r} \)

\( \Delta \) change

\[ \Delta = \text{final} - \text{initial} \]

\[ \Delta \vec{r} = \vec{r}_f - \vec{r}_i \]
Definition of velocity
\[ \vec{V}_{ave} = \frac{\Delta \vec{r}}{\Delta t} = \frac{\vec{r}_f - \vec{r}_i}{t_f - t_i} \]
\[ \vec{V} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt} \]

Position update formula
\[ \vec{r}_f = \vec{r}_i + \vec{V}_{ave} \Delta t \]

Definition of momentum
\[ \Delta \vec{p} = \Delta m \vec{v} = \frac{1}{\sqrt{1 - (\vec{v}/c)^2}} \cdot m \vec{v} \]

Momentum principle
\[ \vec{p}_f = \vec{p}_i + \vec{F}_{net} \Delta t \]
\[ \Delta \vec{p} = \vec{F}_{net} \Delta t \]

For multiparticle sys.
\[ \vec{p}_{tot} = \vec{p}_1 + \vec{p}_2 + \ldots \]
\[ \Delta \vec{p}_{tot} = \vec{F}_{net, ext} \Delta t \]
Conservation of momentum

\[ \Delta \vec{P}_{\text{system}} + \Delta \vec{P}_{\text{surroundings}} = 0 \]

Gravitational force law

\[ \vec{F}_{\text{grav on 2 by 1}} = -G \frac{m_1 m_2 \hat{r}}{r^2}, \quad \vec{r} = \vec{r}_2 - \vec{r}_1 \]

\[ G = 6.7 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg}^2 \]

Electric force law

\[ \vec{F}_{\text{elec on 2 by 1}} = \frac{1}{4\pi \epsilon_0} \frac{q_1 q_2 \hat{r}}{r^2}, \quad \frac{1}{4\pi \epsilon_0} = 9 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2 \]

Spring force law

\[ |\vec{F}_{\text{spray}}| = ks|s| \quad s = L - L_0 \]

Reciprocity

\[ \vec{F}_{\text{on 1 by 2}} = -\vec{F}_{\text{on 2 by 1}} \]
GOAL

Gather ⇒ collect info ⇒ make approx. of
draw picture / estimate answer

Organize ⇒ collect principles that will be used
draw more detailed picture (Freebody <
diagram)

Analyze ⇒ do problem

Learn ⇒ check units, size, how use in future
Clicker Questions

Q1 A proton is at location < 0, 3, -2 > m. An electron is at location < -1, 6, 0 > m. What is the relative position vector from the proton to the electron?

1) < -1, 3, -6 > m
2) < -1, 3, -8 > m
3) < 0, 3, 2 > m
4) < 1, 3, 4 > m
5) < 1, 0, 0 > m

Q2 Consider a bee flying in a straight line with constant speed. At time = 15 s after 9:00 AM, the bee’s position vector was < 2, 4, 0 > m. At time = 15.5 s after 9:00 AM, the bee’s position vector was < 3, 1.5, 0 > m. What is the velocity of the bee?

\[ \frac{\Delta \vec{r}}{\Delta t} = \frac{< 1, 0.5, 0 >}{0.5 s} = < 2, 1, 0 > \text{ m/s} \]

1) < 0.125, -0.005, 0 > m/s
2) < 0.125, 0.007, 0 > m/s
3) 2.236 m/s
4) < 0.560, -0.250, 0 > m/s
5) < 2.000, -1.000, 0 > m/s

Q3 At time 12.18 s after 1:00 PM a ball’s position vector is < 20, 8, -12 > m, and the ball’s velocity is < 4, 0, 0 > m/s. At time 12.21 s after 1:00 PM, what is the vector form of the ball’s position and the velocity hardly changes in this short time interval?

\[ \Delta \vec{r} = \Delta \vec{v} \Delta t + \vec{v}_0 \Delta t \]

\[ \Delta t = 0.03 \]

1) 24.75 m
2) < 20.57, 7.68, -11.82 > m
3) < 0.27, -0.12, 0.18 > m
4) < 129.82, -49.72, 64.08 > m
5) < 130.89, -49.84, 64.25 > m
Q4
Which of these equations correctly relates the average velocity of an object to the object's initial and final positions? (That is, which could you use to predict the final position of an object if you know its initial position and average velocity?)

1) \( v_{av} = \frac{v_f - v_i}{t_f - t_i} \)
2) \( v_f = v_i + \frac{v_{av}}{2} \)
3) \( r = r_i + \frac{v_{av}}{2} (t_f - t_i) \)
4) \( r_f = r_i + v_{av} t_f \)

Q5
Which of the following can NOT be true for an object moving along a straight line at a constant speed?

1. Nothing is interacting with the object (it is in interstellar space, far from all other objects.)
2. The object is interacting with other objects, but the interactions do not interfere
3. The object is experiencing multiple interactions, and those interactions add up to zero
4. The object has no interaction with the rest of the world.

\[ \Delta \vec{v} = 0 = \vec{F} \text{net} \]

Q6
Three protons travel through space at three different speeds.

Proton A: 200 m/s
Proton B: 2.86 m/s
Proton C: 2.96 m/s

For which proton(s) is it reasonable to use the approximation \( \gamma \approx 1 \) when calculating its momentum?

1) A only
2) A and B
3) A and B and C
4) none of the protons