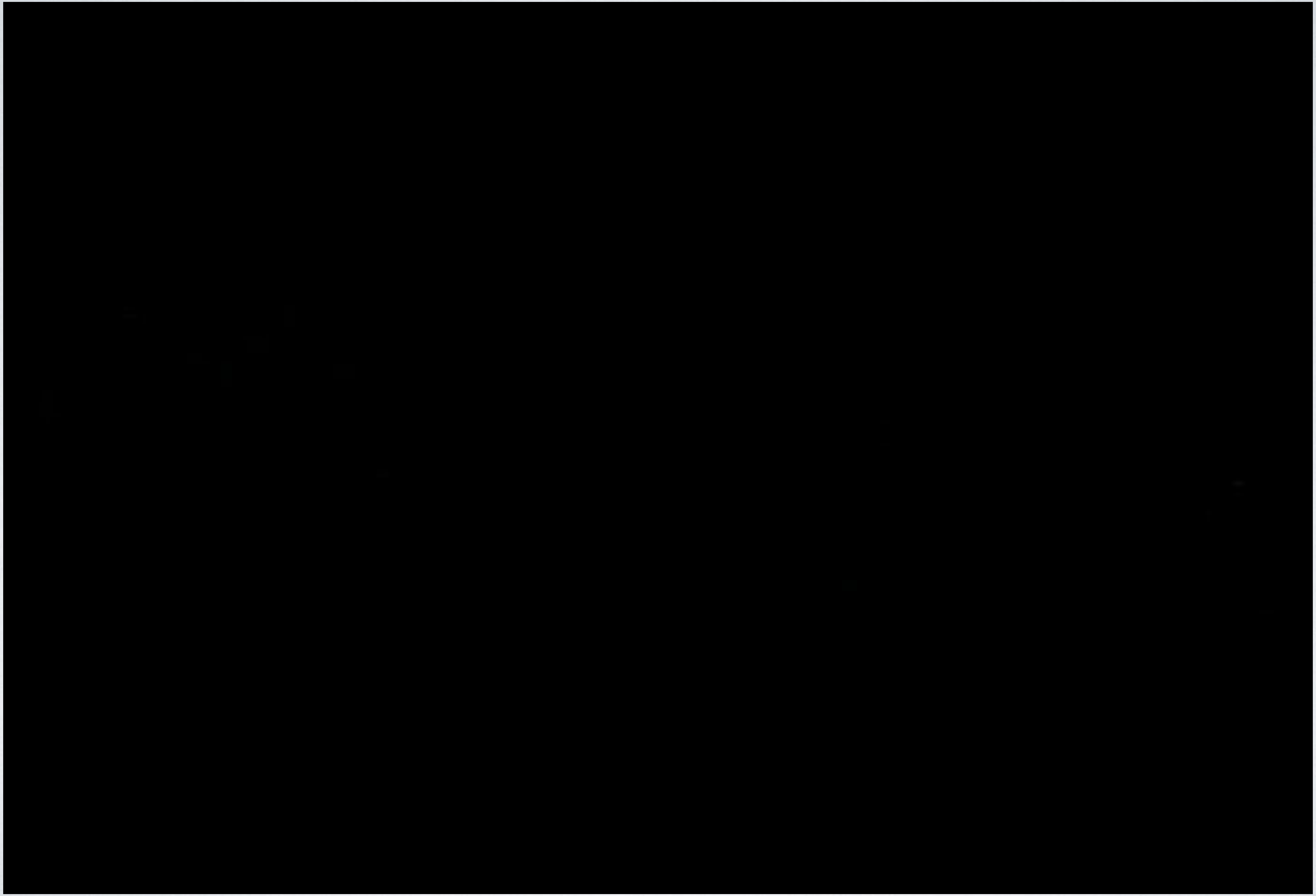
KINEMATICS

Chapter 2



How fast is the imperial cruiser traveling?

It takes about 20s for the imperial cruiser to enter the screen.

You can find online that the length of the cruiser is 1600m.

So the speed of the cruiser is 1600m/20s = 80m/s.

$$80\text{m/s} \times 1\text{km}/1000\text{m} \times 3600\text{s}/1\text{hr} = 288\ \text{km/hr}$$

179 mph

DISPLACEMENT

Kinematics is the study of motion. To start we will only consider motion in one dimension. Soon we will add a second dimension.

In one dimension we can describe the position of our object on some coordinate x. If an object starts initially at some point x_0 and ends up finally at x_f, we say the displacement Δx is given by

$$\Delta x = x_f - x_0$$

We will use the Δ symbol to denote a change in some quantity. Displacement has a direction as well as a magnitude. +2m is usually to the right while -2m is to the left.

VELOCITY

- The velocity of an object is its displacement divided by the time it takes to move from one point to the other. If we measure the time at each location this will be a change in time,

$$\Delta t = t_f - t_0$$

- The average velocity is therefore

$$v = \frac{\Delta x}{\Delta t} = \frac{x_f - x_0}{t_f - t_0}$$

- If Δt is very small we call this the instantaneous velocity. Formally it has to be infinitely small, but that is calculus. Very small is usually the same.

COORDINATE SYSTEMS

- When we talk about displacement and time we will have to make a choice about where 0 is and for displacement which way the x is pointing.

- Often there are obvious choices, but sometimes people will make different choices. This is okay, as long as one stays consistent your answer will be the same no matter what you choose.

- However, the numbers people use before their final answer can be different. If you are comparing with someone who has different numbers check where you assumed to be $x=0$ and $t=0$, and the direction of x, these are your coordinate system.

RUSH (2013)

What's different about the motion in this clip than the first one?

The car goes from 30 to 65 in about 1 second.

Likely it is a European car so we can assume the speedometer is in kilometers per hour.

So thats a change in velocity of 35 km/hr or

$35\ \text{km/hr} \times 1000\text{m/km} \times 1\text{hr}/3600\text{s} = 9.72\text{m/s}$

So that's an acceleration of $9.72\text{m/s} / 1\text{s} = 9.72\ \text{m/s}^2$.

ACCELERATION

- The rate at which velocity changes is called acceleration.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$$

- Note that the times refer to when you measure the instantaneous velocities. The times used to measure those velocities should be very close together.

- Like velocity, there is average and instantaneous acceleration. Ideally for instantaneous acceleration Δt is infinitely small.

EXAMPLE 2.1

- A racehorse coming out of the gate accelerates from rest to a velocity of 15.0 m/s due west in 1.80 s. What is its average acceleration?

- First we have to decide where are coordinate go. Usually we draw x to the right and west to the left, so this would be in the negative x direction. We can take the start of the race as t=0. Then

$v_0 = 0$
$v_f = -15.0$ m/s
$\Delta t = 1.8$s

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0} = \frac{-15.0\, m/s}{1.8\, s} = -8.33\, m/s^2$$

Deceleration always refers to acceleration in the direction opposite to the direction of the velocity. Deceleration always reduces speed. Negative acceleration, however, is acceleration in the negative direction in the chosen coordinate system. Negative acceleration may or may not be deceleration, and deceleration may or may not be considered negative acceleration. For example, consider the figure,

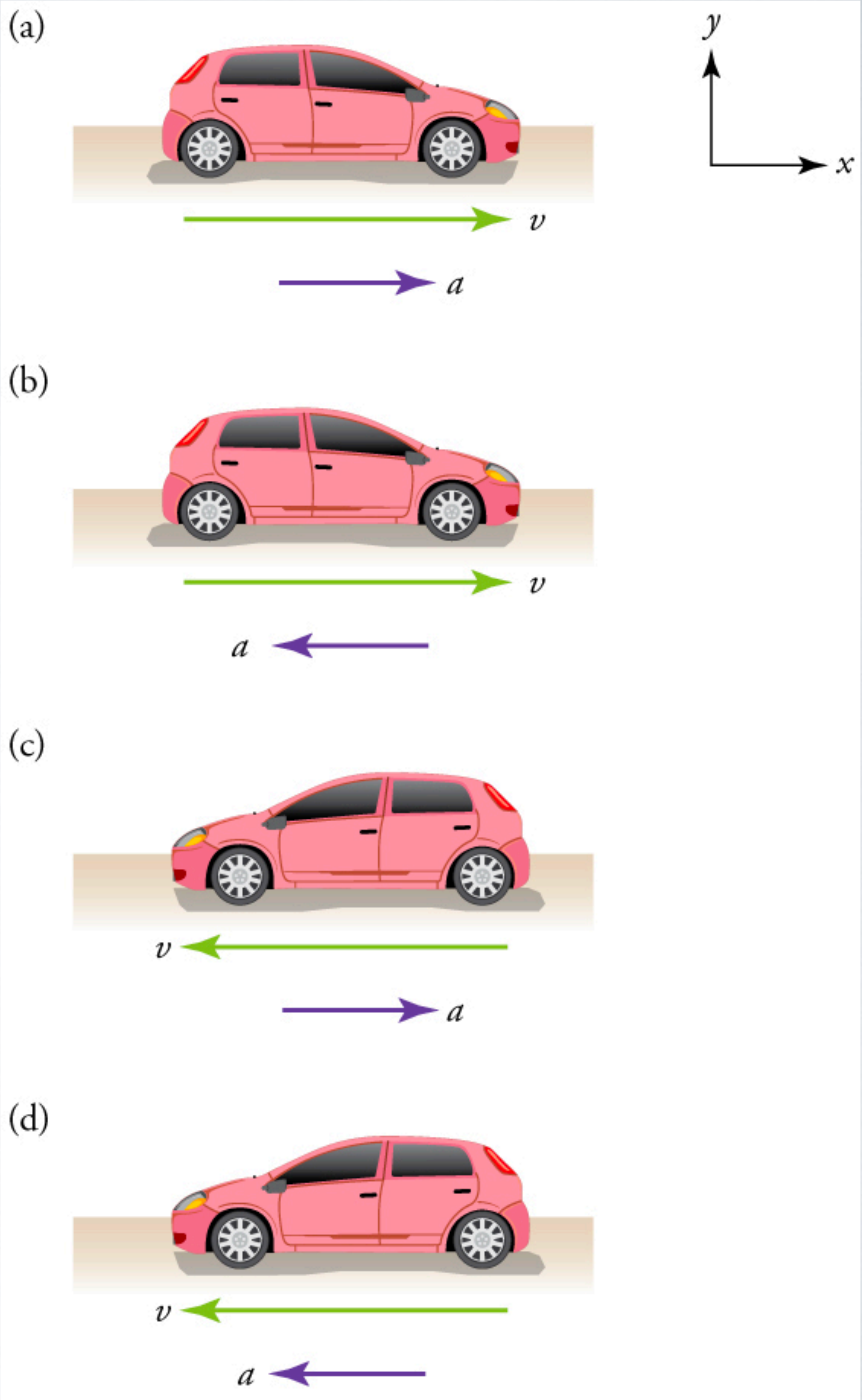
a) acceleration, positive direction

b) deceleration, negative direction

c) deceleration, positive direction

d) acceleration, negative direction

https://phet.colorado.edu/en/simulations/moving-man



CONSTANT ACCELERATION

- Why in principle we can also calculate the rate of change of acceleration and the rate of change of that, we usually stop with acceleration.
- One reason for that is because in many situations acceleration is constant, so its rate of change is zero. In these cases we write down equations of motion for our object.

CONSTANT ACCELERATION

if acceleration is constant then

$$a = \frac{\Delta v}{\Delta t} \quad \text{implies} \quad \Delta v = a\Delta t$$

if we simplify by starting time at 0 so $\Delta t = t$ we have

$$v(t) = v_0 + at$$

in addition for constant acceleration we know

$$\bar{v} = \frac{v(t) + v_0}{2}$$

CONSTANT ACCELERATION

likewise from our definition of velocity we know

average velocity $$\bar{v} = \frac{\Delta x}{\Delta t} \to x(t) - x_0 = \bar{v}t \to x(t) = x_0 + \bar{v}t$$

we can rewrite the average velocity as

$$\bar{v} = \frac{v(t) + v_0}{2} = v_0 + \frac{1}{2}at$$

so the position can be written as

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

CONSTANT ACCELERATION

We get 4 formula

$$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v(t) = v_0 + at$$

replacing t and some algebra gives

$$v^2(t) = v_0^2 + 2a(x - x_0)$$

$$\bar{v} = \frac{v(t) + v_0}{2}$$

EXAMPLE 2.9

- An airplane lands with an initial velocity of 70.0 m/s and then decelerates at 1.50 m/s^2 for 40.0 s. What is its final velocity?

v_0 = 70.0 m/s
a = -1.50 m/s^2
t = 40.0 s

x_0

$$v = v_0 + at \;\; = 70.0m/s + (-1.50m/s^2)(40s) = \boxed{10.0m/s}$$

EXAMPLE 2.10

- Dragsters can achieve average accelerations of 26.0 m/s^2. Suppose such a dragster accelerates from rest at this rate for 5.56 s. How far does it travel in this time?

a = 26.0 m/s^2
t = 5.56s
x = ?

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

$$x = \frac{1}{2}at^2 = 0.5(26.0m/s^2)(5.56s)^2 = \boxed{402m}$$

EXAMPLE 2.11

- Calculate the final velocity of the dragster in Example 2.10 without using information about time.

a = 26.0 m/s^2

x = 402m

v = ?

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$v = \sqrt{2a(x - x_0)} = \sqrt{2(26.0m/s^2)(402m)} = \boxed{145m/s}$$

SOLVING PROBLEMS

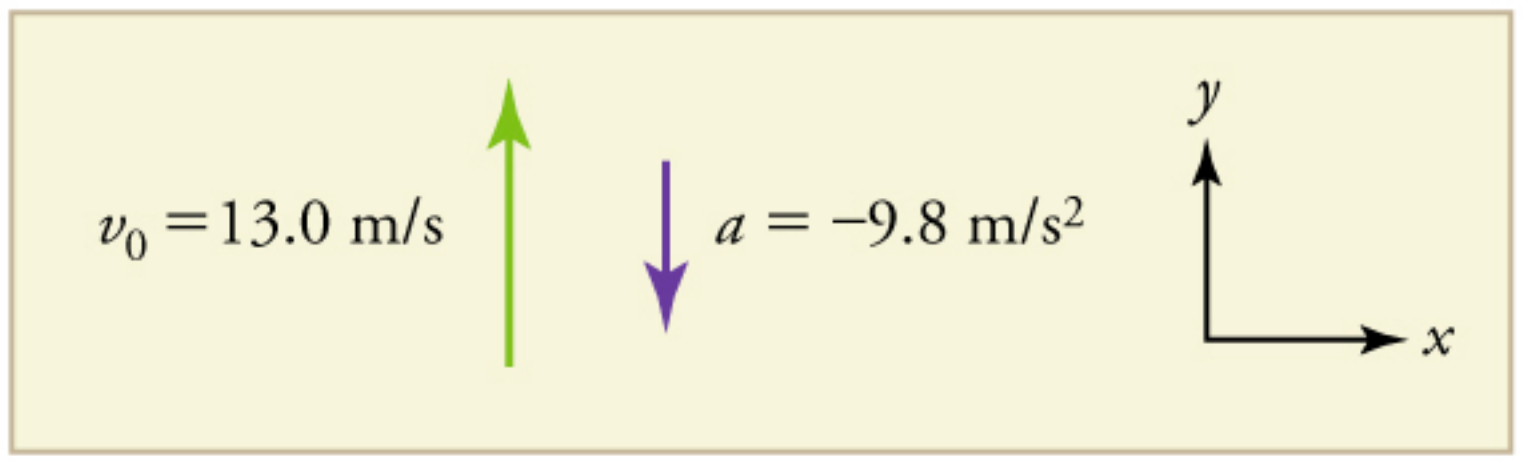
- Draw a Picture
- List what you are given.
- Determine what you are supposed to find.
- Think about the physics that describe the situation
- Find any relevant equations.
- Solve for your unknown.
- Plug in the numbers.
- Estimate the answer and check the units.

FREE FALL

- One of the most common examples of constant acceleration is free fall.
- Galileo discovered this with his famous experiment dropping two different mass objects from a height.
- He observed they reached the ground at the same time, thus they must be accelerating at the same rate.
- On the surface of the Earth this constant is given the symbol g and is equal to 9.81 m/s^2.

EXAMPLE 2.14

- A person standing on the edge of a high cliff throws a rock straight up with an initial velocity of 13.0 m/s. The rock misses the edge of the cliff as it falls back to earth. Calculate the position and velocity of the rock 1.00 s, 2.00 s, and 3.00 s after it is thrown, neglecting the effects of air resistance.



v_0 = 13.0 m/s

a = -g = 9.81 m/s^2

t = 1,2,3 s

$$y = y_0 + v_0 t + \frac{1}{2} a t^2$$

$$y = v_0 t - \frac{1}{2} g t^2$$

$$v = v_0 + at = v_0 - gt$$

$$v(1s) = 13.0 m/s - (9.8 m/s^2)(1s) = 3.20 m/s$$

$$y(1s) = (13.0 m/s)(1s) - 0.5(9.8 m/s^2)(1s)^2 = 8.10 m$$

$$y(2s) = 6.40 m \quad y(3s) = -5.10 m$$

$$v(2s) = -6.60 m/s \quad v(3s) = -16.40 m/s$$

HOME WORK

- Chap 2 - 7, 9, 16, 18, 25, 31, 46, 47