Day 4:
What causes acceleration?
Gravity
Reminders:
HW 2 due Monday
Reading for Tues: 2.2 Bloomfield
Visit Help sessions today
Next up: forces

Acceleration and forces
Which hits the ground first?

Graph shows the velocity of a car as a function of time. What is its acceleration?

a. -0.25 m/s²
b. +0.25 m/s²
c. -0.5 m/s²
d. +0.5 m/s²
e. 0 m/s²

Equations when velocity is changing
What if velocity is changing? ... Accelerating
Acceleration (a) = \( \frac{v_f - v_i}{t_f - t_i} \)
Rearrange:
\( v_f - v_i = a(t_f - t_i) \)
\( v_f = v_i + a(t_f - t_i) \)
Now let \( t_i = 0 \) s and so \( v_i = v_0 \) and drop the f subscript
\( v = v_0 + a t \)

Motion at constant acceleration
\( v(t) = v_0 + at \)
Your velocity at time \( t \) depends on
Your velocity when you started,
How fast and in what direction you are accelerating,
How long you’ve been going

What about position at constant acceleration?
So far:
\( x = x_0 + vt \) \( (a = 0) \) \( (1) \)
\( v = v_0 + at \) \( (a = \text{constant}) \) \( (2) \)
From (1):
\( x = x_0 + v_{\text{avg}}t \) \( (\text{if } a \neq 0) \)
\( v_{\text{avg}} = v_i + \frac{1}{2} (\text{change in velocity}) \)
\( (\text{change in velocity}) = v - v_i = a(t_f - t_i) \)
\( \Rightarrow x = x_0 + v_0 + \frac{1}{2} at^2 \) \( (4) \)
Substitute (4) into (3)
\( x = x_0 + (v_0 + \frac{1}{2} at)t \)

Tuesday:
Motion at constant velocity:
\( x = x_0 + vt \)
Motion at constant acceleration:
\( v = v_0 + at \)
- Velocity is the gradient of a position time graph
- Acceleration is the gradient of a velocity versus time graph

Today:
Motion at constant acceleration (cont):
\( x = x_0 + v_0 t + \frac{1}{2} at^2 \)
But what causes acceleration? \( \rightarrow \) Forces
Motion with constant force and acceleration
- Newton's second law: \( F_{\text{net}} = ma \)
- Force and acceleration due to gravity

What about position at constant acceleration?
So far:
\( x = x_0 + vt \) \( (a = 0) \) \( (1) \)
\( v = v_0 + at \) \( (a = \text{constant}) \) \( (2) \)
From (1):
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\( (\text{change in velocity}) = v - v_i = a(t_f - t_i) \)
\( \Rightarrow x = x_0 + v_0 t + \frac{1}{2} at^2 \) \( (4) \)
Substitute (4) into (3)
\( x = x_0 + (v_0 + \frac{1}{2} at)t \)
Position at constant acceleration

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

where:
- \( x(t) \) is your position at time \( t \)
- \( x_0 \) is where you started,
- \( v_0 \) is how fast and in what direction you started going,
- \( a \) is how fast and in what direction you’re accelerating,
- \( t \) is how long you have been going.

A car accelerates at a steady rate from stationary along a straight road. Sketch position, velocity and acceleration as a function of time.

Motion down a ramp 1 (with forces!)

Sketch position, velocity and acceleration vs. time graphs for the car moving away from the motion detector and speeding up at a steady rate.

Hints:
- The origin is always at the motion detector
- \( a \) is slope of \( v \) vs \( t \)
- \( v \) is slope of \( x \) vs \( t \)

Force

- Force is a VECTOR
- Units: Newton (N)
- \( 1N = 1kg \times 1m/s^2 \)
- Net force on object = Vector sum of all forces acting on object
- N2: \( F_{\text{net}} = ma \)

Motion down a ramp (with forces!)

What causes the acceleration down the track?

The net force on the car

\[ F_{\text{net}} = ma \]

(Newton’s second Law of motion)

- Force and Acceleration are vectors, mass is a scalar
- Acceleration is always in same direction as net force
- Force is pointing in positive direction. So acceleration is also positive

Motion down a ramp 2 (with forces!)

Sketch velocity, acceleration and net force vs. time graphs for the car moving away from the motion detector and slowing down at a steady rate.
Motion down a ramp 3 (with forces!)

Start car up ramp with velocity \( v_0 \) (give it a push). Sketch velocity, acceleration and net force vs. time graphs for the motion that follows.

Motion down a ramp 4 (with forces!)

The car is released from rest and exhibits the velocity, acceleration and net force graphs given by the dashed lines. Now, add weights to the car and redo experiment. Sketch the new velocity, acceleration and net force graphs on the same axes.

Motion down a ramp 4

When weights added:
- Greater net force on car.
- More mass.
- These 2 changes cancel

\[ F_{\text{net}} = \text{mass} \times \text{acceleration} \]

\[ \text{Acceleration} = \frac{F_{\text{net}}}{\text{mass}} \]

Gravity

Force and acceleration due to gravity

Dropping stuff

I drop heavy metal ball and a hacky sack from lecture hall ceiling
a. the light ball will fall fastest and hit the ground first
b. they will fall at the same speed and hit the ground together
c. the heavy ball will fall fastest and hit the ground first.
d. neither will fall, they will stay suspended in mid air

e. they will both fall up and hit the ceiling.

Dropping stuff

\[ F_{\text{gravity}} = \text{mass} \times g \]

Where \( g = 9.8 \, \text{m/s}^2 \) (on earth)

\[ F_{\text{net}} = ma \Rightarrow a = \frac{F_{\text{net}}}{m} \]

In this case, \( F_{\text{net}} = F_{\text{gravity}} = mg \)

\[ a = \frac{mg}{m} = g \]

\[ a = 9.8 \, \text{m/s}^2 \] for both hacky sack and metal ball!

Acceleration due to gravity is independent of mass!

\[ v = v_0 + at \]

\[ s = s_0 + \frac{1}{2} at^2 \]
The leaning tower

Question: Relating position, velocity and acceleration
Toss a basketball straight up in air with initial velocity $v_0$.
Plot position, velocity and acceleration vs time.

If I drop the basketball off a tall building, what will the ball's the velocity be after 0.5 s (define up as positive direction):
a. 1 m/s  b. 9.8 m/s  c. -9.8 m/s
d. Not enough information given to determine  e. -4.9 m/s

Common confusion: Weight and Mass......
Mass is a measure of how much stuff an object has
Units: kg (old fashioned units = lb)

Force = mass X acceleration
Units: Newton (N).
1 kg X 1 m/s$^2$ = 1N

Weight = force of gravity on an object of mass m
Measured in N NOT kg or lb
kg and lb are units of mass

The acceleration due to gravity on the Moon is less than it is on Earth.
Suppose $m_E$ = your mass on Earth
$m_M$ = your mass on the Moon
$w_E$ = your weight on Earth
$w_M$ = your weight on the Moon.

Which statement is correct?
a) $m_E > m_M$, $w_E > w_M$
b) $m_E = m_M$, $w_E = w_M$
c) $m_E > m_M$, $w_E = w_M$
d) $m_E > m_M$, $w_E > w_M$
e) None of these