FREE-FALL

How Fast, How Far, How quickly How Fast Changes

- The confusion occurs in analyzing the motion of objects came about from mixing up “how fast” and “how far”
- When we want to specify how fast something freely falls from rest after a certain elapsed time, we are talking about speed (velocity)
  - Equation = $v = gt$
- When we want to know how far something will fall, this is distance
  - equation = $d = \frac{1}{2} gt^2$

- One of the most confusing concepts encountered is acceleration, or "how quickly does speed or velocity change"
- What makes it so complex is that it is a *rate of a rate*
- It took people 2000 years from the time of Aristotle to Galileo to achieve a clear understanding of motion

Free Fall: How Fast

- An apple falls from a tree—Does it accelerate?
- We know it starts from rest and gains speed as it falls
  - Because—it would be safe to catch if it fell from a few meters, but not if it fell from a high flying balloon
- Thus, the apple must gain more speed during the time it drops from a great height than during the shorter time it takes to drop a meter

- Gravity causes the apple to accelerate downward once it begins falling
- In real life, air resistance affects the acceleration of a falling object
- For the time being, let's imagine there is no air resistance and that gravity is the only thing affecting a falling object
  - This is termed **free fall**

- Freely falling objects are affected only by gravity

Elapsed time (seconds)	Instantaneous Speed (m/s)
0	0
1	10
2	20
3	30
4	40
.	.
t	10t

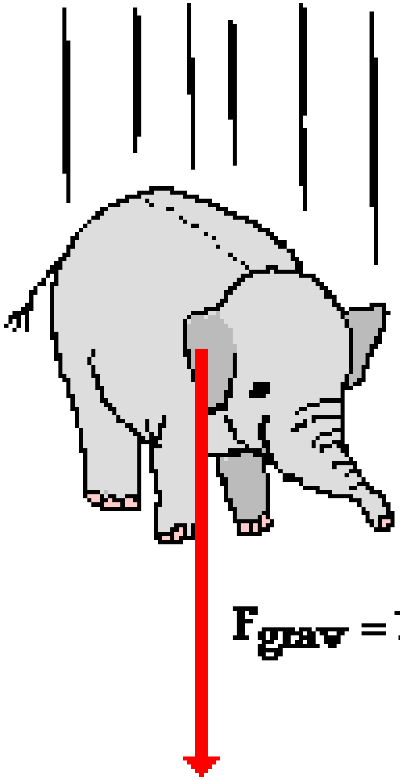
- The acceleration of an object falling under conditions where air resistance is negligible is about 10 m/s^2
- For free fall, it is customary to use the letter g to represent the acceleration because the acceleration is due to gravity
- Instantaneous speed = acceleration x elapsed time
  - $V = gt$

- What would the speedometer reading on a falling rock be 4.5 seconds after it drops from rest?
  - 45 m/s
- 8 seconds?
  - 80 m/s
- 15 seconds?
  - 150 m/s

- Now consider an object thrown straight up
- It continues to move upward for a while, then it come back down
- At the highest point, when the object is changing its direction of motion from upward to downward, its instantaneous speed is zero
- It then starts downward, just as if it was dropped from rest

- During the upward part of this motion, the object slows from its initial upward velocity to zero velocity
- We know that the object is accelerating because its velocity is changing
- How much does its speed decrease each second?
- The speed decreases at the same rate it increases when it moves downward—
  - 10 meters per second each second

$m = 1000\ kg$



$F_{grav} = 10\,000\ N$

$$a = \frac{F_{net}}{m} = \frac{10\,000\ N}{1000\ kg}$$

$a = 10\ m/s/s$

$m = 1\ kg$

$F_{grav} = 10\ N$

$$a = \frac{F_{net}}{m} = \frac{10\ N}{1\ kg}$$

$a = 10\ m/s/s$

Free-Fall: How Far

- How *fast* something moves is entirely different from how *far* it moves—speed and distance are not the same
- At the end of the 1st second, the falling object has an instantaneous speed of 10 m/s. Does this mean it falls a distance of 10 meters during the first second?

Elapsed time (seconds)	Instantaneous Speed (m/s)
0	0
1	10
2	20
3	30
4	40

- No. Here's where the difference between instantaneous and average speed comes in
- If the object falls 10 meters the first second, its *instantaneous* speed is 10 m/s at the end of the second.
- But we know the speed began at zero and took a full second to get to 10 m/s
- So the average speed is between zero and 10 m/s

- For any object moving in a straight line with constant acceleration, we find the average speed the same way we find the average of two numbers—divide by 2
- So adding the initial speed of zero and the final speed of 10 m/s and then dividing by 2, we get 5 m/s
- During the 1st second, the object has an average speed of 5 m/s

- During the span of the second time interval, the object begins at 10 m/s and ends at 20 m/s. What is the average speed of the object during this 1-second interval? What is the acceleration?
- $(10\ m/s + 20 m/s)/2 = 30 m/s/2 = 15\ m/s$
- $(20 m/s – 10 m/s)/(1 s) = 10\ m/s^2$

Elapsed Time (s)	Distances Fallen (m)
0	0
1	5
2	20
3	45
4	80
5	125
.	.
.	.
T	$1/2gt^2$

- These distances form a mathematical pattern: at the end of time t, the object has fallen a distance d of $1/2gt^2$

Time (s)	Average Velocity (m/s)
0	0
1	5
2	15
3	25
4	35
556	45

- An apple drops from a tree and hits the ground in one second. What is its speed upon striking the ground? What is its average speed during the one second? How high above ground was the apple when it first dropped?
- $V = gt = 10\ m/s^2 \times 1$ second $= 10\ m/s$
- Average $= (0 + 10 m/s)/2 = 5\ m/s$
- $d = \frac{1}{2} gt^2 = 5 m/s^2 (1 sec) = 5\ m$
- OR
- $d =$ average speed $\times\ t = 5\ m/s \times 1$ sec $= 5m$

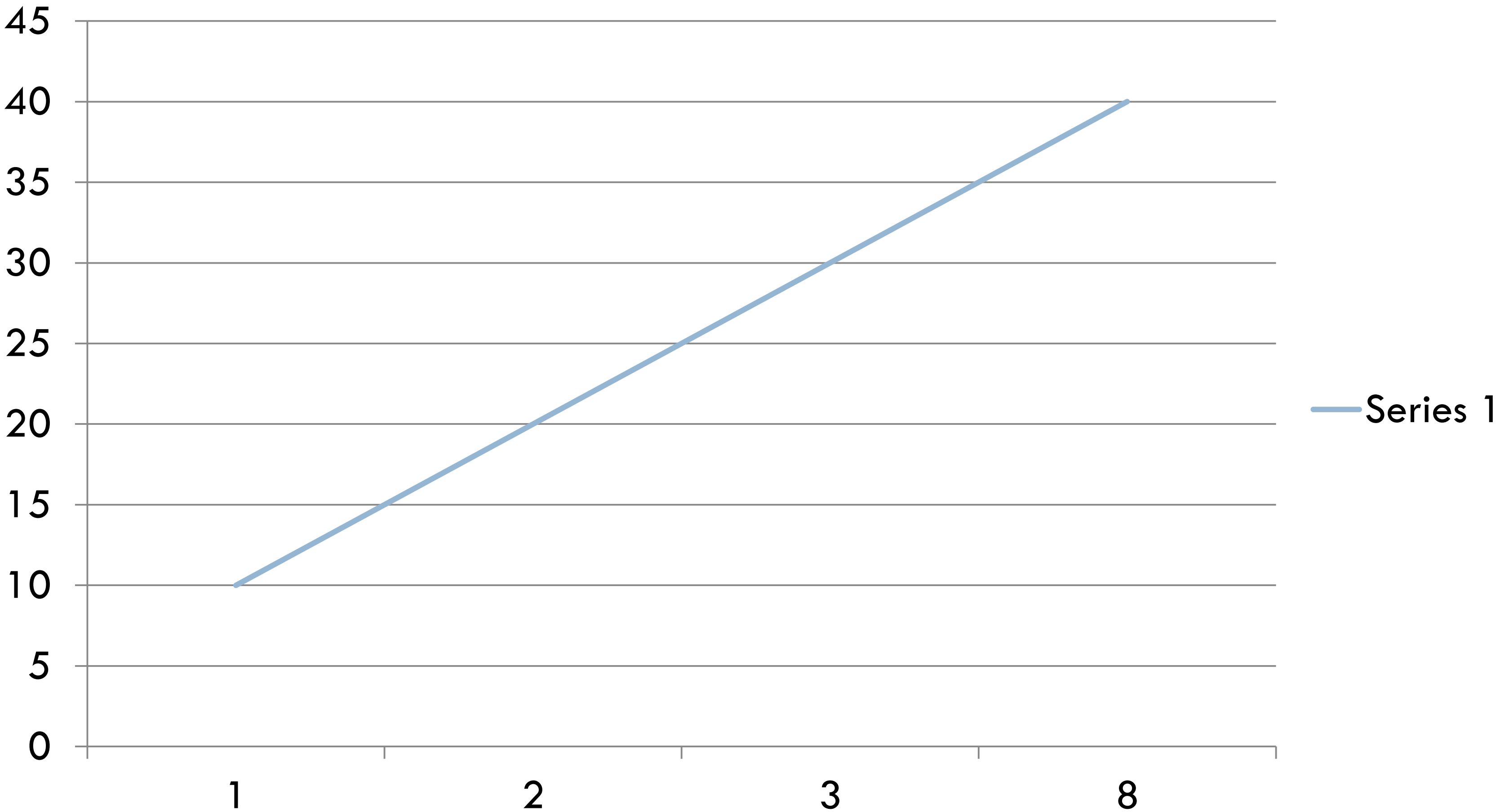
Reaction Time

- Hold a dollar bill so that the midpoint hangs between your fingers. Challenge yourself to catch it be snapping your fingers shut when someone releases it. The bill won't be caught!
- It takes at least 1/7 second for nerve impulses to travel from the eye to the brain to the fingers.
- According to the equation $d = 1/2gt^2$, in only 1/8 second the bill falls 8 centimeters—half the length of the bill

Graphs of Motion

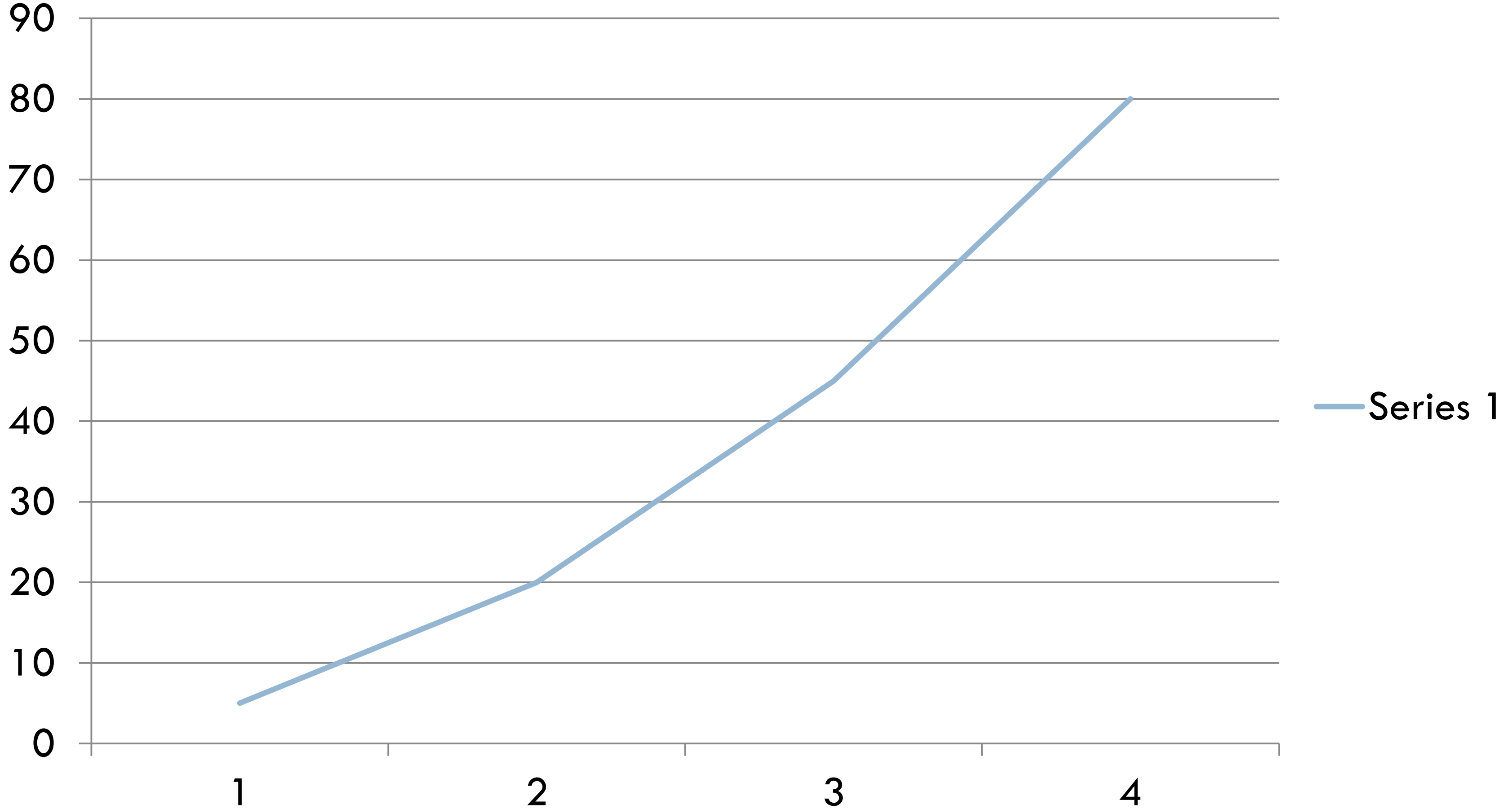
- Equations and tables are not the only way to describe relationships such as velocity and acceleration
- We use graphs that visually describe relationships

Speed v. time for a Freely Falling Object



- For every increase of 1 second, there is the same 10 m/s increase in speed
- The curve is a straight line, so its slope is constant
- On this graph the slope measures speed per time, or acceleration
- The slope indicates that the acceleration is constant
- If the acceleration were greater, the slope of the graph would be steeper

Distance v. Time for a Freely Falling Object



- The result is a curved line
- The curve shows the relationship between distance traveled and time is not linear
- When we double t, we do not double d; we quadruple it—distance depends on time squared
- A curved line also has a slope, this graph has a certain slant or steepness at every point—it changes from one point to the next
- It is speed, the rate at which distance is covered per unit of time
- In this graph the slope steepens (becomes greater) as time passes—speed increases as time passes

Air Resistance and Falling Objects

- Air resistance noticeable alters the motion of things like falling feathers or pieces of paper
- Air resistance less noticeably affects the motion of more compact objects like stones and baseballs
- In many cases the effect of air resistance is small enough to be neglected

Hang Time

- Read page 22 in your book
- Now calculate your own personal hang time