Physics 101: Lecture 04

Kinematics + Dynamics

Today’s lecture will cover Textbook Chapter 4

If you are new to the course, please read the course description on the course web page (and email policy from Lecture 1 note)!
Review

Kinematics: Description of Motion

- **Position**
- **Displacement**
- **Velocity** \( v = \frac{Dx}{Dt} \)
  - average
  - instantaneous
- **Acceleration** \( a = \frac{Dv}{Dt} \)
  - average
  - instantaneous
- **Relative velocity**: \( v_{ac} = v_{ab} + v_{bc} \)
• Which x vs t plot shows positive acceleration?

89% got this correct!!!!

“This shows that more distance is being covered per second as the graph proceeds. This means that the speed of the car is increasing which means a positive acceleration.”

This is x(t) graph, not v(t)
Equations for Constant Acceleration
(text, page 113-114)

- \( x = x_0 + v_0 t + \frac{1}{2} at^2 \)
- \( v = v_0 + at \)
- \( v^2 = v_0^2 + 2a(x-x_0) \)
- \( \Delta x = v_0 t + \frac{1}{2} at^2 \)
- \( \Delta v = at \)
- \( v^2 = v_0^2 + 2a \Delta x \)

\[ \bar{v} = (x - x_0) / t \]

\[ x = x_0 + \bar{v} t \]

\[ \bar{v} = (v_0 + \frac{1}{2} at) \]

\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]

\[ x = x_0 + (v_0 + \frac{1}{2} at)t \]
Kinematics Example

- A car is traveling 30 m/s and applies its breaks to stop after a distance of 150 m.
- How fast is the car going after it has traveled \( \frac{1}{2} \) the distance (75 meters)?

A) \( v < 15 \text{ m/s} \)  
B) \( v = 15 \text{ m/s} \)  
C) \( v > 15 \text{ m/s} \)

\[
\begin{align*}
\nu^2 &= \nu_o^2 + 2a \Delta x \\
a &= \frac{\nu_f^2 - \nu_o^2}{2(150)} = \frac{-30^2}{2(150)} \\
\nu_{75}^2 &= 30^2 + 2a(75) \\
\nu_{75}^2 &= 30^2 + 2 \left( \frac{-30^2}{2(150)} \right)(75) \\
\nu_{75}^2 &= 30^2 + \frac{1}{2}(-30^2) \\
\nu_{75} &= \sqrt{\frac{1}{2}30} = 21 \text{ m/s}
\end{align*}
\]
Acceleration ACT

A car accelerates uniformly from rest. If it travels a distance \( D \) in time \( t \) then how far will it travel in a time \( 2t \) ?

A. \( D/4 \)
B. \( D/2 \)
C. \( D \)
D. \( 2D \)
E. \( 4D \) \( \text{Correct } x=1/2 \, at^2 \)

Follow up question: If the car has speed \( v \) at time \( t \) then what is the speed at time \( 2t \) ?

A. \( v/4 \)
B. \( v/2 \)
C. \( v \)
D. \( 2v \) \( \text{Correct } v=at \)
E. \( 4v \)
Newton’s Second Law $F_{Net} = ma$

Position and velocity depend on history.

Net Force determines acceleration.
A force $F$ acting on a mass $m_1$ results in an acceleration $a_1$. The same force acting on a different mass $m_2$ results in an acceleration $a_2 = 2a_1$. What is the mass $m_2$?

(A) $2m_1$  (B) $m_1$  (C) $1/2 m_1$

- $F_{\text{Net}} = ma$
- $F_{\text{Net}} = m_1a_1 = m_2a_2 = m_2(2a_1)$
- Therefore, $m_2 = m_1/2$

- Or in words...twice the acceleration means half the mass
A tractor T (m=300Kg) is pulling a trailer M (m=400Kg). It starts from rest and pulls with constant force such that there is a positive acceleration of 1.5 m/s². Calculate the horizontal thrust force on the tractor due to the ground.

X direction: Tractor

\[ F_{Net} = ma \]
\[ F_{Th} - T = m_{tractor}a \]
\[ F_{Th} = T + m_{tractor}a \]

X direction: Trailer

\[ F_{Net} = ma \]
\[ T = m_{trailer}a \]

Combine:

\[ F_{Th} = m_{trailer}a + m_{tractor}a \]
Net Force ACT

Compare $F_{\text{tractor}}$, the net force on the tractor, with $F_{\text{trailer}}$, the net force on the trailer from the previous problem.

A) $F_{\text{tractor}} > F_{\text{trailer}}$
B) $F_{\text{tractor}} = F_{\text{trailer}}$
C) $F_{\text{tractor}} < F_{\text{trailer}}$

\[ SF = m \cdot a \]
\[ F_{\text{tractor}} = m_{\text{tractor}} \cdot a \]
\[ = (300 \text{ kg}) (1.5 \text{ m/s}^2) \]
\[ = 450 \text{ N} \]

\[ F_{\text{trailer}} = m_{\text{trailer}} \cdot a \]
\[ = (400 \text{ kg}) (1.5 \text{ m/s}^2) \]
\[ = 600 \text{ N} \]
Pulley Example

Two boxes are connected by a string over a frictionless pulley. Box 1 has mass 1.5 kg, box 2 has a mass of 2.5 kg. Box 2 starts from rest 0.8 meters above the table, how long does it take to hit the table.

• Compare the acceleration of boxes 1 and 2

A) $|a_1| > |a_2|$  B) $|a_1| = |a_2|$  C) $|a_1| < |a_2|$

1) $T - m_1 g = m_1 a_1$
2) $T - m_2 g = -m_2 a_1$

2) $T = m_2 g - m_2 a_1$
1) $m_2 g - m_2 a_1 - m_1 g = m_1 a_1$

$a_1 = \frac{(m_2 - m_1)g}{(m_1 + m_2)}$
Pulley Example

Two boxes are connected by a string over a frictionless pulley. Box 1 has mass 1.5 kg, box 2 has a mass of 2.5 kg. Box 2 starts from rest 0.8 meters above the table, how long does it take to hit the table.

\[ a = \frac{(m_2 - m_1)g}{m_1 + m_2} \]

\[ a = 2.45 \text{ m/s}^2 \]

\[ \Delta x = v_0 t + \frac{1}{2} a t^2 \]

\[ \Delta x = \frac{1}{2} a t^2 \]

\[ t = \sqrt{\frac{2 \Delta x}{a}} \]

\[ t = 0.81 \text{ seconds} \]

• Compare the acceleration of boxes 1 and 2

A) \( |a_1| > |a_2| \)
B) \( |a_1| = |a_2| \)
C) \( |a_1| < |a_2| \)
Summary of Concepts

• Constant Acceleration
  - \( x = x_0 + v_0 t + \frac{1}{2} at^2 \)
  - \( v = v_0 + at \)
  - \( v^2 = v_0^2 + 2a(x-x_0) \)

• \( F = ma \)
  - Draw Free Body Diagram
  - Write down equations
  - Solve

• Next time: textbook section 4.3, 4.5