September 8

GOAL Protocol

Gather info about problem

Common sense ideas for reasonable values, educated guess about answer, what are you after?

Organize the information

Chose a system, draw diagrams, identify initial and final states, identify fundamental principles and definitions, prepare table with given info and what is being asked, PLAN the problem

Analyze the problem

Use principles/definitions to solve for unknowns (may be intermediate steps). AFTER completing algebra/calculus, substitute in known values organized previously, draw box around answer

Learn from your efforts

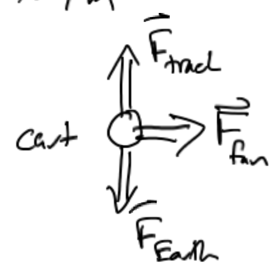
See if results fit original ideas, why where you assigned this problem, how is it different , special step in solution?

Fan cart mass 400g, constant net force due to air and friction is <0.20, 0, 0> N. Release from rest at 0.15 m. Where is it 1.0 s later?

G: Move to the right (+x) about ~1m

O: System is the cart + fan

Surrounding (Earth, air, track)



time initially 0s

finally 1.0s

position initially 0.15m $\langle 0.15m, 0m, 0m \rangle$

final ?

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

$\vec{r}_f = \vec{r}_i + \vec{v}_{ave}\Delta t$ $\vec{F}_{track} = -\vec{F}_{earth}$

GATHER: expect it to move in positive x direction

Final displacement should be small, on order of a meter

ORGANIZE:

System: cart w/fan. Indicated by a circle as shown here

Surroundings: Earth, track, air

Initial time = 0 Final time = 1.0 s

Will use Momentum Principle $\vec{p}_f = \vec{p}_i + \vec{F}_{\text{Net}}\Delta t$

Analyze

$$\vec{p}_{\text{f}} = \vec{p}_{\text{i}} + \vec{F}_{\text{net}}\Delta t = \vec{p}_{\text{i}} + \left(\vec{F}_{\text{track}} + \vec{F}_{\text{Earth}} + \vec{F}_{\text{air}}\right)\Delta t \qquad \vec{F}_{\text{track}} = -\vec{F}_{\text{Earth}}$$

$$\vec{p}_{\text{f}} = \vec{0} + \langle 0.20,0,0\rangle \text{N}(1.0 \text{ s}) = \langle 0.20,0,0\rangle \ \text{N}\cdot\text{s}$$

$$\vec{v}_{\text{f}} = \frac{\vec{p}_{\text{f}}}{m} = \frac{\langle 0.20,0,0\rangle \ \frac{\text{kg}\cdot\text{m}}{\text{s}^2}\cdot\text{s}}{0.400 \text{ kg}} = \langle 0.50,0,0\rangle \tfrac{\text{m}}{\text{s}} \qquad \vec{v}_{\text{i}} = \langle 0,0,0\rangle \tfrac{\text{m}}{\text{s}} \qquad \vec{v}_{\text{avg}} = \langle 0.25,0,0\rangle \tfrac{\text{m}}{\text{s}}$$

$$\vec{r}_{\text{f}} = \vec{r}_{\text{i}} + \vec{v}_{\text{avg}}\Delta t = \langle 0.15,0,0\rangle \text{m} + \langle 0.25,0,0\rangle \tfrac{\text{m}}{\text{s}}(1.0 \text{ s}) = \langle 0.40,0,0\rangle \text{m}$$

Learn

Check: Speed increased, which is reasonable since force in same direction as momentum.

Note: This is correct calculation of average velocity only when net force is constant.

See example pg 48, where initial velocity is <1.2,0,0> m/s and final time is 3 s.

Example: A ball with negligible air resistance

A ball of mass 500 g is initially on the ground, at location $\langle 0, 0, 0 \rangle$ m , and you kick it with initial velocity $\langle 3, 7, 0 \rangle$ m/s . (a) Where will the ball be half a second later? (b) At what time will the ball hit the ground? Make the approximation that air resistance is negligible, and use the previous analytical result for motion with a constant force.

Example: A ball with negligible air resistance

A ball of mass 500 g is initially on the ground, at location $\langle 0, 0, 0\rangle$ m, and you kick it with initial velocity $\langle 3, 7, 0\rangle$ m/s. (a) Where will the ball be half a second later? (b) At what time will the ball hit the ground? Make the approximation that air resistance is negligible, and use the previous analytical result for motion with a constant force.

1. Momentum principle

System: ball
Surroundings: Earth (neglecting air resistance)
Initial time: just after the kick
Final time: just before hitting the ground

2. Position update

(a) Using results from the analytical solution in the previous example:

$\vec{F}_{net} = \langle 0, -mg, 0 \rangle$, so $F_{net,y} = -mg$

$x_f \approx x_i + v_{ix}\Delta t$

$x_f \approx (0 + (3\text{m/s})(0.5\text{ s}) = 1.5\text{ m})$

$$y_f \approx y_i + v_{iy}\Delta t + \frac{1}{2}\left(\frac{(-mg)}{m}\right)(\Delta t)^2$$

$$y_f = 0 + (7\text{m/s})(0.5\text{ s}) - \tfrac{1}{2}(9.8\text{N/kg})(0.5\text{ s})^2 = 2.275\text{ m}$$

$\vec{r}_f = \langle 1.5, 2.275, 0 \rangle$ m

3. Check: correct units. Ball has moved in appropriate direction.

(b) At the instant the ball hits the ground, $y_f = 0$, so

$$0 = 0 + v_{iy}\Delta t + \frac{1}{2}(-g)(\Delta t)^2$$

Solving this quadratic equation for the unknown time Δt, we find two possible values:

$$\Delta t = 0 \text{ and } \Delta t = \frac{2v_{iy}}{g}$$

The first value, $\Delta t = 0$, corresponds to the initial situation, when the ball is near the ground, just after the kick. The second value is the time when the ball returns to the ground, just before hitting:

$$\Delta t = \frac{2(7\text{m/s})}{(9.8\text{N/kg})} = 1.43\text{ s}$$

In this case, the mass of the ball cancels, because the gravitational force is proportional to mass.

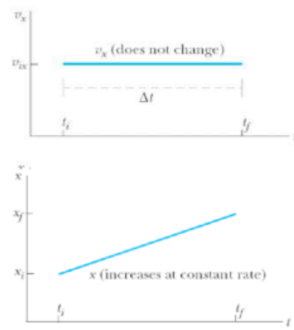


Figure 2.16 Motion graphs for the thrown ball. Top: v_x vs. t, bottom: x vs. t. Note that v_x does not change because the net force acted only in the y direction.

Introduction to 3D computer modeling

Lab: Motion in the *x* direction

A: Cart and Track

B: Fan Cart Movies

C: Modeling Motion with VPython