Tuesday January 21

- Assignment 2 – Due Friday by 11:59pm
- Help Room: W/Th 6-9PM - Walter 245
- Lab Next week: *Reminders*
  - ***No Open-toed shoes; No food or drinks***
  - **Print lab writeup & bring to lab**
  - Do pre-lab. Bring a calculator & ruler.

- Office Hours: Tues 11am - Noon
  - Edwards Accelerator Lab room 204
  - Or by appointment (meisel@ohio.edu)
- SI: Mon & Tues 5:20-6:10pm, Morton

Today:
- Constant acceleration
- Interpreting problems
- Free-fall

1D, *a*=constant Eqns:

1. $x = x_o + \bar{v}t$
2. $\bar{v} = \frac{v_0+v}{2}$
3. $v = v_0 + at$
4. $x = x_0 + v_o t + (½)at^2$
5. $v^2 = v_0^2 + 2a(x - x_0)$

- *Write these equations in your notes if they're not already there.*
- *<u>You will need them for class today</u>.*
- *You will want them for Exam 1 & the Final.*

last time on PHYS2001...

Problem Solving Example: Plane Landing

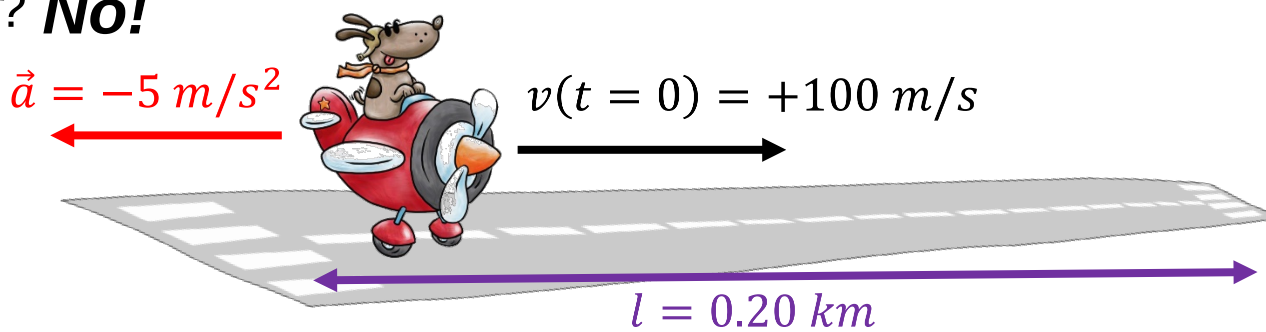
Sect 2.5

A jet plane lands with a velocity of +100m/s and with full brakes on can accelerate at a rate of -5.0m/s^2.

a) From the instant it touches the runway, what is the minimum time needed before it can come to rest?

b) Can this plane land on a small island airport where the runway is 0.2km long? ***No!***

1. Read
2. Draw
3. Know?
4. Processes
5. Formulas
6. Solve
7. Reasonable?



- 1D-kinematics, constant acceleration
- (a) $v = v_0 + at$
- (b) $v^2 = v_0^2 + 2a(x - x_0)$

a) $v = v_0 + at = \left(+100\frac{m}{s}\right) + \left(-5.0\frac{m}{s^2}\right)t = 0 \;\rightarrow\; t = \left({}^{-100m/s}\!/_{-5m/s^2}\right) = 20\ s$

b) $v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; (0\ m/s)^2 = (100\ m/s)^2 + 2(-5\frac{m}{s^2})(x - 0\ m)$

$\rightarrow\; 0\frac{m^2}{s^2} = 10000\frac{m^2}{s^2} - (10\frac{m}{s^2})\ x \;\rightarrow\; \mathrm{x} = \left(-10^4\frac{m^2}{s^2}\right) / \left(-10\frac{m}{s^2}\right) = 1000m = 1km$

Problem Solving Example: Accelerating Car

A car accelerates uniformly from rest to a speed of 25 m/s in 8.0s.

Find the distance the car travels in this time and the constant acceleration of the car. Define the +x direction to be in the direction of motion of the car.

1D, *a*=constant Eqns:

1. $x = x_o + \bar{v}t$
2. $\bar{v} = \frac{v_0+v}{2}$
3. $v = v_0 + at$
4. $x = x_0 + v_o t + (½)at^2$
5. $v^2 = v_0^2 + 2a(x - x_0)$

What do we know?

- "Accelerates uniformly": a = constant
- "from rest": $v_i = v(t{=}0) = 0$ m/s
- "to a speed of 25 m/s in 8 s": $v_f = v(t{=}8\text{s}) = 25$ m/s

What do we want to know?

- "Find the distance": $x_f - x_i$ = ? (say x_i=0, so x_f = ?)
- Find "the acceleration": a = ?

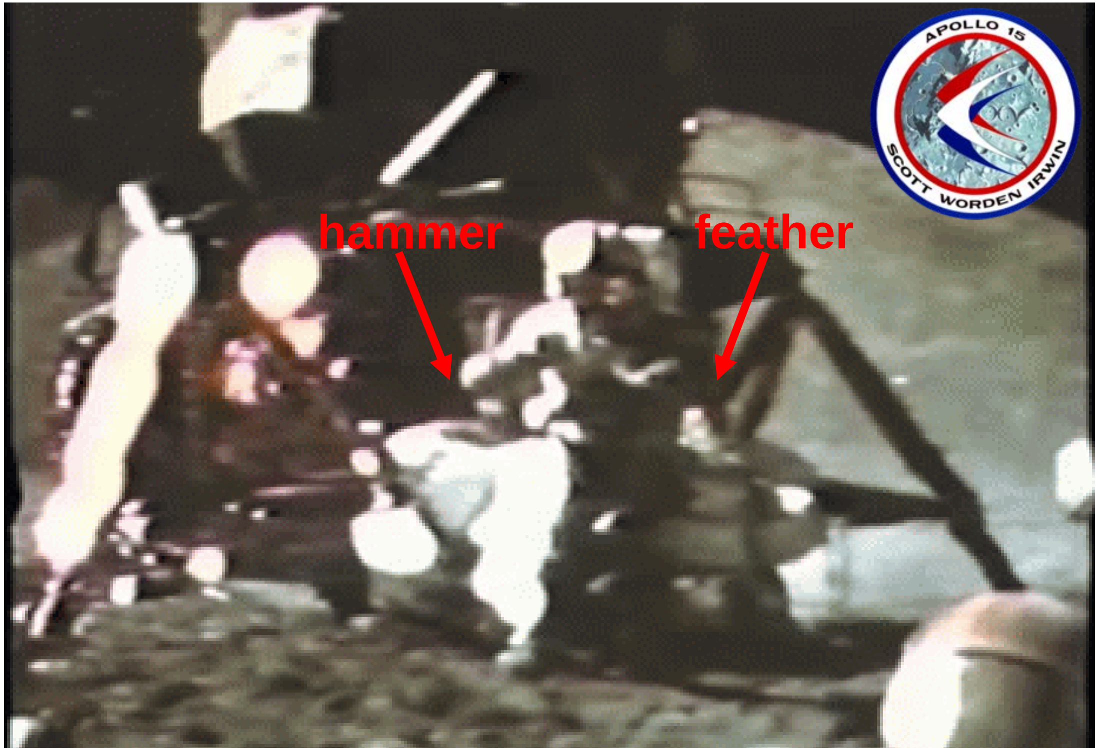
Which equations are useful?:

- Eqn. 1 gives distance …but need to combine with 2 to get average velocity
- Eqn. 3 gives the acceleration if you know the initial and final velocities

Solutions:

1. $x - x_0 = \bar{v}t = 0.5\left(0\,\frac{m}{s} + 25\,\frac{m}{s}\right)(8\ s) = 100\ m$
2. $a = \frac{(v-v_0)}{t} = \left(25\,\frac{m}{s} - 0\,\frac{m}{s}\right)\frac{1}{(8\ s)} = 3.1\ m/s^2$

Constant Acceleration Example: Gravity



see: https://www.youtube.com/watch?v=-4_rceVPVSY

see: https://www.youtube.com/watch?v=oBdalzRJR5g

An object's mass does <u>not</u> affect the rate it speeds up in free-fall.

Free Fall on Earth:

An object starting from rest accelerates at a rate of $9.80 m/s^2$.
How much time does it take to travel 20.0 m?

(A) 0.520s (B) 1.02s (C) 1.43s (D) 2.02s
(E) 23.71s (F) 4.08s (G) 6.28s (H) 9.80s

Know:

$x_0 = 0$ m
$x = 20.0$m
$v_0 = 0$
$a = 9.8 m/s^2$

Want :

$t = ?$

Useful Equation(s):

$x = x_0 + v_0 t + (1/2)at^2$

Solve:

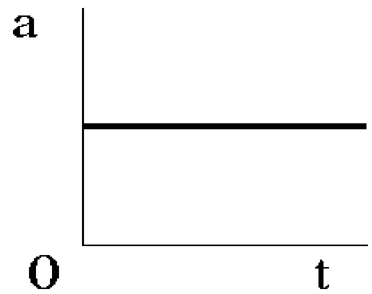
1. $x = x_0 + v_0 t + (1/2)at^2$
2. $20m = 0 + 0*t + (1/2)(9.8 m/s^2)(t^2)$
3. $20m = (4.9 m/s^2)(t^2)$
4. $t^2 = (20m)/(4.9 m/s^2) = 4.08 s^2$
5. $t = \sqrt{4.08 s^2} = 2.02$ s

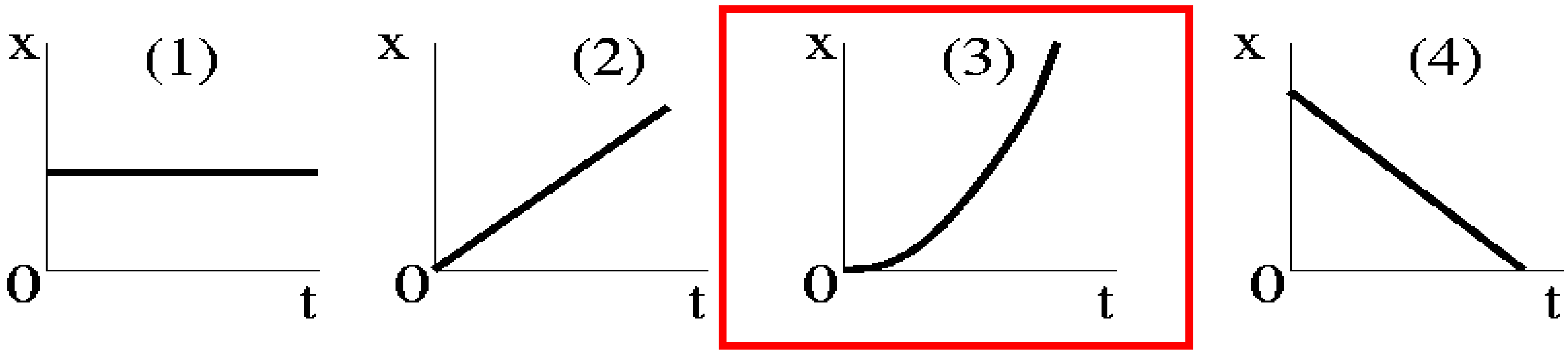
Is this reasonable?:

1D, a=constant Eqns:

1. $x = x_o + \bar{v}t$
2. $\bar{v} = \frac{v_0 + v}{2}$
3. $v = v_0 + at$
4. $x = x_0 + v_o t + (½)at^2$
5. $v^2 = v_0^2 + 2a(x - x_0)$

Which displacement plot corresponds to this acceleration plot?





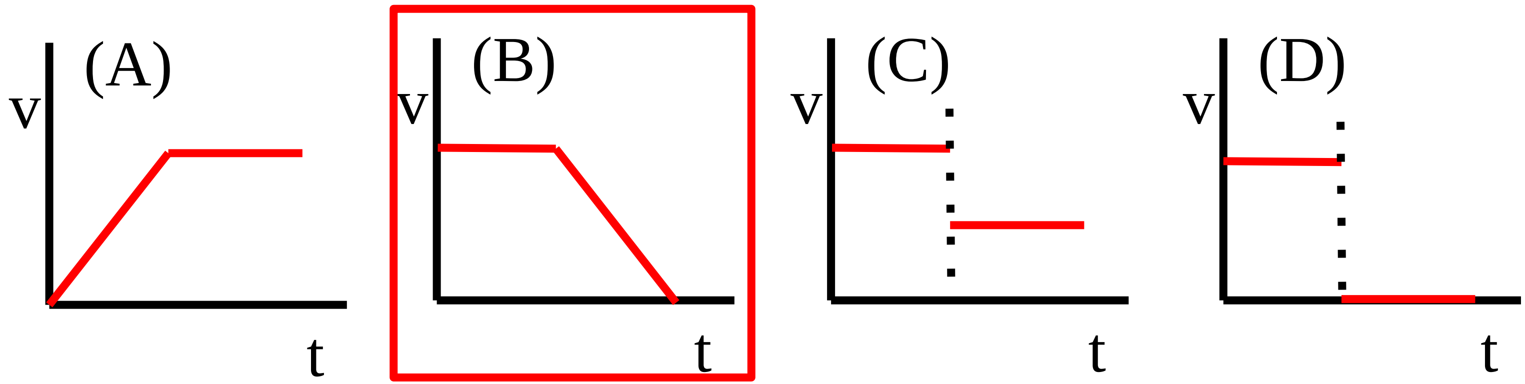
When x vs t function curves upward → positive acceleration.

When x vs t function curves downward → negative acceleration.

If it curves over shorter time → greater acceleration.

Constant Acceleration Example: Deer in the Road

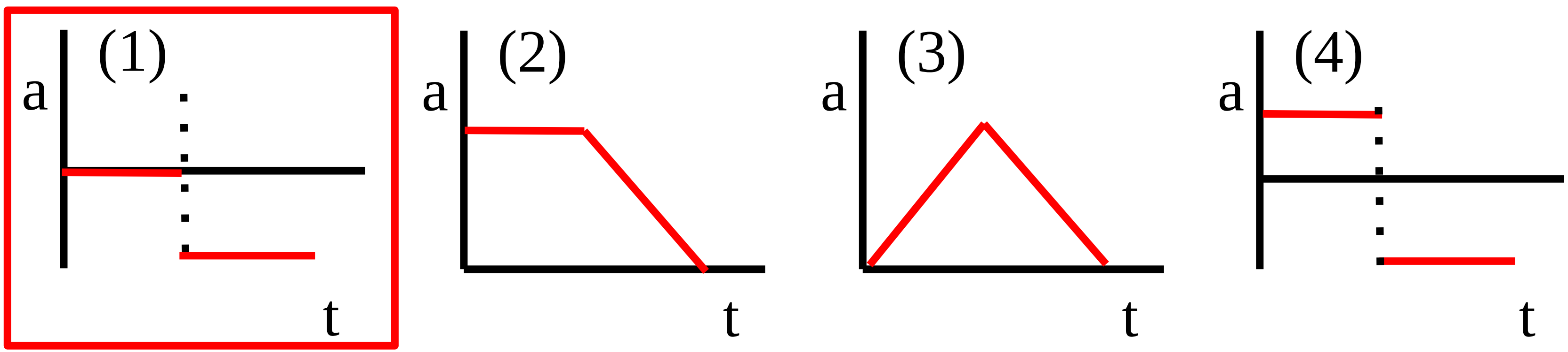
You are driving home at night along US-50 traveling at a constant speed when a deer jumps out in the road ahead. The deer freezes in your headlights. After a certain reaction time, you apply the brakes and eventually come to a stop. Which graph best represents your speed as a function of time?



Constant Acceleration Example: Deer in the Road

You are driving home at night along US-50 traveling at a constant speed when a deer jumps out in the road ahead. The deer freezes in your headlights. After a certain reaction time, you apply the brakes and eventually come to a stop.

Which graph best represents the acceleration from the time you see the deer until the point when you come to a stop?



Acceleration: More advanced example

You are driving home at night along US-50 traveling at 30m/s when a deer jumps out in the road 150m ahead. The deer freezes in your headlights.

After a reaction time of t, you apply the brakes to produce a constant acceleration of -4.0m/s^2.

What is the maximum reaction time allowed in order to not hit the deer?

The acceleration changes! (Moving uniformly, then slamming on the brakes)

→ Must break into 2 problems, each one with constant acceleration:

1. How far does the car travel after we've hit the brake?

   $v^2 = v_0^2 + 2a(x - x_0)$ → (0m/s)^2 = (30m/s)^2 + 2(-4m/s^2)(x-0)

   → x = 112.5m, after hitting the brake

2. How much distance is remaining from the 150m stopping distance?

   150m - 112.5m = 37.5 m

   How long would it take to travel this distance moving at 30m/s?

   v = 30m/s = Δx/Δt = (37.5m)/(Δt) → Δt = (37.5m)/(30m/s) = 1.25s

Free-Fall: Constant acceleration due to gravity

Sect 2.6

- If we can ignore air resistance and other forces besides gravity:
  - All objects speed up at same rate when falling
  - Which means, the acceleration is the same
- Acceleration from gravity = g = 9.80 m/s^2 downward
  - (Sign applied after define coordinates)
- g, a.k.a "Little g", is fairly constant at Earth's surface.
  - This depends predominantly on distance from center of Earth and mass of Earth

  - For a very different g: Need dramatically different altitude, different planet
- Free-fall implies there is a constant force (gravity) and therefore a constant acceleration, which is straight up/down …so can use 1D kinematic equations
- *Free-fall means gravity is the only force acting on the object*.
- Important to note that an object can be traveling upward and be in "free-fall"

An object is tossed into the air (assume +y is upwards).
Which plot best represents the velocity vs time graph for the motion of this object in free-fall (i.e. just after it is tossed)?
Note that speed & direction matter for “velocity”.

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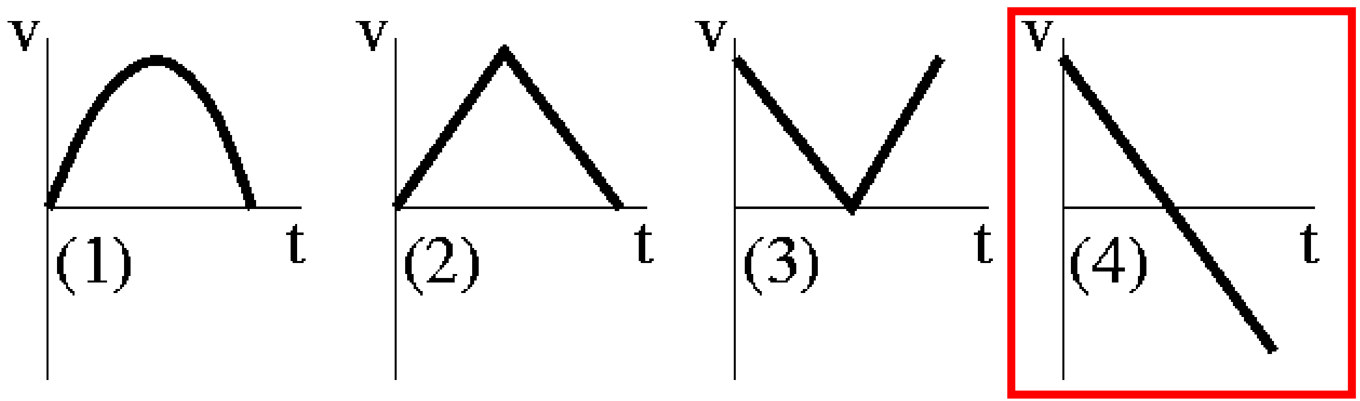


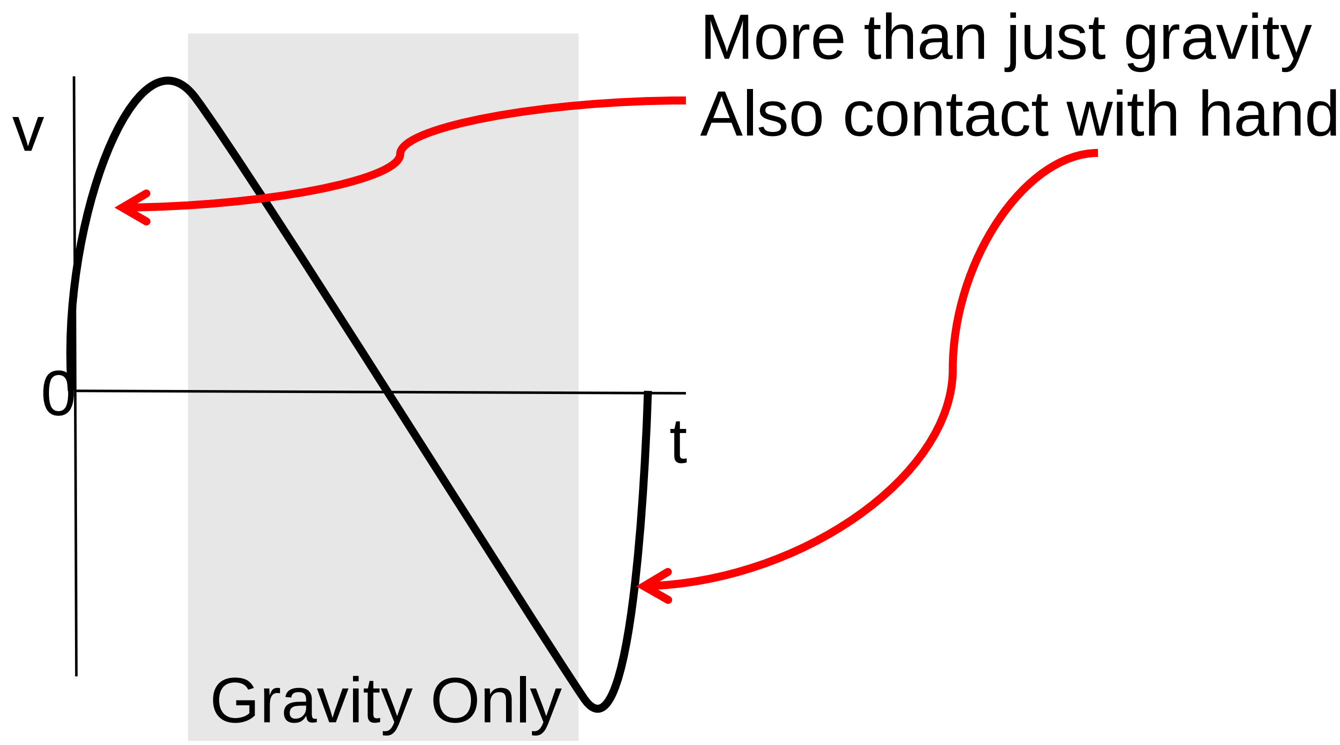
Velocity starts upward (+), then transitions to downward (-).

Velocity is vector, will have direction (in 1-d represented by sign).

Free-fall = Constant acceleration = fixed slope for velocity vs time

Notice when throwing an object, we will often say “Just after leaves hand” / “Just before hits hand”. Why?

If we plot velocity from rest in hand, throw, then land in hand ...



Free-fall means <u>gravity is the only force</u> acting on the object.

An object is tossed into the air. Consider the direction of acceleration as the object is traveling upward and as it is traveling downward. Which of the following statements is true?

1. acceleration is upward when object is traveling up; downward when traveling down
2. acceleration is downward when object is traveling up; downward when traveling down
3. acceleration is upward when object is traveling up; upward when traveling down
4. acceleration is downward when object is traveling up; upward when traveling down

The force due to gravity does not change directions.

An object is tossed into the air. Consider the velocity and acceleration at the point when the object reaches its maximum height. Which of the following statements is true?

A. the velocity is zero and the acceleration is zero

B. the velocity is non-zero and the acceleration is zero

C. the velocity is zero and the acceleration is non-zero

D. the velocity is non-zero and the acceleration is non-zero

- At maximum height, the velocity is momentarily zero
  ….however, it is constantly changing.
- Gravity doesn’t “turn-off”. For free-fall: a = constant = g

An object is dropped from the roof of a building that is 20m tall. How fast is the object traveling just before it hits the ground?

<u>What do we know?</u>

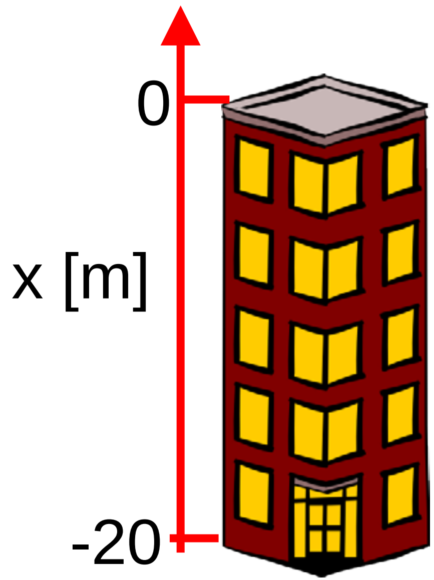
- "Dropped": $v_i = v(t{=}0) = 0$ m/s
- "Dropped": $a = g = -9.80$ m/s^2 (on Earth)
- "from … 20m tall": $x_i = x(t{=}0) = 0$m
  $x_f = x(t_{final}) = -20$m

<u>1D, *a*=constant Eqns:</u>

1. $x = x_o + \bar{v}t$
2. $\bar{v} = \frac{v_0+v}{2}$
3. $v = v_0 + at$
4. $x = x_0 + v_o t + (½)at^2$
5. $v^2 = v_0^2 + 2a(x - x_0)$

<u>What do we want to know?</u>

- "How fast … just before it hits": $v_f = ?$



<u>Pick a coordinate convention & identify suitable equation(s):</u>

- Choose +x as upward (so the value for *g* is negative)
- Note that, we want to know *v*, we know x-x_0 and v_0
  … so Eqn 5 looks promising

<u>Solution:</u>

1. $v^2 = v_0^2 + 2a(x - x_0) = 0m/s^2 + 2\left(-9.8\frac{m}{s^2}\right)(-20m - 0m)$
   $\rightarrow v = 19.8m/s$

An object is dropped from the roof of Building A.
It hits the ground after 3 seconds.
The same object is dropped from Building B and takes 6 seconds to hit the ground. The height of building B is ____ times the height of Building A.
(Ignore air resistance.)

(A) ¼ (B) ½ (C) 1 (D) 2 (E) 4

Know *a* is constant and we know *t*.
Want to compare *height* = x-x_0.
.... Equation 4 looks like it can do the job.

$$x = x_0 + v_o t + (½)at^2$$
$$= 0m + \left(0\frac{m}{s}\right)t + \frac{1}{2}at^2$$
$$= \frac{1}{2}at^2$$

So, if we double *t*, then *x* becomes four times as large.

1D, *a*=constant Eqns:
1. $x = x_o + \bar{v}t$
2. $\bar{v} = \frac{v_0+v}{2}$
3. $v = v_0 + at$
4. $x = x_0 + v_o t + (½)at^2$
5. $v^2 = v_0^2 + 2a(x - x_0)$

Things to note when interpreting questions:

- “Uniform” = constant.   “Uniform motion” = constant velocity
- “Max Height” = velocity is zero at that point (for free-fall)
- “From rest” = initial velocity is zero
- “Just before”/“just after”: only under the influence of gravity for free-fall problems

- Examine examples in textbook & notes.
- Generally the different examples in the text will highlight different aspects of a type of problem.

An object is thrown up into the air at a speed of 25 m/s. How high does the object travel?

1D, *a*=constant Eqns:

1. $y = y_o + \bar{v}t$
2. $\bar{v} = \frac{v_0 + v}{2}$
3. $v = v_0 + at$
4. $y = y_0 + v_o t + (½)at^2$
5. $v^2 = v_0^2 + 2a(y - y_0)$

Interpreting the Question:

- "Speed" is the magnitude of the velocity
- "Up" tells us the direction of the velocity
- "thrown up" = free-fall ($a = g = -9.80$ m/s^2)
- "How high" tells us we want maximum height
    - Note that velocity is zero at the max height

What do we know, want to know?

- v_i=25m/s, v_f = 0m/s, $a = g$ = -9.80m/s^2
- Max height = $y(v{=}0)$ = ?

Which equation should we use?

- Know v_f, v_i, and a. Want y. … so Equation #5 looks like our best bet.

Solution:

- $v^2 = v_0^2 + 2a(y - y_0)$ → (0m/s)^2 =(25m/s)^2+2.(-9.80m/s^2)(y-0m)

  → 0m^2/s^2 = 625m^2/s^2 - (19.6m/s^2)y → y = (625m^2/s^2)/(19.6m/s^2) = 31.9m