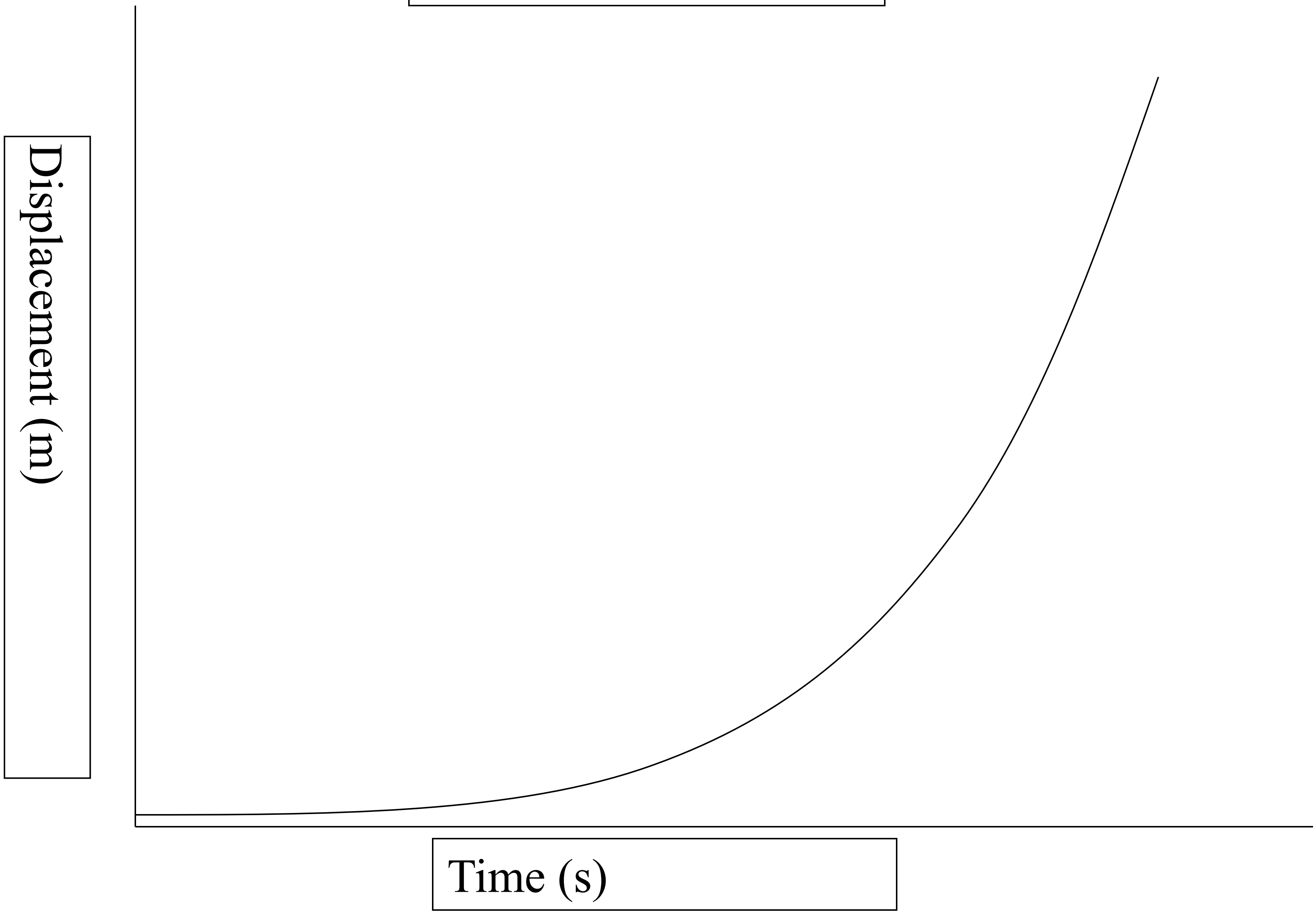
Topic 2.1: Kinematics

- How do we analyze the motion of objects?

Characteristic Graphs

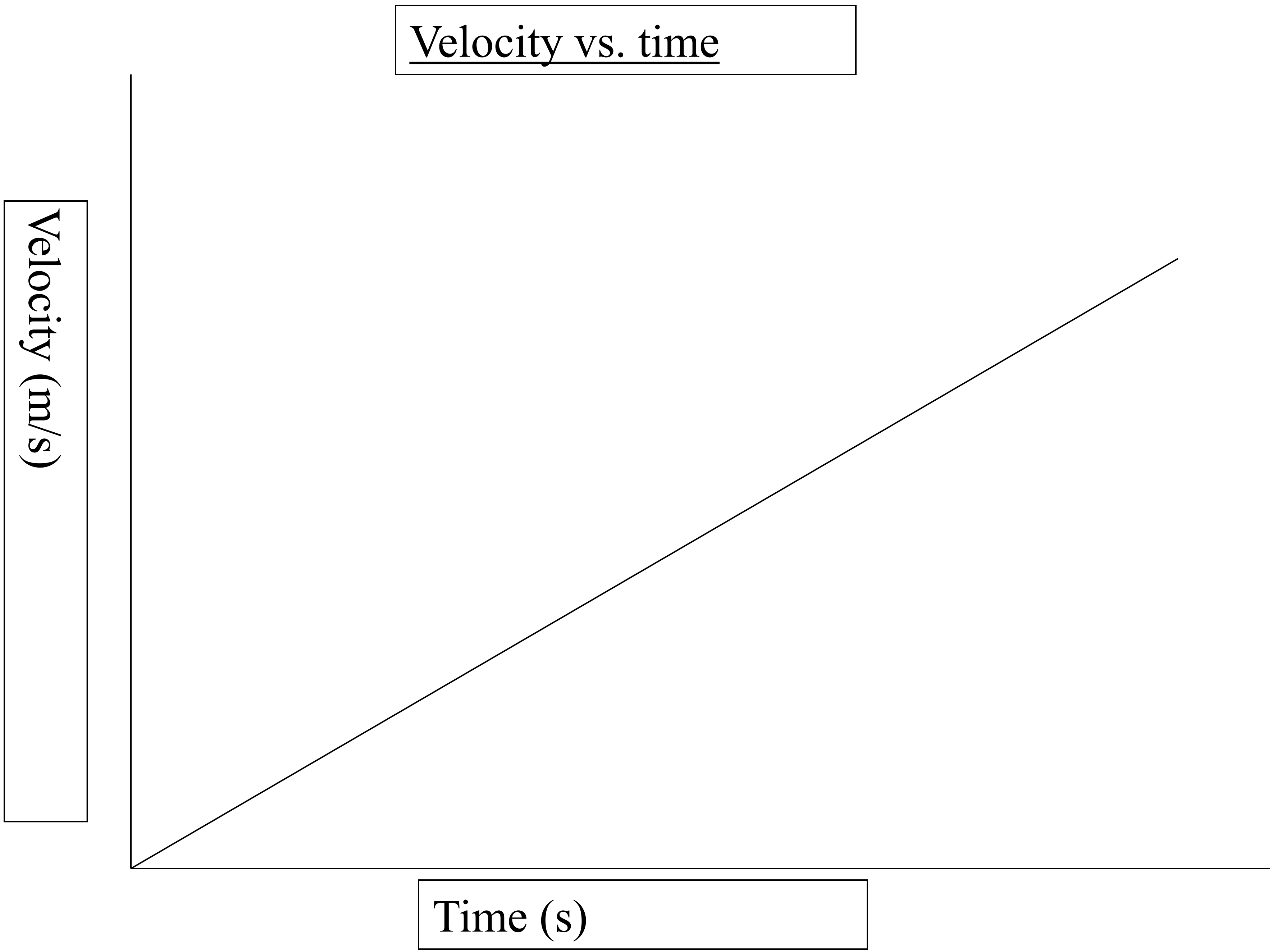
- The most common kinematics problems involve uniform acceleration from rest
- These have a characteristic shape for each of s-t, v-t, and a-t graphs

Displacement vs. time

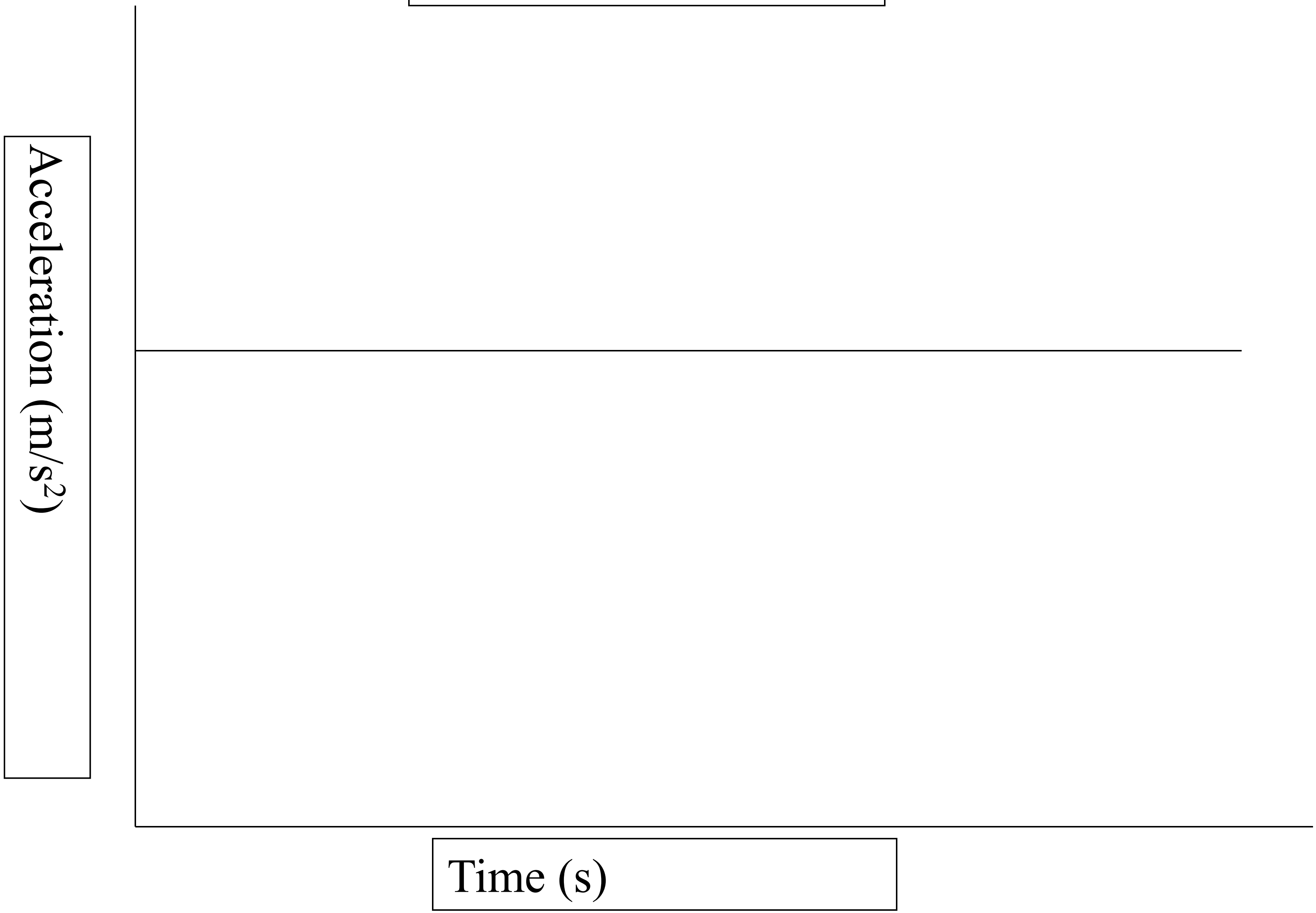


Information from Graphs

- We can get information from a graph using one of three strategies:
  - Read data directly from the graph
  - Calculate the slope
  - Calculate the area under the graph

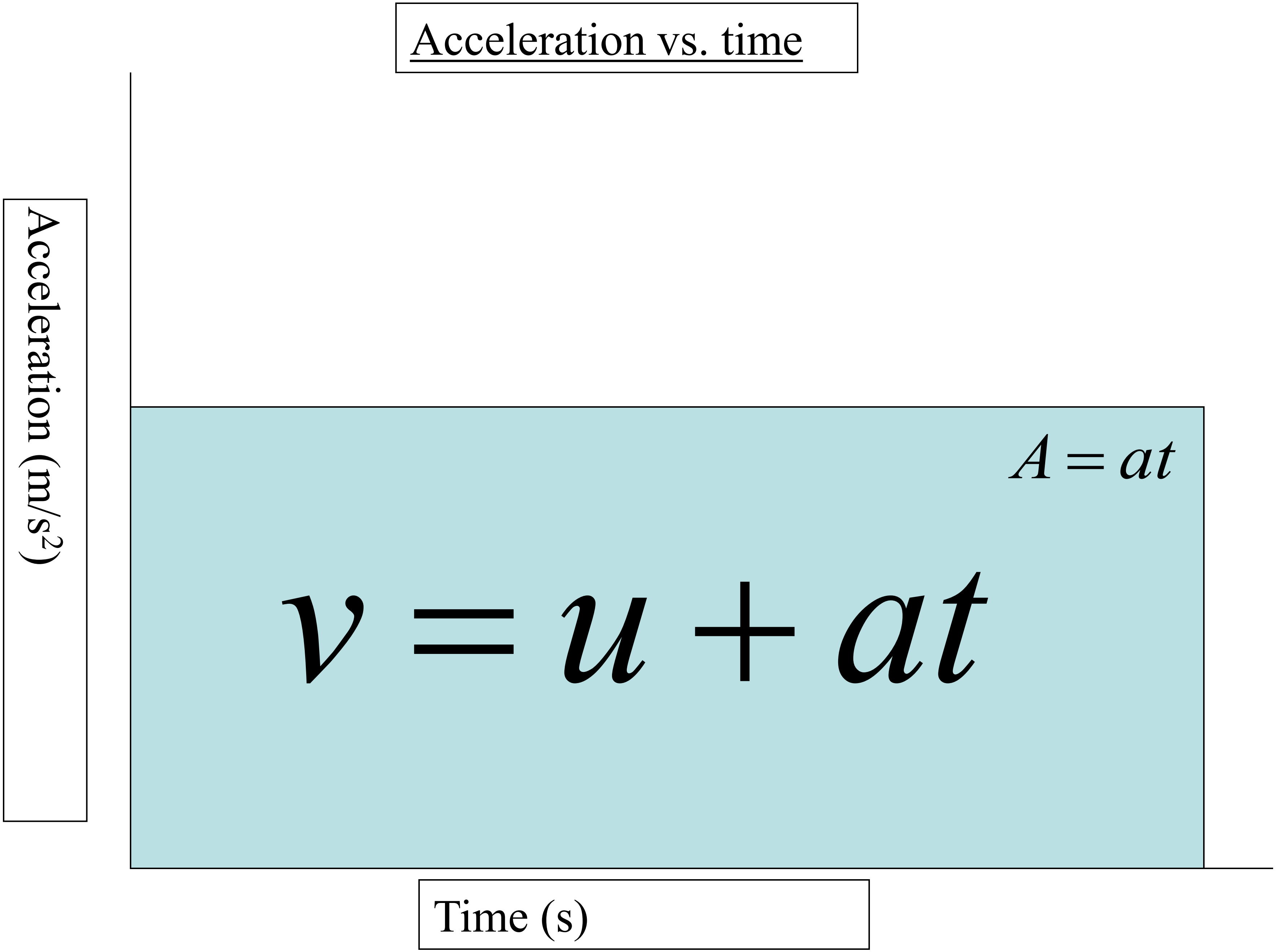

Velocity vs. time
Velocity (m/s)
Time (s)

Acceleration vs. time



Graphical Integration

- If we go from s $\rightarrow$ v $\rightarrow$ a by finding slope, how do we go the opposite direction?
- Area!
- The area under the a-t graph gives v, the area under a v-t graph gives displacement s!


Acceleration vs. time
Acceleration (m/s^2)
$A = at$
$v = u + at$
Time (s)

Ex 1:

- Find the initial velocity of a car that takes 3.0 s to accelerate at $4.9 m/s^2$ up to 42 m/s

Variables:

- $a=4.9m/s^2$
- u= ?
- v= 42m/s
- t= 3.0s

$$v = u + at$$

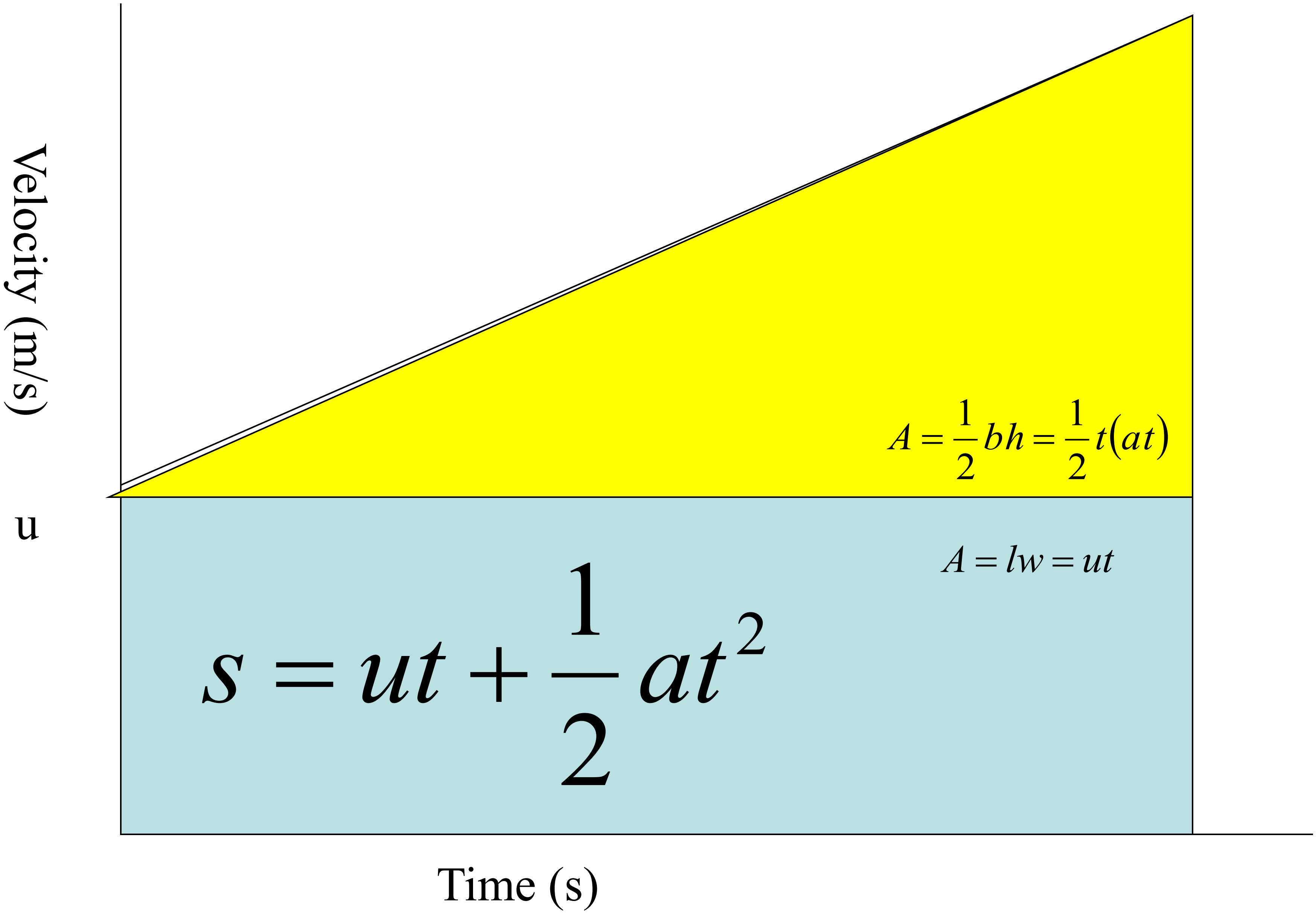
$$u = v - at$$

$$u = 42 \, {}^{m}\!/_{s} - 4.9 \, {}^{m}\!/_{s^2} \cdot 3s = 27 \, {}^{m}\!/_{s}$$

Displacement

- If we got velocity from an a-t graph, can we get displacement from a v-t graph?

Velocity vs. time



Ex 1:

- Find the displacement of a car that accelerates for 2.5s from a stop light at 3.5 m/s^2

Variables:

- a=3.5m/s^2
- u= 0
- s= ?
- t= 2.5s

$$s = \cancel{u}t + \frac{1}{2}at^2$$

$$s = \frac{1}{2}3.5\,{}^{m}\!/_{s^2}\left(2.5s\right)^2$$

$$s = 11m$$

Ex 2:

- Find your reaction time, given the ruler is falling at -9.8 m/s^2

Variables:

- a=-9.8m/s^2
- u= 0
- s= -0.11m+/-0.01
- t= ?s

$$s = \cancel{u}t + \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2s}{a}}$$

$$t = \sqrt{\frac{2(-0.11)}{-9.8}}$$

$$t = 0.15s$$

Practice:

- Read p. 35-53
- Watch Ringo
- Exercises p. 53 #1-8

How does gravity work?

- Do we disappear if we sail off the edge of the Earth?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Free Fallin’


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Gravitational Acceleration “g”

- How fast do things fall?
  - First, do heavy objects fall faster than light objects?
  - Try it!!
- If all free falling objects fall with the same acceleration, can we find this elusive “g”?
  - Throw a golf ball, take a video
  - Graph the variation of vertical velocity with time, find the slope!!

Gravitational Acceleration “g”

- How fast do things fall?
  - First, do heavy objects fall faster than light objects?
  - Try it!!
- If all free falling objects fall with the same acceleration, can we find this elusive “g”?
  - Drop a ball from a height of 1.00 m
  - time its fall, solve for g!!

$$s = \frac{1}{2} g t^2 \qquad g = \frac{2s}{t^2} \qquad g = -9.8 \, {}^{m}\!/_{s^2} \, ?$$

Ex 1:

- How long should a ball take to fall 1.00m?

Variables:

- a=g
- u= 0
- s= -1.00m
- t= ?

$$s = u\cancel{t} + \frac{1}{2}at^2 \qquad t = \sqrt{\frac{2s}{g}}$$

$$t = \sqrt{\frac{2(-1.00m)}{-9.8 \, m/s^2}}$$

$$t = 0.45s$$

Showing your work

$$t = \sqrt{\frac{2(-1.00m)}{-9.8\,m/s^2}}$$

- Without the "why" you are powerless!

Ex 2:

- Find the position of a ball that is thrown up at 24 m/s, after 4.5s of flight

Variables:

- a=g
- u=24m/s
- s= ?
- t= 4.5s

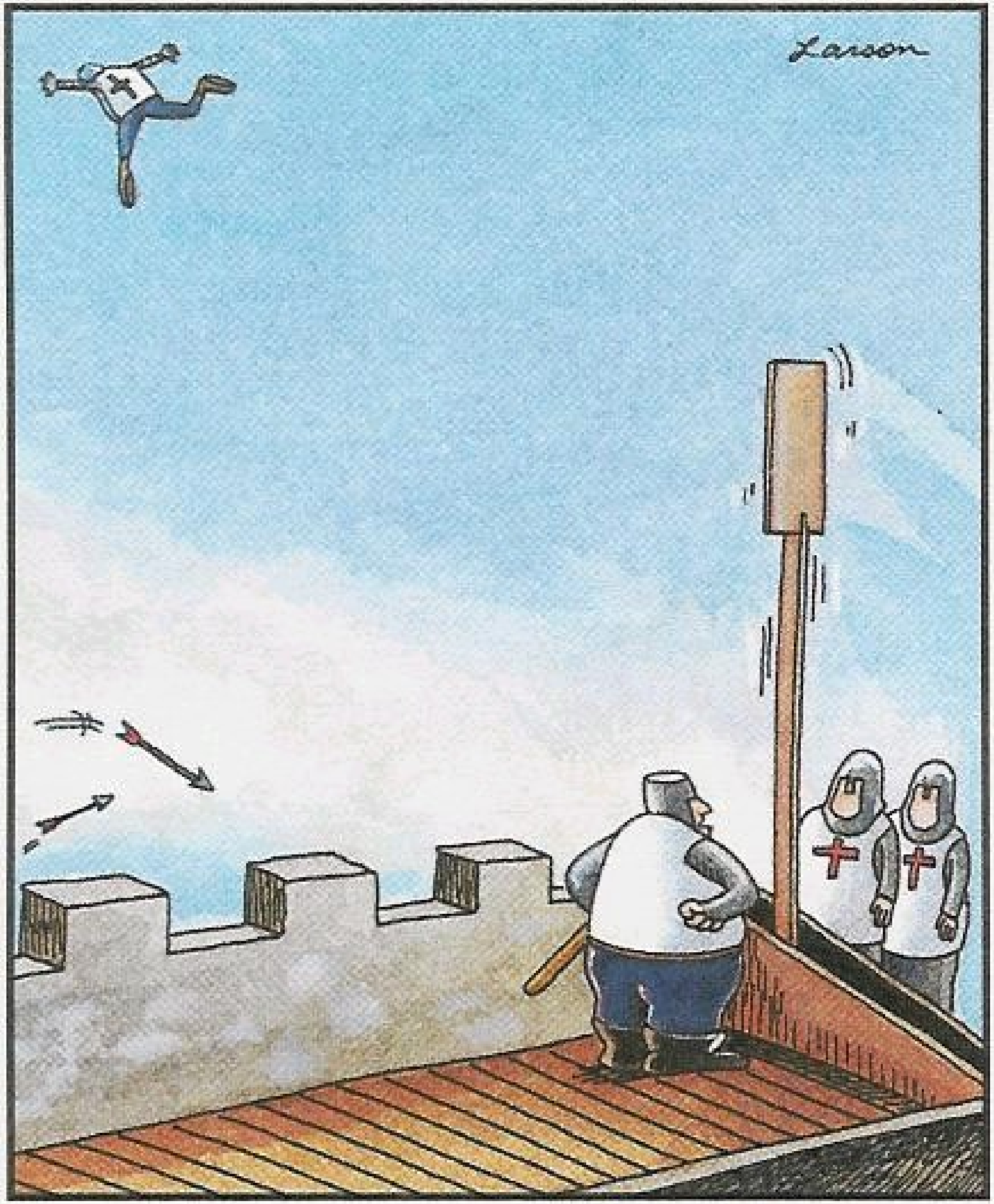
$$s = ut + \frac{1}{2}at^2$$

$$s = 24\,{}^{m}\!/_{s} \cdot 4.5s + \frac{1}{2}\left(-9.8\,{}^{m}\!/_{s^2}\right)(4.5s)^2$$

$$s = 8.8m$$

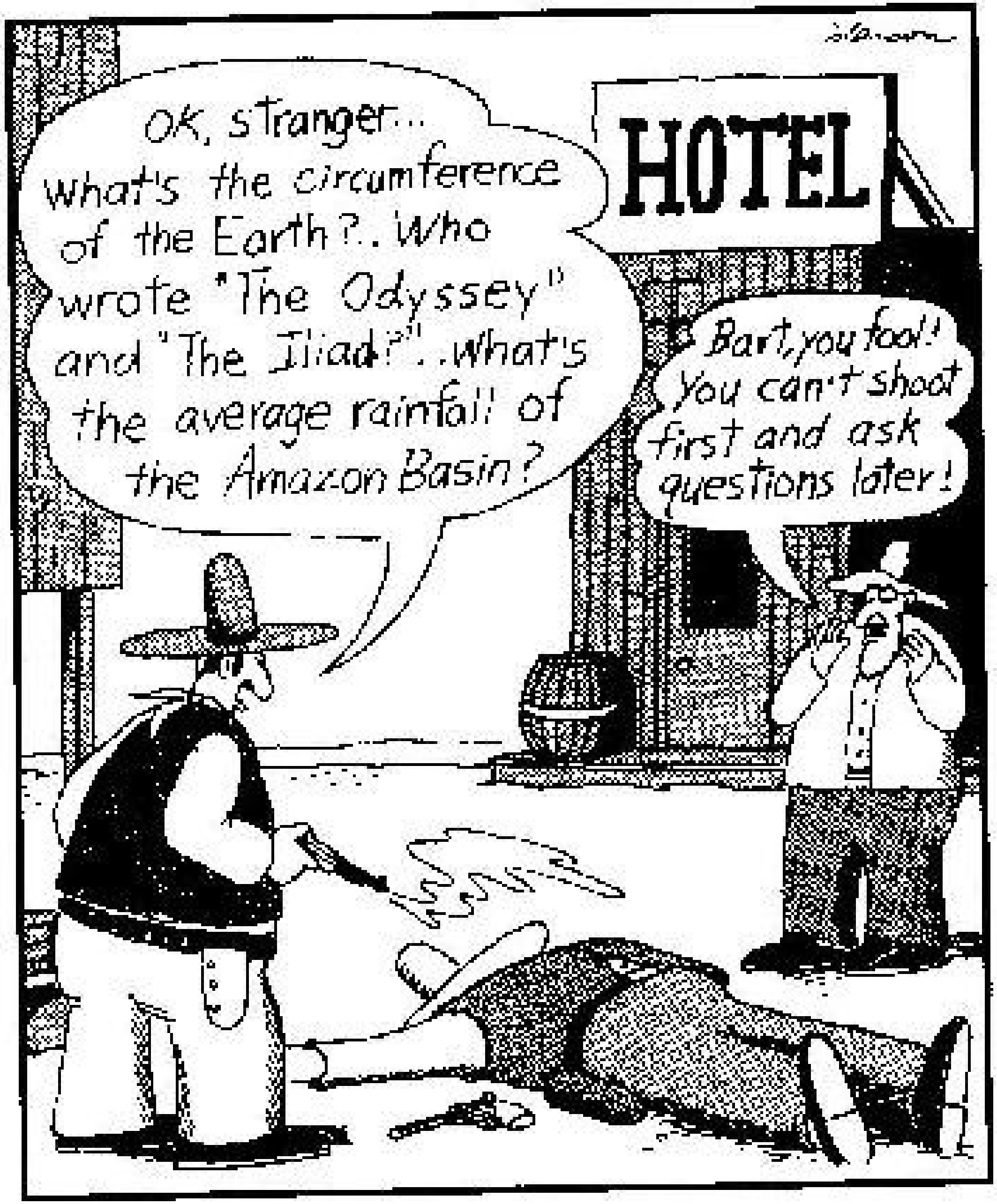
Projectiles

Any object in free fall



"I told you guys to slow down and take it easy or something like this would happen."

Yes, even you!


HOTEL
OK, stranger... what's the circumference of the Earth?.. Who wrote "The Odyssey" and "The Iliad?".. What's the average rainfall of the Amazon Basin?
Bart, you fool! You can't shoot first and ask questions later!

What do we know about free fall?

- Horizontal acceleration is zero (neglecting air resistance)
- Vertical acceleration is $-9.8 m/s^2$ (on Earth)
- The path is always a parabola
- We can solve each component independently, using “t” to connect them

Ex 1: A student runs off a 10m cliff at 8.5 m/s
a) How far from the bottom does he land?

Variables:

- a=-9.8m s^{-2}
- s=-10m
- u= 8.5 m/s
- t= ?
- x=?

x	y
$u_x = u\cos\theta = 8.5m\cdot s^{-1}$	$u_y = u\sin\theta = 0$
$x = ut + \cancel{\frac{1}{2}at^2}$	$s = \cancel{u_y t} + \frac{1}{2}at^2$
$x = 8.5m\cdot s^{-1}\cdot 1.43s$	$t = \sqrt{\frac{2s}{a}}$

$$t = \sqrt{\frac{2(-10m)}{-9.8m/s^2}} = 1.43s$$

$$x = 12m$$

b) With what velocity does he hit the water?

x	y
$u_x = u\cos\theta = 8.5\, {}^{m}/_{s}$	$u_y = u\sin\theta = 0$
	$v_y = \cancel{u_y} + gt$
	$v_y = -9.8m/s \cdot 1.43s = -14m/s$

$$v = \sqrt{v_x^{\ 2} + v_y^{\ 2}} \quad v = 16m/s$$

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) \qquad \theta = -59^\circ$$

Exercises

- Continue p. 53 #1-33
- FIAQD

Special Cases

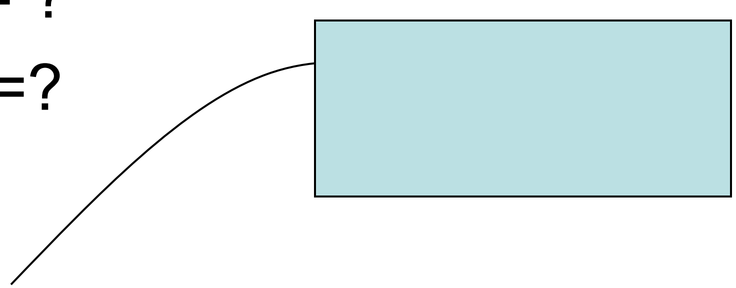
- Horizontal Launch: $u_y=0$
- Vertical launch: $u_x=0$
- Max height: $v_y=0$
- Level ground: $v_y=-u_y$
  - range formula: $R=(-u^2\sin 2\theta)/g$
- Max. range for 45°

Ex 1: Find the location at maximum height for a projectile launched at 32m/s, 41°

x	y
$u\cos\theta = 24 \, {}^{m}\!/\!_{s}$	$u\sin\theta = 21m/s$
$s = ut$	$v = u + at$
$s = 24(2.14)$	$t = \dfrac{v-u}{a}$ $\quad t = \dfrac{0-21}{-9.8}$
$s = 51m$	$s = \dfrac{u+v}{2}t$
	$s = \dfrac{21+0}{2}2.14$ $\quad s = 22m$

Variables:

- $g=-9.8m/s^2$
- u= 32 m/s
- ϴ=41°
- y=?
- t= ?
- x=?



Ex 2: Golf ball launched at 48m/s, 45° above horizontal. Find range for a level landing

Variables:

- $g=-9.8 m/s^2$
- $v_0= 48$ m/s
- $\theta= 45°$
- t= ?
- x=?

x	y
$u_x = u\cos\theta = 33.9m/s$	$u_y = u\sin\theta = 33.9m/s$
$s = ut + \cancel{\frac{1}{2}at^2}$	$\cancel{s} = ut + \frac{1}{2}at^2$
$s = 33.9 \cdot 6.92$	$t(u + \frac{1}{2}at) = 0$
$d = 235m$	$t = -2u/a$
	$t = 6.92s$

Ex 2: Motorcycle launched at 35m/s, 35° above horizontal. Find range for a level landing

x	y
$u_x = u\cos\theta = 29\,{}^{m}\!/_{s}$	$u_y = u\sin\theta$
$s = ut$	$v_y = v_{y0} + gt$
$s = 29m/s \cdot 4.1s$	$t = \dfrac{\Delta v}{g} = \dfrac{-40m/s}{-9.8m/s^2}$
$s = 118m$	$t = 4.1s$

Variables:

- g=-9.8m/s^2
- v_0= 35 m/s
- Θ= 35°
- t= ?
- x=?

Ex 3: A student launches her textbook out a 5m window at 23m/s, 15 ° above horiz. Find x

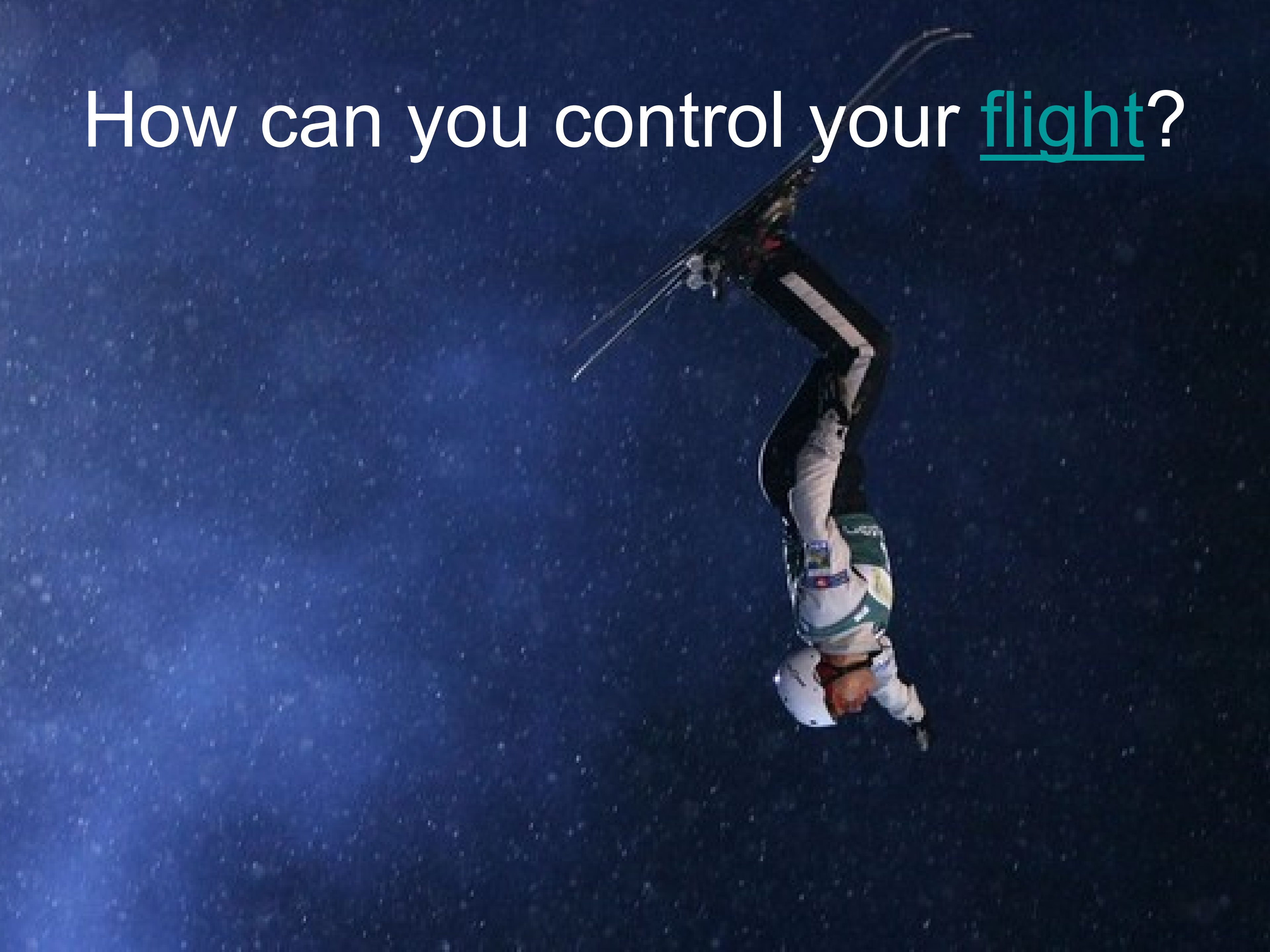
x	y
$u\cos\theta = 22.2m\cdot s^{-1}$	$u\sin\theta = 5.95m\cdot s^{-1}$
$s = ut$	$v^2 = u^2 + 2as$
$= 22.2m/s \cdot 1.78s$	$v = \pm\sqrt{5.95^2 + 2(-9.8)(-5)}$
$x = 40m$	$v = -11.5m\cdot s^{-1}$
	$v = u + at \quad t = \frac{(v-u)}{a}$

Variables:

- $g=-9.8m/s^2$
- $v_0= 23$ m/s
- $\Theta= 15°$
- y=-5m
- t= ?
- x=?

$$t = 1.78s$$

How can you control your flight?



Ex 4: Projectile launched at 32m/s, 41° up onto a 6.5m roof. Where does it land?

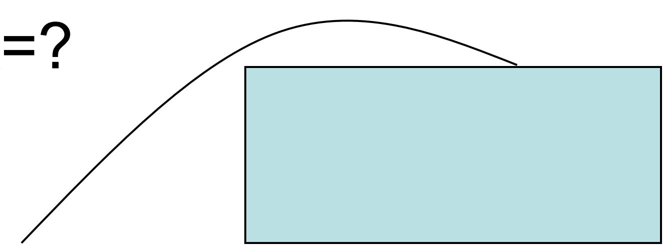
x	y
$v_{x0} = v_0 \cos\theta = 24 \frac{m}{s}$	$v_{y0} = v_0 \sin\theta = 21 m/s$
$x = v_x t$	$y = v_{y0} t + \frac{1}{2} g t^2$
$x = 24 m/s \cdot 3.95 s$	$-4.9t^2 + 21t - 6.5 = 0$
$x = 95m$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$t = \frac{-21 \pm 17.7}{-9.8} s$$

$$t = 0.34s \qquad t = 3.95s$$

Variables:

- $g = -9.8 m/s^2$
- $v_0 = 32$ m/s
- $\theta = 41°$
- $y = 6.5m$
- t= ?
- x=?



Puzzler! Projectile launched at 17m/s, 32° up onto a 8.0m roof. Where does it land?

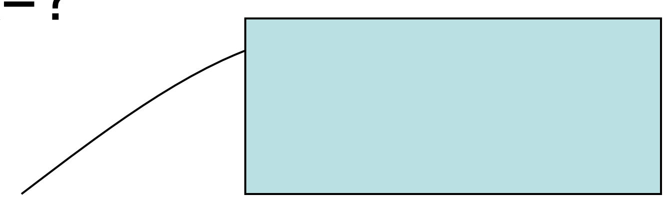
x	y
$v_{x0} = v_0 \cos\theta = 14.4 \,{}^{m}\!/\!{}_{s}$	$v_{y0} = v_0 \sin\theta = 9.0 m/s$
$x = v_x t$	$y = v_{y0}t + {}^{1}\!/\!{}_{2}\, g t^2$
	$-4.9t^2 + 9.0t - 8.0 = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{-21 \pm 8.7}{-9.8} s$$

Variables:

- $g = -9.8 m/s^2$
- $v_0 = 17$ m/s
- $\Theta = 32°$
- $y = 8.0m$
- $t = ?$
- $x = ?$



"Real Life" Ex 1: Projectile launched at 15° above horizontal. Find the launch velocity

x	y
$x = v_x t$	
$v_x = \frac{x}{t} \quad = \frac{6.08m}{0.7837s}$	
$v_{x0} = v_0 \cos\theta$	

Variables:

- $g=-9.8m/s^2$
- $v_0= ?$
- $\theta= 15°$
- $t= 0.7837$
- $x=6.08m$

$$v_0 = \frac{v_{x0}}{\cos\theta} \quad = \frac{7.758}{\cos 15}$$

$$= 8.03m/s$$

"Real Life" Ex 2: Projectile launched at 8.66m/s, theta° above horizontal. Find range and compare (% diff)

x	y
$v_{x0} = v_0 \cos\theta$	$v_{y0} = v_0 \sin\theta$
$x = v_x t$	$y = v_{y0} t + \frac{1}{2} g t^2$

Variables:

- $g=-9.8\text{m/s}^2$
- $v_0=9.01$ m/s
- $\Theta=$ choose°
- t=
- x=?
- y=-1.18m

$$-4.9t^2 + 2.87t + 1.18 = 0$$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad = -0.34s, 0.68123s$$

“Real Life” Ex 1: Projectile launched at ?m/s, 35° above horizontal. Find range and compare (% diff)

- The x=7.50
- Exp x=7.80m

$$\%diff = \frac{Experimental - Theoretical}{Theoretical}$$

$$\%diff = \frac{7.80m - 7.50m}{7.50m}$$

$$\%diff = 4.0\%$$

"Real Life" Ex 3: Projectile launched at 13m/s, 45° above horizontal. Find range

Variables:

- $g=-9.8 m/s^2$
- $v_0 = 13$ m/s
- $\Theta = 45°$
- t=
- x=?

x	y
$v_{x0} = v_0 \cos\theta$	$v_{y0} = v_0 \sin\theta$
$v_{x0} = 13 \, m/s \cos 45$	$v_{y0} = 13 \, m/s \sin 45$
$v_{x0} = 9.19 \, m/s$	$v_{y0} = 9.19 \, m/s$

$$x = v_x t$$

$$x = 10.2 \, m/s \cdot 0.7356 s$$

$$x = 7.4 m$$

$$y = v_{y0} t + \frac{1}{2} g t^2$$

$$0 = -4.9 t^2 + 9.19 t + 1.195$$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = -0.3315 s, 0.7356 s$$

"Real Life" Ex 4: Projectile launched at 13 m/s, 23° above horizontal. Where does the ball hit?

Variables:

- a=-9.8m/s^2
- u= 13 m/s
- Θ= 23°
- t= ?
- X=?
- y=1.22m

x	y
$u_x = u\cos\theta$	$u_y = u\sin\theta \quad = 5.080\, m/s$
$v_{x0} = 13\, m/s \cos 23$	$s = ut + \frac{1}{2}at^2$
$v_{x0} = 11.97\, m/s$	
	$-4.9t^2 + 5.08t - 1.22 = 0$

$$s = ut$$

$$t = 0.66s$$

$$s = 11.97(0.66)$$

$$s = 7.9m$$

"Real Life" Ex 2: Projectile launched at ?m/s, 35° above horizontal. Find range and compare (% diff)

- The x=9.48
- Exp x=9.50m

$$\%diff = \frac{Experimental - Theoretical}{Theoretical}$$

$$\%diff = \frac{9.50m - 9.51m}{9.51m}$$

$$\%diff = 0.1\%$$

“Real Life” Ex 3: Projectile launched at 9.27m/s, 15° above horizontal. Find range and compare (% diff)

Variables:

- $g=-9.8 m/s^2$
- $v_0 = 9.27$ m/s
- $\Theta = 15°$
- $y=-1.15m$
- $t= ?$
- $x=?$

x	y
$v_{x0} = v_0 \cos\theta = 8.95 \, {}^{m}\!/_{s}$	$v_{y0} = v_0 \sin\theta = 2.40 m/s$
$x = v_x t$	$y = v_{y0} t + {}^{1}\!/_{2} g t^2$
$x = 8.95 m/s \cdot 0.79 s$	$-4.9t^2 + 2.40t + 1.15 = 0$
$x = 7.05 m$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$t = \frac{-2.40 \pm 5.32}{-9.8} s \quad \cancel{= -0.30}$$

$$t = 0.79 s$$

“Real Life” Ex 3: Projectile launched at 9.27m/s, 15° above horizontal. Find range and compare (% diff)

- The x=9.05
- Exp x=9.08m

$$\%diff = \frac{Experimental - Theoretical}{Theoretical}$$

$$\%diff = \frac{9.08m - 9.05m}{9.05m}$$

$$\%diff = 0.3\%$$

Experiment

- Design and carry out a lab, measuring launch velocity and angle
- Calculate horizontal displacement, then compare to measured displacement

% difference

- The x=9.05
- Exp x=9.08m

$$\%diff = \frac{Experimental - Theoretical}{Theoretical}$$

$$\%diff = \frac{9.08m - 9.05m}{9.05m}$$

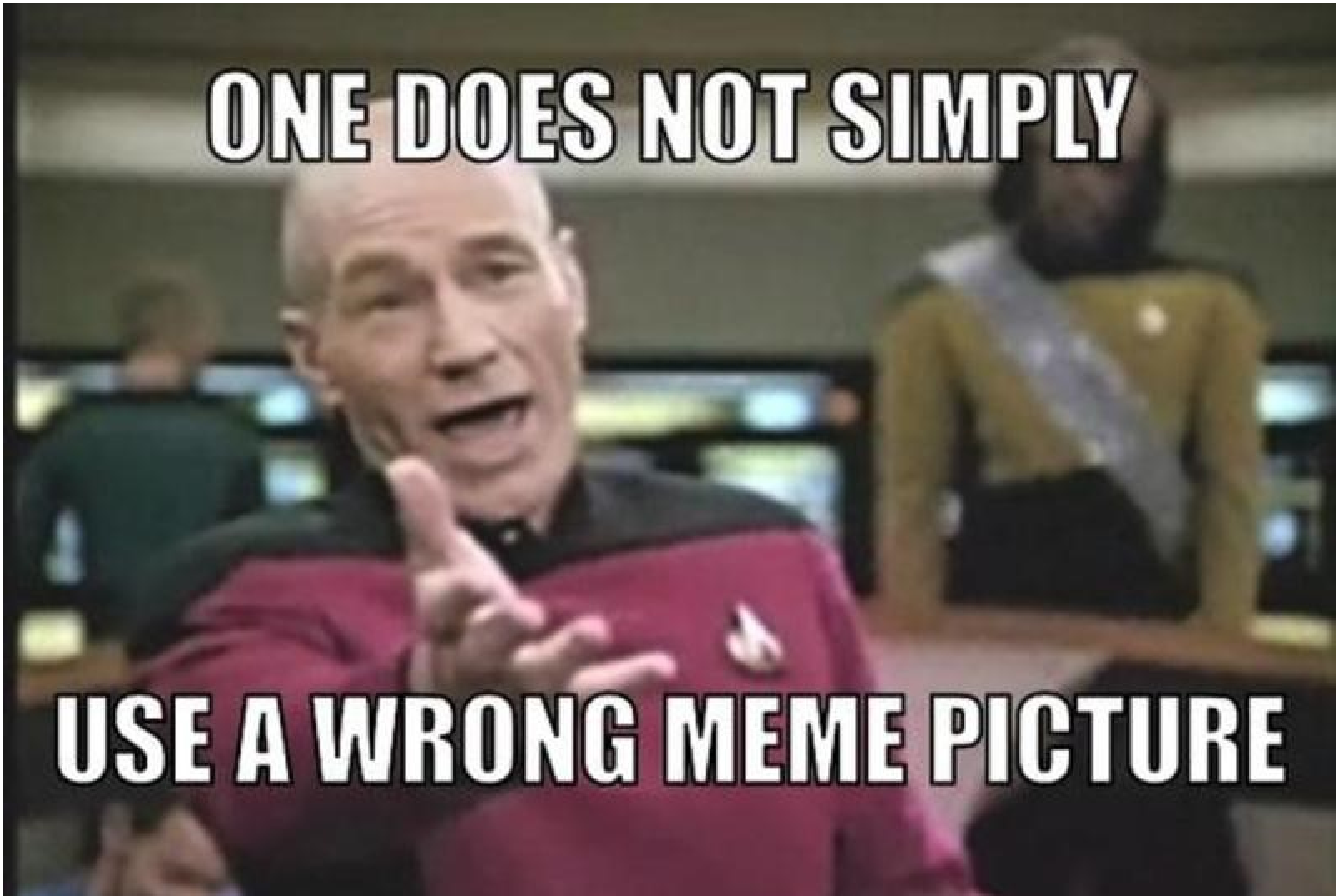
$$\%diff = 0.3\%$$

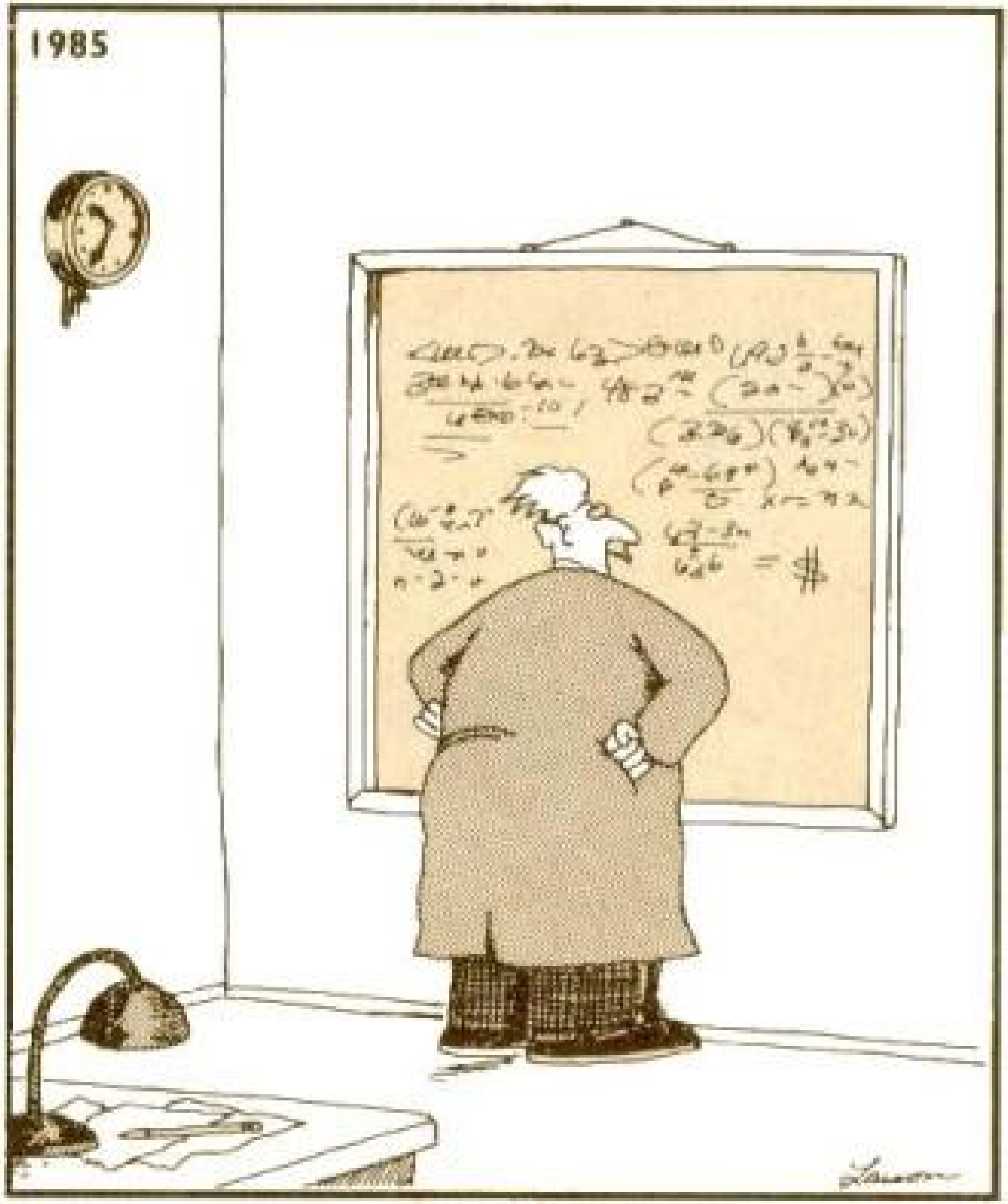
Exercises

- Start p. 56-57 #25-33

One does not simply…

…mix up their x and y variables





Einstein discovers that time is actually money.

What if we don't know time?

- We can combine these two equations to eliminate t:

$$v = u + at \qquad\qquad s = ut + \frac{1}{2}at^2$$

$$t = \frac{v-u}{a} \longrightarrow s = u\left(\frac{v-u}{a}\right) + \frac{1}{2}a\left(\frac{v-u}{a}\right)^2$$

$$s = \frac{uv-u^2}{a} + \frac{1}{2}a\left(\frac{v^2-2vu+u^2}{a^2}\right)$$

$$2as = 2uv - 2u^2 + v^2 - 2vu + u^2$$

$$v^2 = u^2 + 2as$$

Variables:

- a=?
- u= 35m/s
- v= 0
- s=59m

- Ex 3: Find the acceleration of a car that stops from 35 m/s in a distance of 59 m

$$v^2 = u^2 + 2as$$

$$\frac{v^2 - u^2}{2s} = a$$

$$a = \frac{(0)^2 - \left(35\,{}^{m}\!/_{s}\right)^2}{2 * 59m}$$

$$a = -10.4\frac{m}{s^2}$$

- The last equation of this unit solves problems involving quadratics:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- Ex 4: How long does it take for a ball thrown upwards at 13 m/s to reach a height of 3.2 m?

$$s = ut + \frac{1}{2}at^2$$

- Ex 4: How long does it take for a ball thrown upwards at 13 m/s to reach a height of 3.2 m?

Variables:

- a=g
- u= 13m/s
- t= ?
- s=3.2m

$$s = ut + \frac{1}{2}at^2 \qquad \frac{1}{2}at^2 + ut - s = 0$$

$$-4.9\,{}^{m}\!/_{s^2}\,t^2 + 13\,{}^{m}\!/_{s}\,t - 3.2m = 0$$

$$\boxed{x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}}$$

$$t = \frac{-13 \pm \sqrt{13^2 - 4(-4.9)(-3.2)}}{2(-4.9)}$$

$$t = \frac{-13 \pm 10.3}{-9.8}s \qquad t = 2.4s \quad t = 0.28s$$

- Ex 2: When does a ball thrown upwards from a 4.5m roof at 3.2 m/s hit the ground?

Variables:

- a=g=-9.8m/s^2
- u= 3.2m/s
- t= ?
- s=-4.5m

$$s = ut + \frac{1}{2}at^2 \qquad \frac{1}{2}at^2 + ut - s = 0$$

$$-4.9\,{}^{m}\!/_{s^2}\, t^2 + 3.2\,{}^{m}\!/_{s}\, t + 4.5m = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{-3.2 \pm \sqrt{3.2^2 - 4(-4.9)(4.5)}}{2(-4.9)}$$

$$t = \frac{-3.2 \pm 9.92}{-9.8}s \qquad t = 1.34s \qquad t = -0.69s$$

- Ex 3: When does a ball thrown upwards at 1.4 m/s hit the 3.2m high ceiling?

Variables:

- a=g
- v_0= 1.4m/s
- t= ?
- d=3.2m

$$s = ut + \frac{1}{2}at^2 \qquad \frac{1}{2}at^2 + ut - s = 0$$

$$-4.9\,{}^{m}\!/\!{}_{s^2}\,t^2 + 1.4\,{}^{m}\!/\!{}_{s}\,t - 3.2m = 0$$

$$\boxed{x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}}$$

$$t = \frac{-1.4 \pm \sqrt{1.4^2 - 4(-4.9)(-3.2)}}{2(-4.9)}$$

$$t = \frac{-1.4 \pm err?}{-9.8}s$$

Which one?

- A quadratic yields two roots.
- Sometimes the physics rules out the possibility of one of the roots
  - eg. negative time, etc.
- In the first case, we had two solutions to the problem:
  - one on the way up, one on the way down


f(x)=-4.9x^2+13x
Height (m)
y
x
time (s)
1
2
3
4
5
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6

- Ex 4: How long does it take for a ball thrown upwards at 13 m/s to reach a height of 3.2 m? Solve without q.f?

Variables:

- a=g
- u= 13m/s
- t= ?
- s=3.2m

$$v^2 = u^2 + 2as$$

$$v = \pm\sqrt{u^2 + 2as}$$

$$v = \pm\sqrt{13^2 + 2(-9.8)3.2}$$

$$v = \pm 10.3 m \cdot s^{-1}$$

- Ex 4: How long does it take for a ball thrown upwards at 13 m/s to reach a height of 3.2 m? Solve without q.f?

Variables:

- a=g
- u= 13m/s
- t= ?
- s=3.2m

$$v = u + at$$

$$t = \frac{v - u}{a}$$

$$t = \frac{10.3 - 13}{-9.8}$$

$$t = 0.28s$$

Problem solving strategy

- Step 1: start with what you know

Variables:

- a=
- u=
- t= ?
- s=

- Step 2: find a formula containing only those variables

$$v = u + at$$

- Step 3: rearrange if necessary

$$t = \frac{v - u}{a}$$

- Step 4: insert numbers and calculate
- *Step 5: bask in the admiration of all your family and friends :)*

Practice:

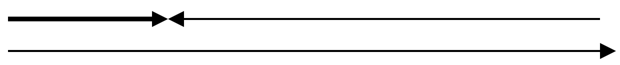
- Continue Chapter Review Problems p. 40-41 #11-17
- Finished? Start Test Yourself p. 43 #1-8

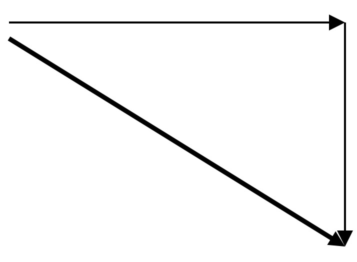
Scalars vs. $\overrightarrow{\text{Vectors}}$

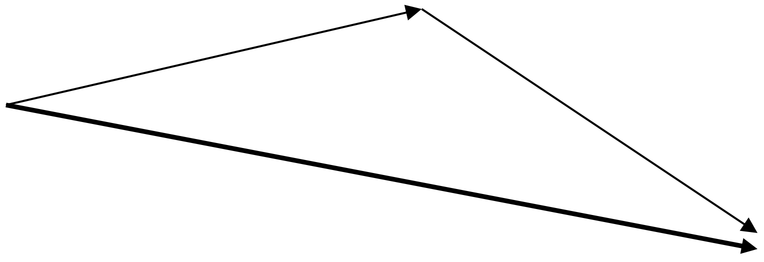
- Scalars: have a magnitude but no direction:
  - mass
  - time
  - distance
  - speed
- Vectors: have magnitude and direction
  - force
  - momentum
  - displacement
  - velocity

Adding Vectors

- We always rearrange vectors to add them tip-to-tail.
- The resultant is the vector that reaches from the tail of the 1st to the tip of the 2nd

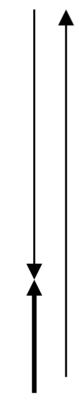


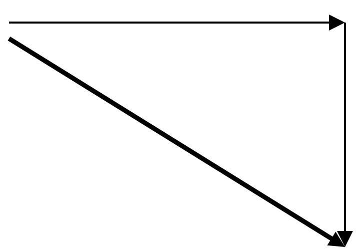


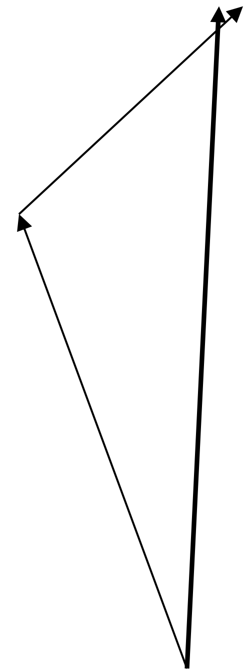


Adding Vectors

- Ex: Draw a scale diagram for:
- 5 m North + 3 m South
- 4 N East + 3 N South
- 10 m North + 5 m Northeast

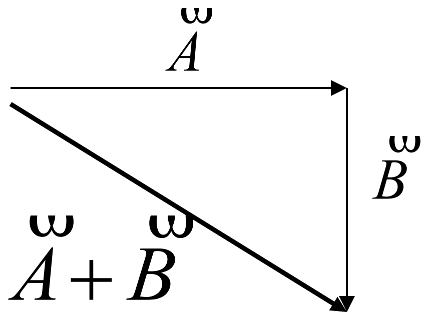


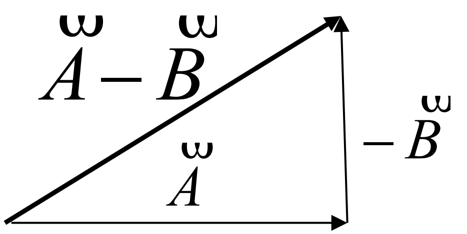




Subtracting Vectors

- We can think of vector A – B as being equivalent to A + (-B)



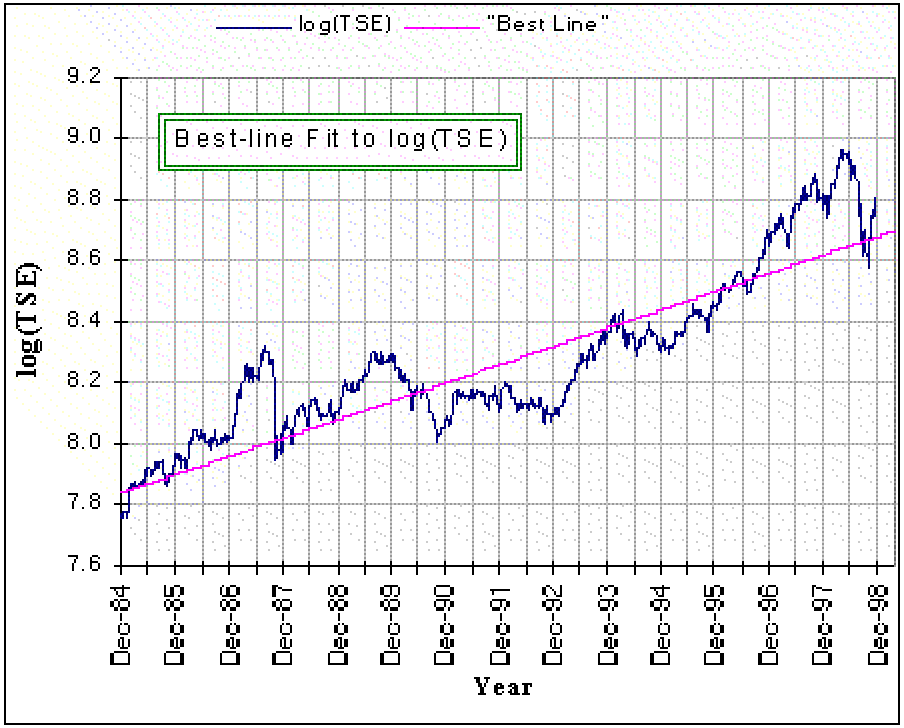


Exercises

- P. 18 #1-2
- P. 19 #1

Graphs

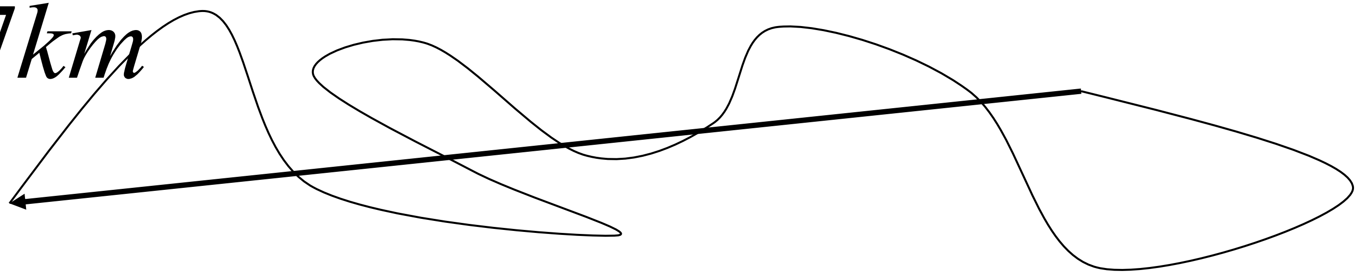
- Must have:
  - title
  - appropriate labels,
  - scaled axes
  - best fit line, **not** connect-the-dots!
- Should take up most of the page
- Should give us useful information…



Displacement

- Distance is a measurement of how far you have travelled and depends on the path

$$d = 57km$$

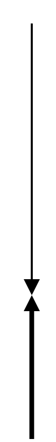


- Displacement is independent of path because it simply measures the change in position

$$\vec{d} = 12km \leftarrow West$$

- Ex 1. Eric walks 15 blocks North then 10 blocks South. Find his:
  - distance:

    d=15 blocks + 10 blocks=25 blocks
  - displacement



$$\vec{d} = 15 blocks + (-10 blocks) \vec{N}$$

$$\vec{d} = 5 blocks \uparrow North$$

- Ex 2. Ken walks 7 m East then 10 m North. Find his displacement :

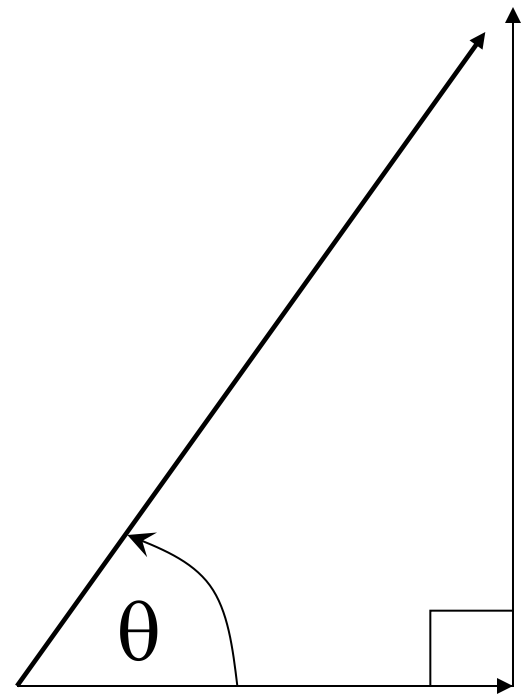
- Ex 2. Ken walks 7 m East then 10 m North. Find his displacement :

$$a^2 + b^2 = c^2$$

$$d^2 = 7^2 + 10^2$$

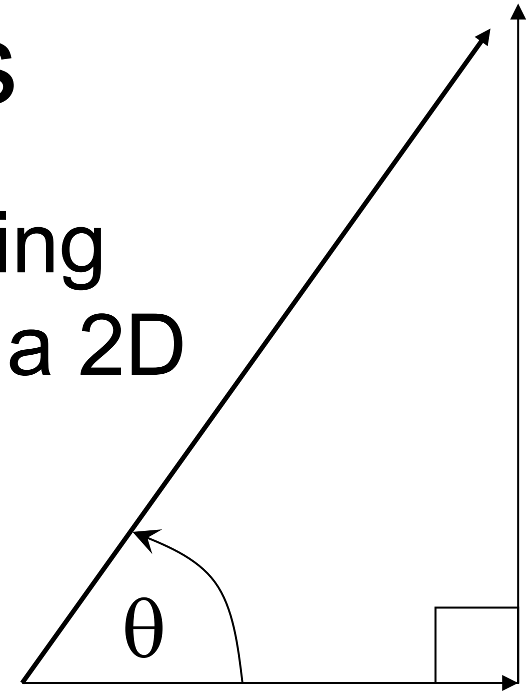
$$d = 12m$$

$$\theta = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{10}{7}\right)$$



$$\vec{d} = 12m, 55° N of E$$

Components



- What is the opposite of adding perpendicular values to get a 2D vector?
- Finding Components ☺

- Ex: Vector A=55N, 30° above horizontal

$$A_x = A\cos\theta \qquad A_y = A\sin\theta$$

$$= 48N \qquad = 28N$$

Ex 2: Motorcycle launched at 35m/s, 35° above horizontal. Find range for a level landing

Variables:

- a=-9.8m/s^2
- u= 35 m/s
- Θ= 35°
- t= ?
- x=?

x	y
$u_H = u\cos\theta = 29\,{}^{m}\!/_{s}$	$u_V = u\sin\theta = 20\,{}^{m}\!/_{s}$
$s = u_H t$	$v_V = u_V + at$ $s = u_V t + {}^{1}\!/_{2}\,at^2$
$s = 29m/s \cdot 4.1s$	$0 = u_V t + {}^{1}\!/_{2}\,at^2$

$$0 = t\left(u_V + {}^{1}\!/_{2}\,at\right)$$

$$t = \frac{\Delta v}{g} = \frac{-40m/s}{-9.8m/s^2} = 4.1s$$

$$x = 118m$$

Ex 3: A student launches her textbook out a 5m window at 23m/s, 15 ° above horiz. Find x

x	y
$v_x = v_{x0} = v_0 \cos\theta = 22.2 \, m/s$	$v_{y0} = v_0 \sin\theta = 5.95 m/s$
$x = v_x t$	$y = v_{y0} t + \tfrac{1}{2} g t^2$
$x = 22.2 m/s * 1.78 s$	$-4.9t^2 + 5.95t + 5 = 0$
$x = 40m$	$x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Variables:

- g=-9.8m/s^2
- v_0= 23 m/s
- Θ= 15°
- y=-5m
- t= ?
- x=?

$t = 1.78s$ $\quad \cancel{= -0.57}$

Exercises

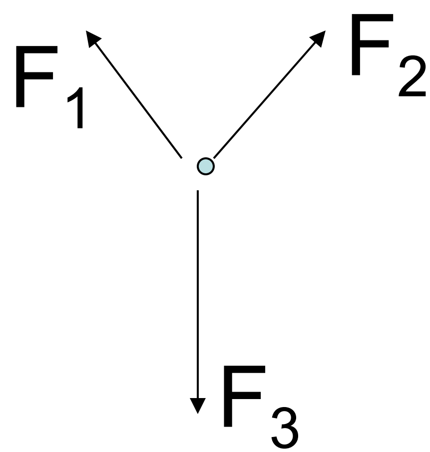
- Finish experiment p. 53 choose 10

- Time for a trip to the library?

Free Body Diagrams

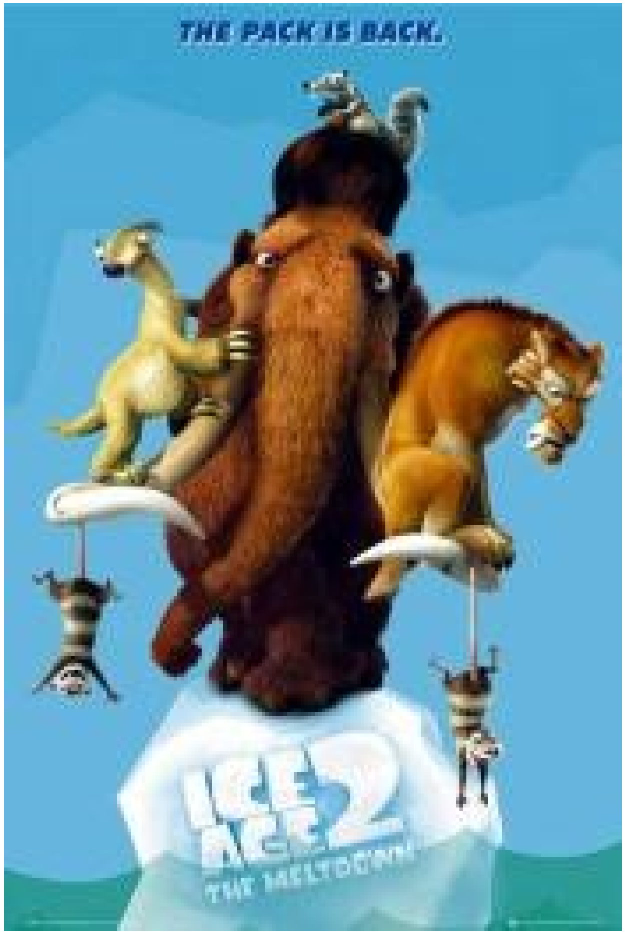
- The point of a FBD is to simplify the dynamics involved
- We only point out the forces acting **on** the body in question
- To get to the point, we draw the body as a…

  point!



- The forces are drawn **pointing away** from the body

How do you reach equilibrium?



Translational Equilibrium

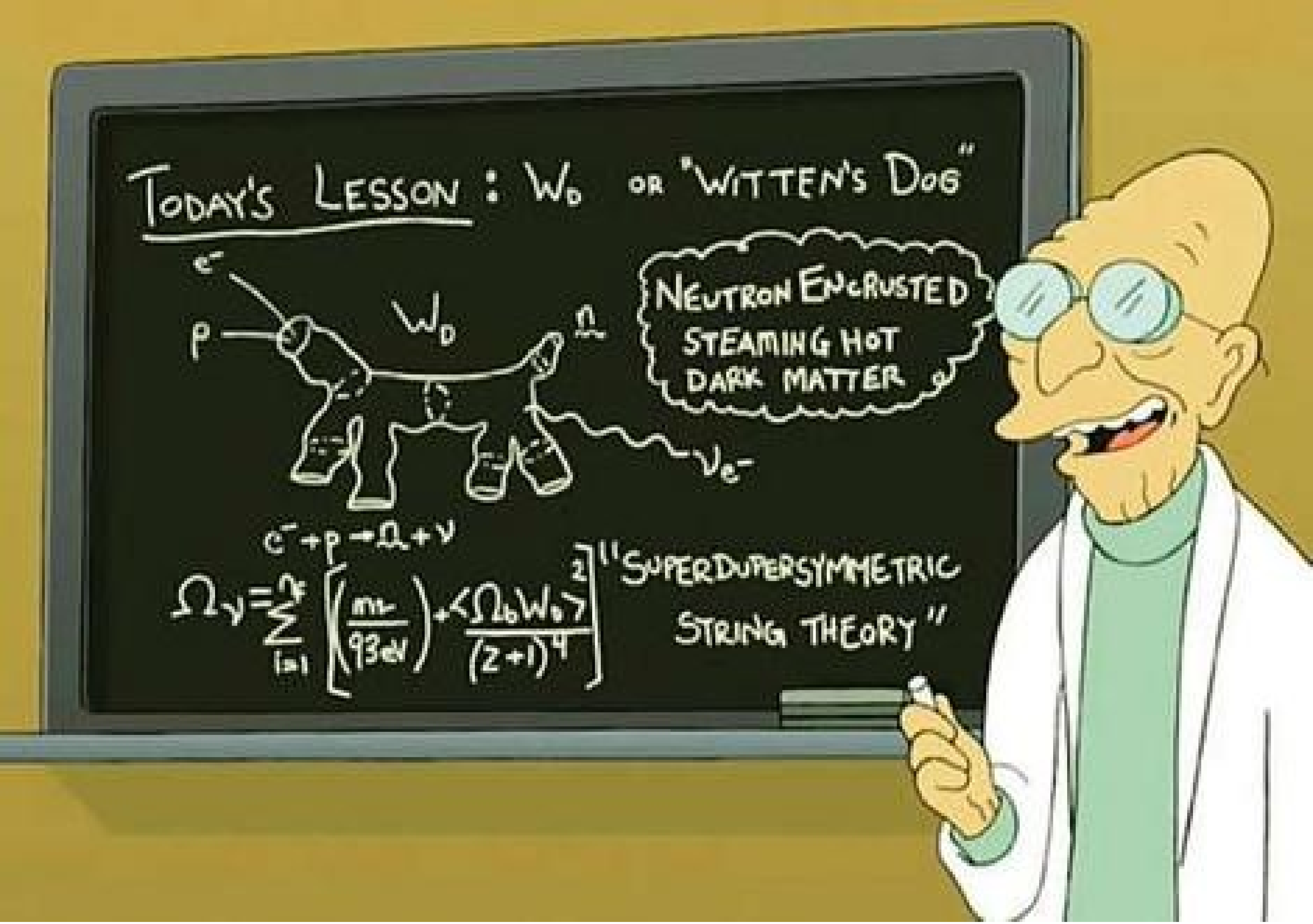
- This is a fancy way of saying a=0
- It then follows from Newton's 2nd that:
  - – or –

$$\vec{F}_{net} = 0 \qquad \sum \vec{F} = 0$$

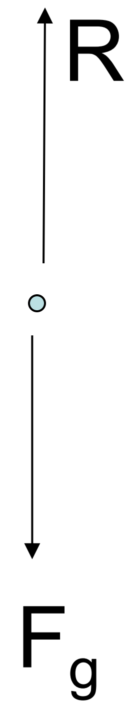
- Since we deal with Newton's 2nd law in one dimension at a time, we can also say:
  - and

$$\sum \vec{F}_x = 0 \qquad \sum \vec{F}_y = 0$$

- Ex 1: Traffic light equilibrium
  - find the weight of the traffic light from the following diagram:


TODAY'S LESSON : W_D OR "WITTEN'S DOG"
NEUTRON ENCRUSTED STEAMING HOT DARK MATTER
e⁻ + p → Ω + ν
"SUPERDUPERSYMMETRIC STRING THEORY"

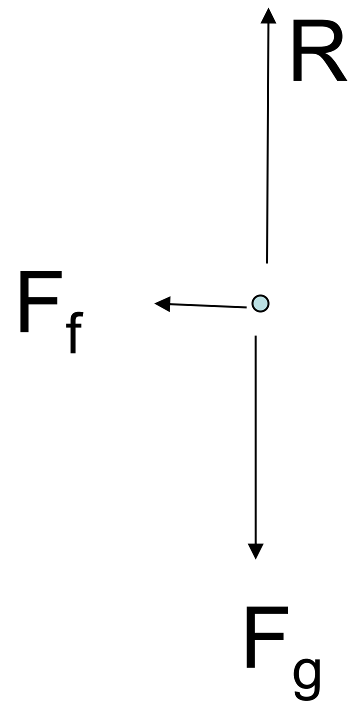
Ex: draw a FBD for a book resting on your table



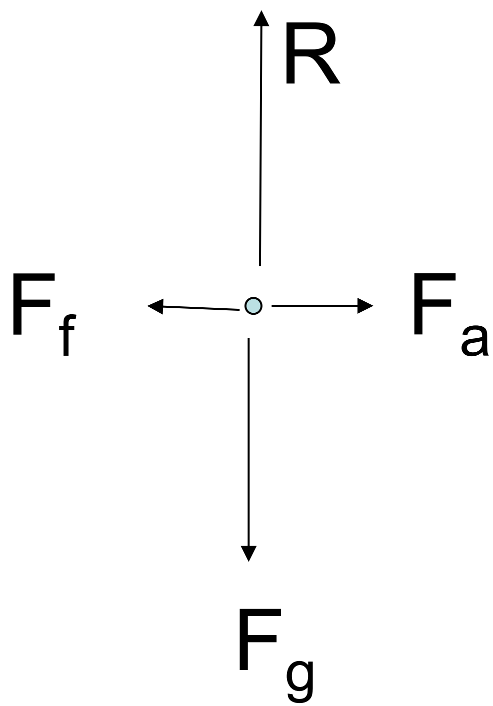
$$\sum \vec{F} = 0$$

- If the book weighs 13 N, find R
- Fg+R=0 R=-Fg=-(-13N)=13N

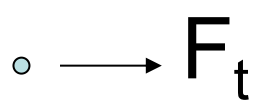
Ex: draw a FBD for a book sliding across your table



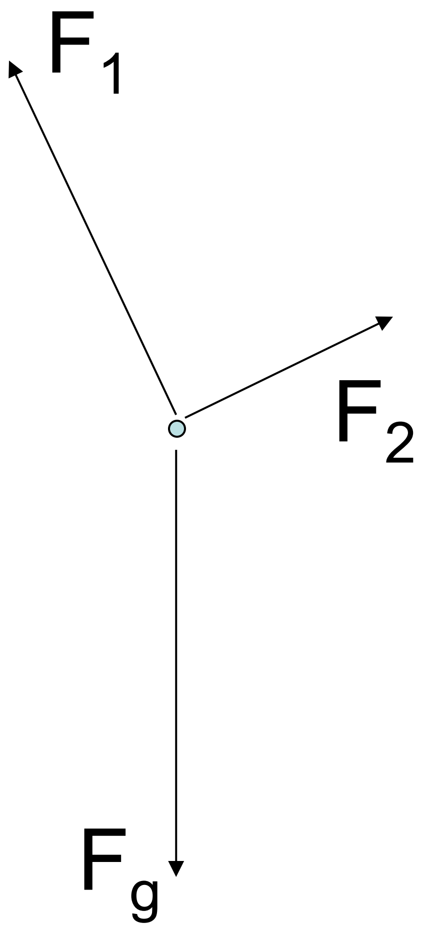
Ex: draw a FBD for a book being pushed with constant velocity across your table

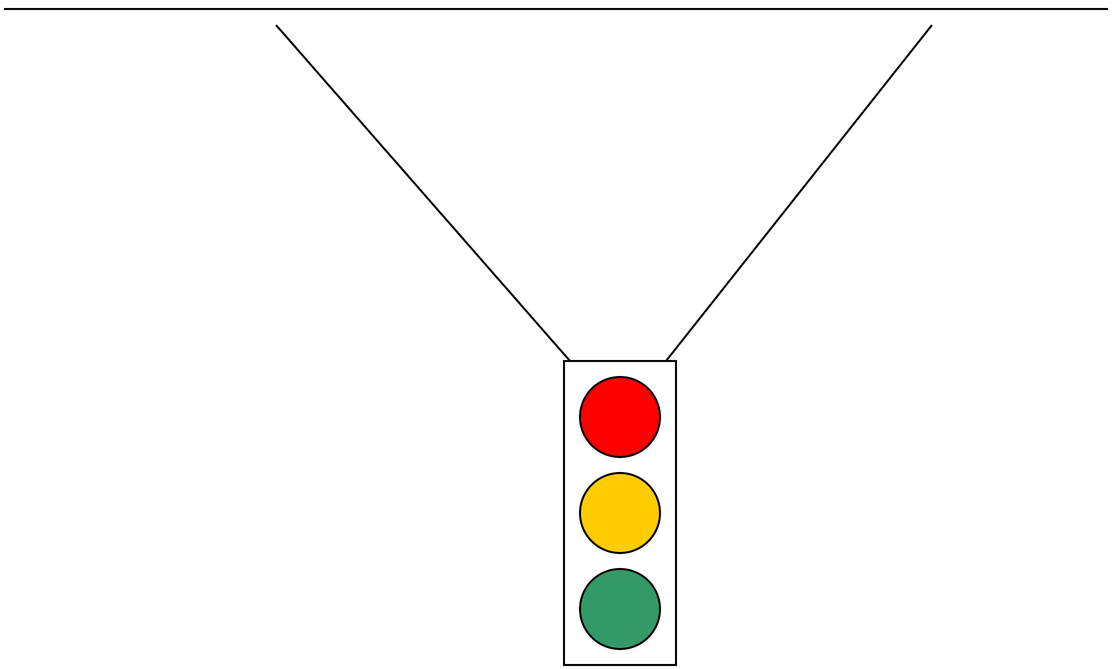


Ex: draw a FBD for a rocket ship in space

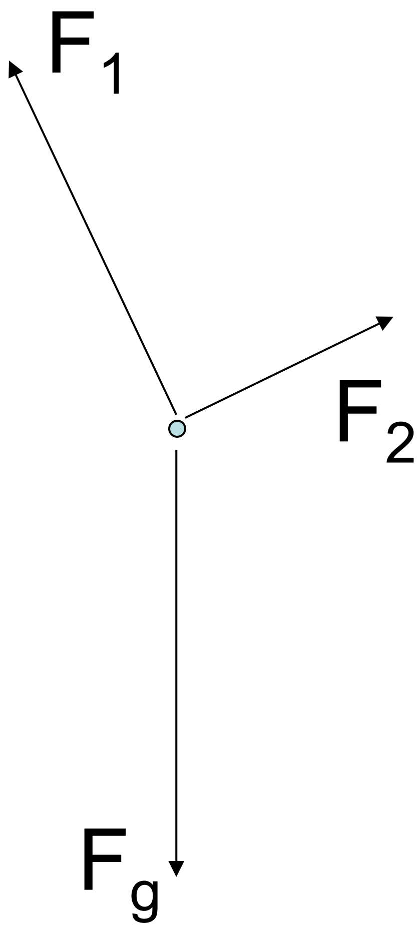


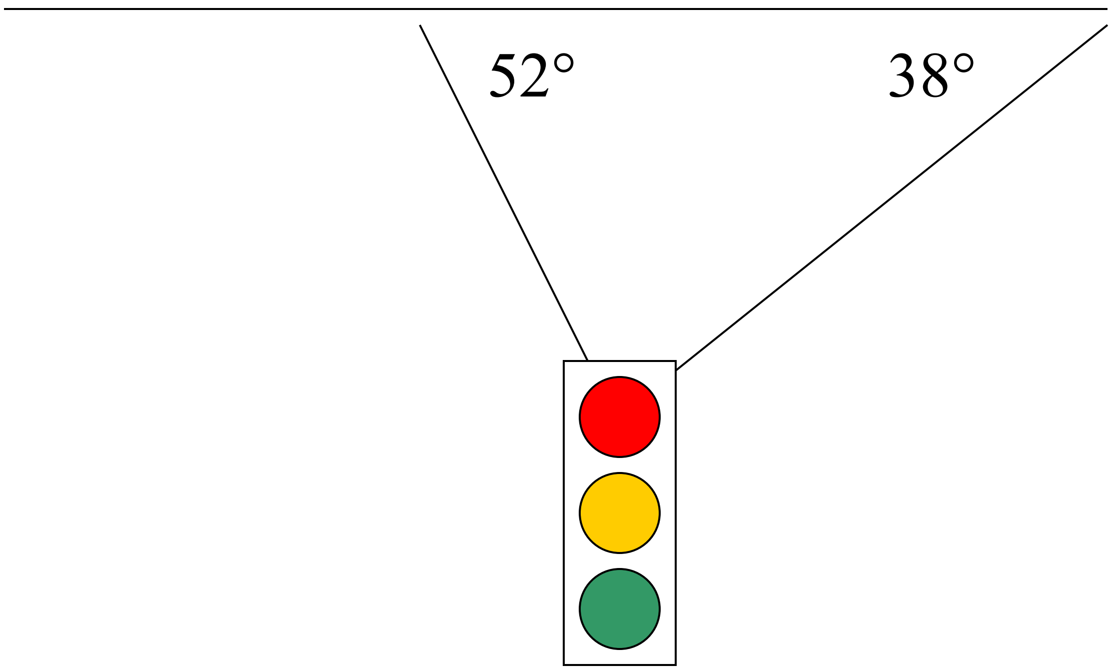
- Draw a free body diagram for this traffic light



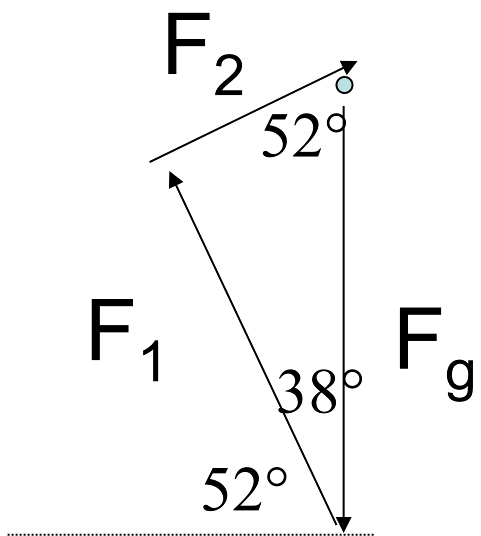


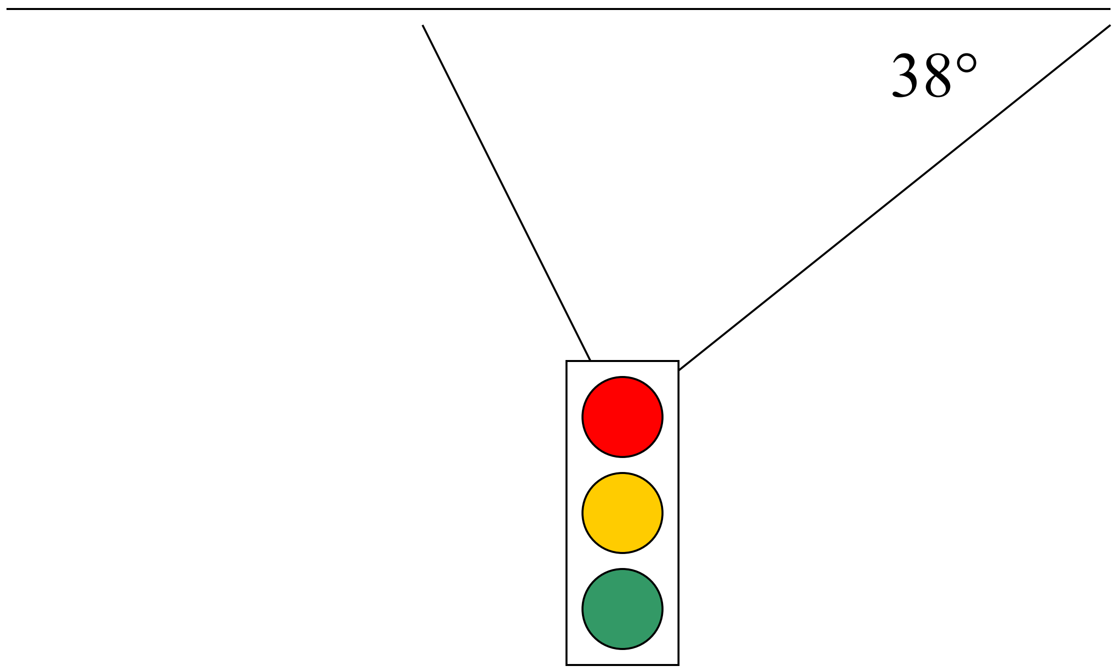
- Find F2 if F1 is 427N of tension





- Find F2 if F1 is 427N of tension
- Equilibrium, so Fg+F1+F2=0
- F2=427/tan52
- F2=334N





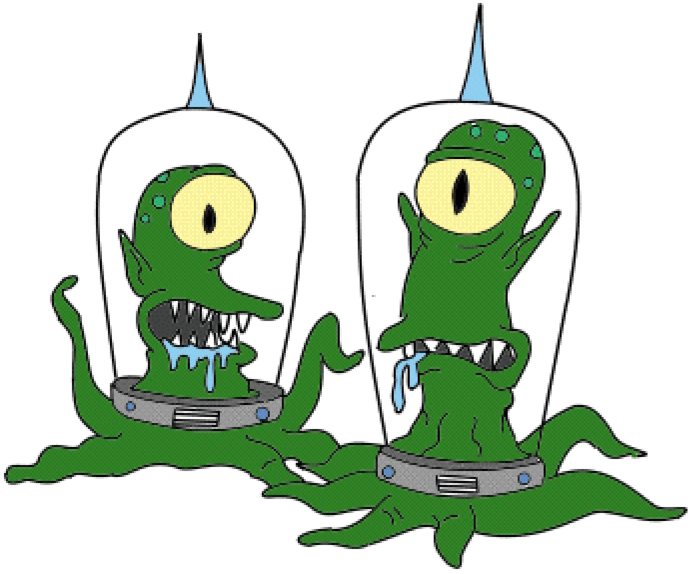
Exercises

- Read p. 31-35
- P. 33-35 #17-21

What if we all [jumped]at once?

Newton’s 1st Law

- Objects with mass have Inertia: the tendency to stay at rest (or moving!)
- The more mass an object has, the more difficult it is to move it (or stop it!)



Percent Difference

$$\%Diff = \frac{Experimental - Theoretical}{Theoretical} \times 100\%$$

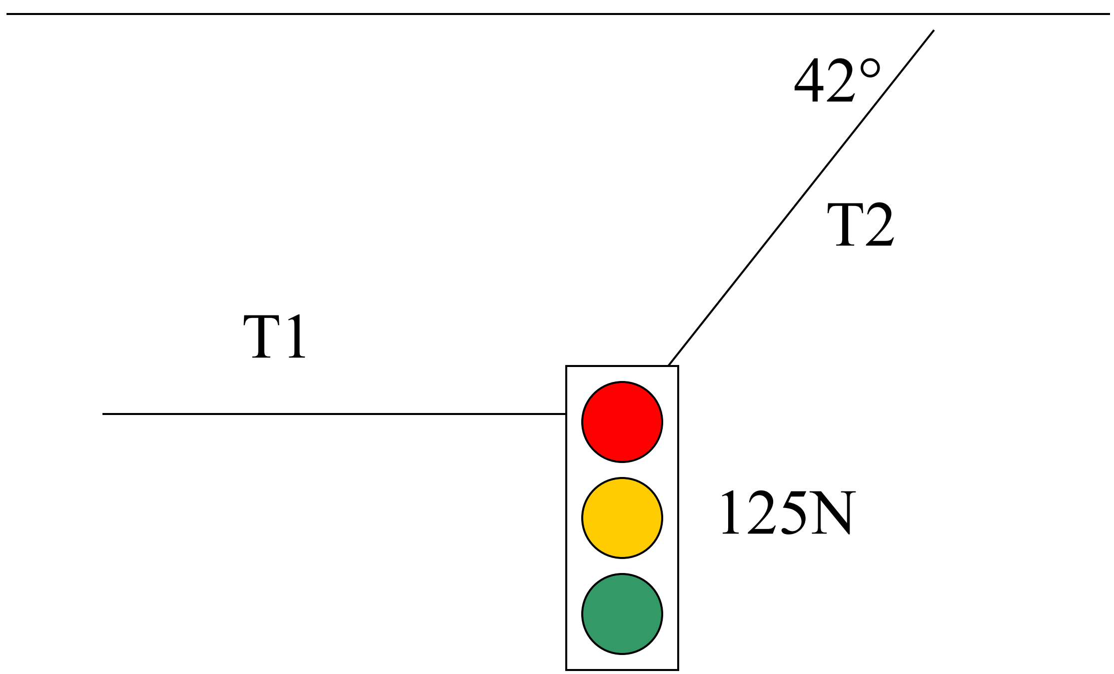
$$\%Diff = \frac{4.64 - 4.9}{4.9} \times 100\% \quad = 5.3\%$$

Evaluation

Your conclusion should describe the results, relevant to the research question (forces and equilibrium), and supported by the data

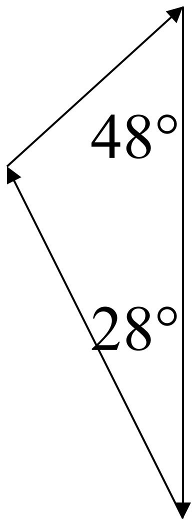
List limitations and sources of error. Address each with suggestions for improvement

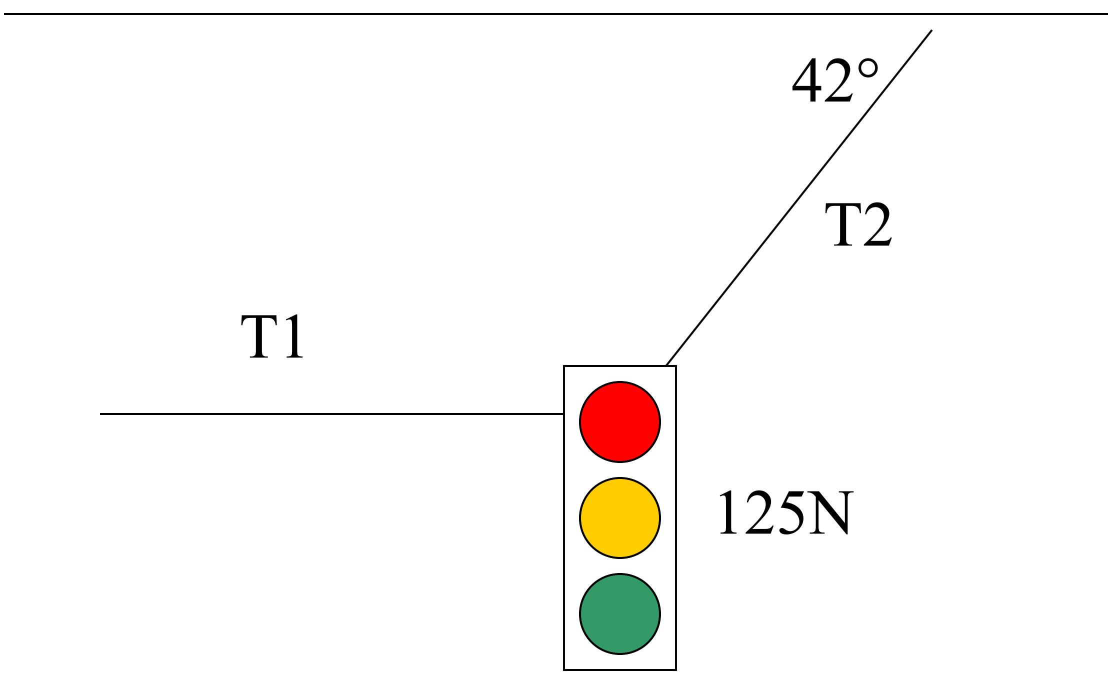
- Mini Quiz:
- 1) Find T2 (3 marks)
- 2) What will happen to the magnitude of T1 if we increase from 42 to a larger angle? (3 marks)



- Mini Quiz: Find T2

$$\frac{\sin 104}{F_g} = \frac{\sin 48}{427N}$$





MOMENTUM IS THE PRODUCT OF MASS AND VELOCITY

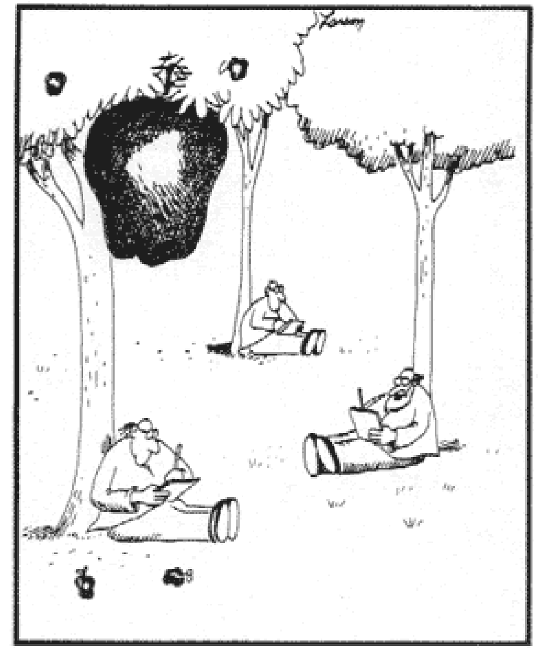
$$p = m \cdot v$$

What is the momentum of a 120 kg rugby player running at 11 m/s?

- p=mv
- p=120kg · 11 m · s^{-1} /s
- p=1320 kg ·m ·s^{-1}

Newton's 2nd Law

- "Impulse": change in momentum



"Nothing yet . . . How about you, Newton?"

$$\text{Impulse} = F\Delta t = \Delta p$$

Can we find the impulse Venus applies to this 57g tennis ball?

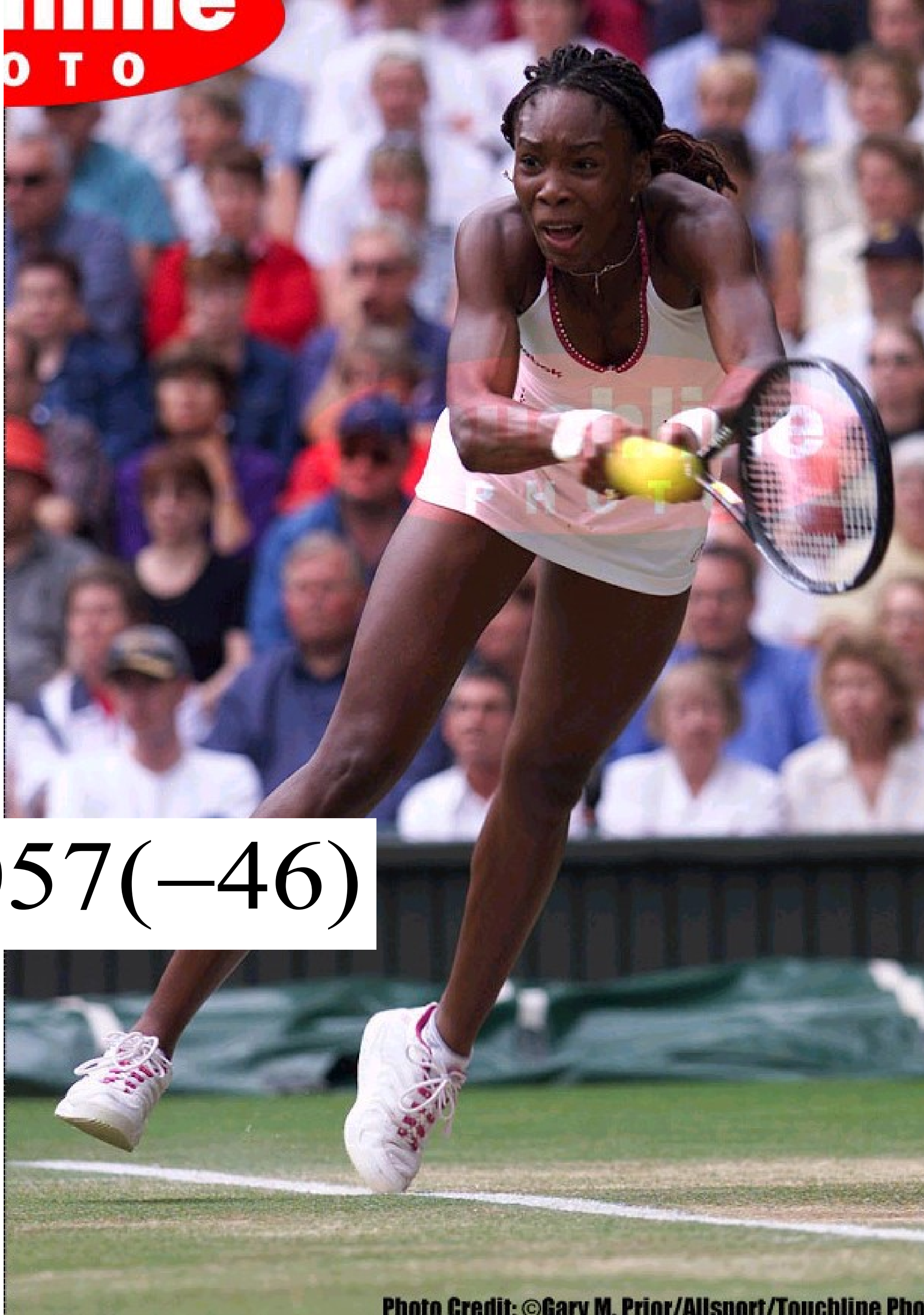
She returns a 46m/s serve at 35m/s

$$\text{Impulse} = \Delta p$$

$$= mv - mu$$

$$= 0.057(35) - 0.057(-46)$$

$$= 4.6 kg \cdot m \cdot s^{-1}$$

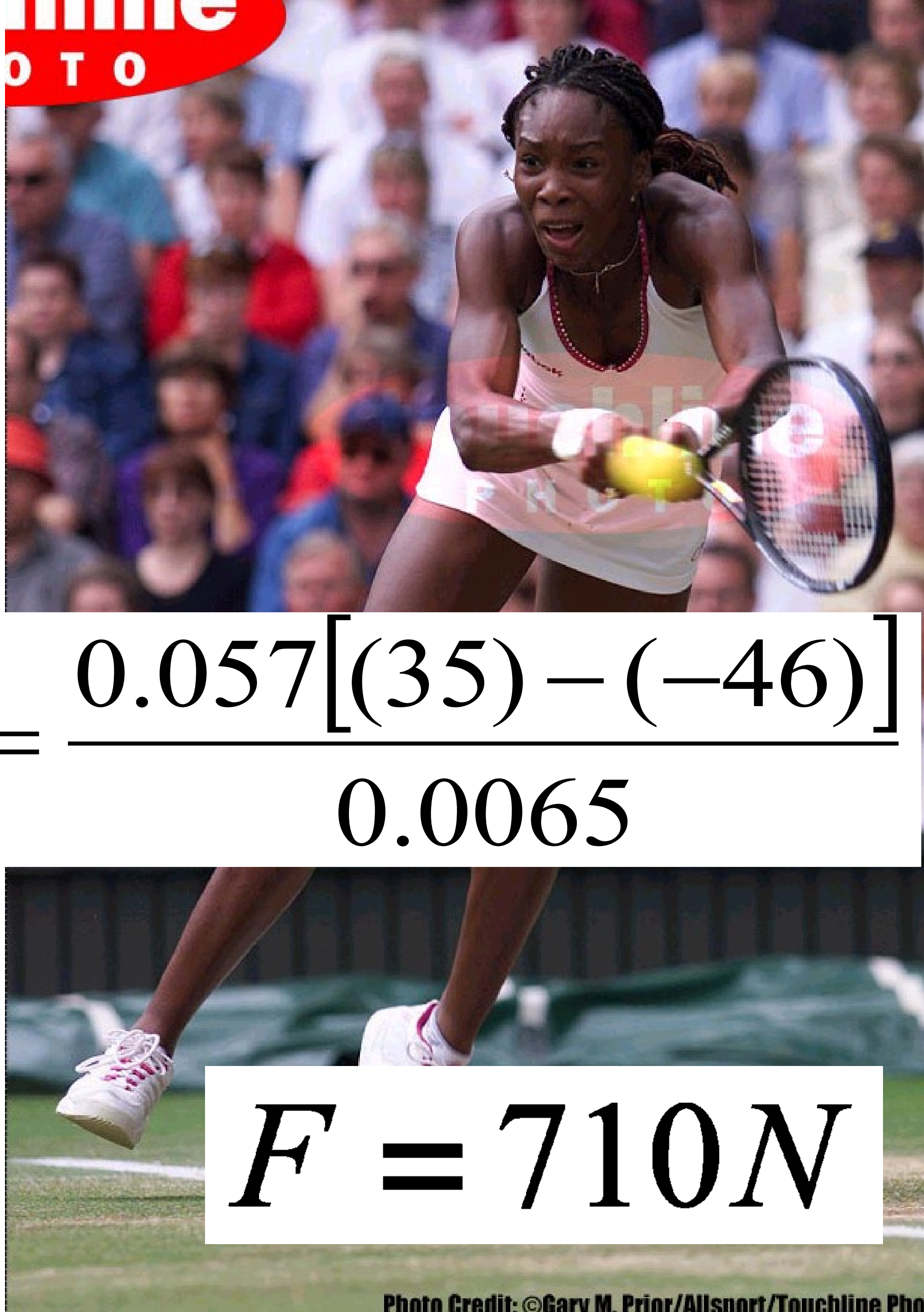


p. 38 #24-25

- Start “Personal Engagement” assignment
  - Using the iPads, write an introductory paragraph for a possible IA topic.
  - Include a research question, and reasons why you chose that particular topic

Can we find the Force [Venus] applies to this 57g tennis ball?

She returns a 46m/s serve at 35m/s and the ball only contacts the racquet for 6.5ms



$$F\Delta t = \Delta p = \frac{0.057\left[(35)-(-46)\right]}{0.0065}$$

$$F = \frac{\Delta p}{\Delta t}$$

$$F = 710N$$

Newton's 2nd Law

- Rearranging the impulse formula gives us:

$$F = ma$$

- Ex 1: how much force is necessary to accelerate a 80kg student at 10 m/s^2?

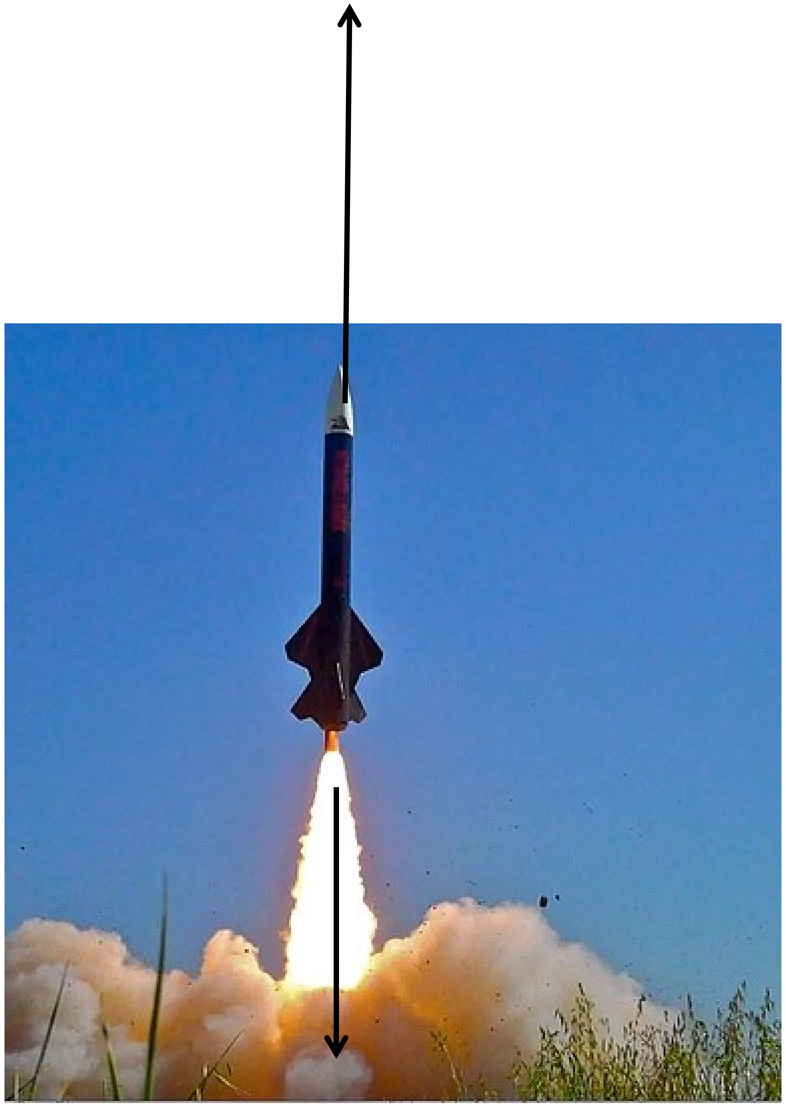
$$F = ma = 80(10) \quad = 800N$$

What do we mean “net” force?

- Net force is zero if there are no *unbalanced* forces
- We usually do not notice forces until they become unbalanced
- Ex. What are the forces acting on a suction cup?

Find the acceleration of
this 300 kg rocket

$$T = 4500N$$



$$W = 2940N$$

$$F = mg = 300 \cdot 9.8$$

$$a = \frac{F}{m}$$

$$a = \frac{4500N + (-2940N)}{300kg}$$

$$a = 5.2m \cdot s^{-2} = \frac{5.2m \cdot s^{-2}}{9.8m \cdot s^{-2}} = 0.53g$$

Find:

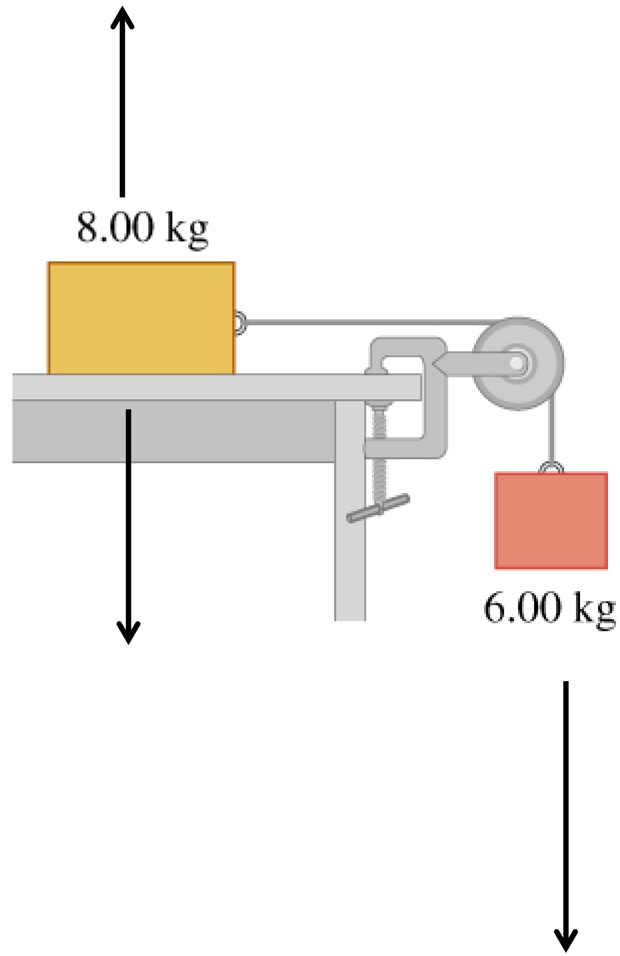
A) the acceleration of these masses, neglecting friction

$$W = mg \quad = 6 \cdot 9.8$$

$$a = \frac{F}{m}$$

$$a = \frac{58.8N}{(8+6)kg}$$

$$a = 4.2 m \cdot s^{-2}$$

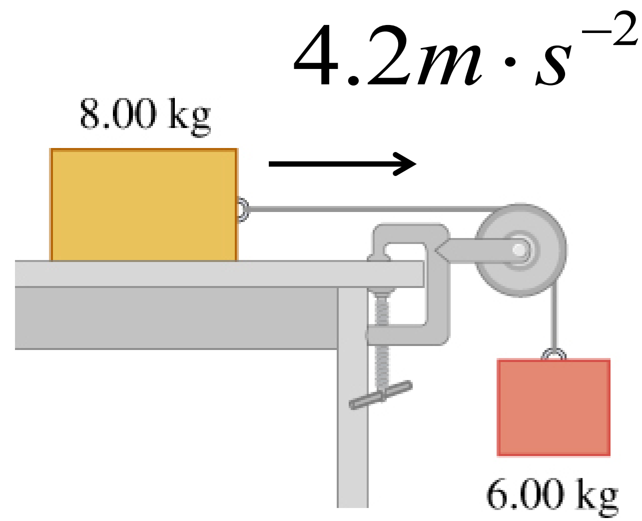


$$58.8N$$

Find:

b) the tension in the string

$$F = ma$$



$$T = 8 \cdot 4.2$$

$$T = 33.6N$$

Find R for this 55 kg elevator passenger

$$F = ma$$

$$W + R = ma$$

$$R = -W + ma$$

$$R = -(-539) + 55(-3.2)$$

$$3.2m \cdot s^{-2}$$

$$R = 363N$$

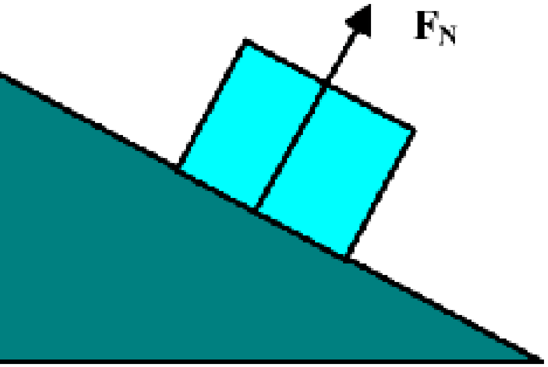
p. 41 #26-31

- Start “Personal Engagement” assignment
  - Using the iPads, write an introductory paragraph for a possible IA topic.
  - Include a research question, and reasons why you chose that particular topic

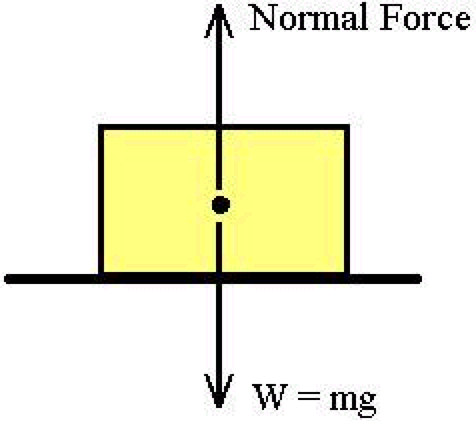
Newton's 3rd Law

- For every action there is an equal and opposite reaction
- When you hit something, it hits back!


DAREK
WIZJA
SPORT



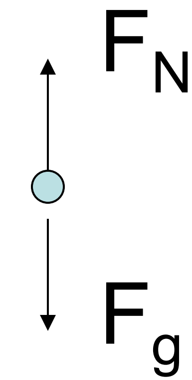
Normal Force



- When an object is in contact with a supporting surface, it pushes down on that surface
- Newton's 3rd Law states the surface pushes back with an equal and opposite force
- This is often (but not always!) equal to the object's weight
- We sometimes refer to Normal force as the "apparent weight"

Simple case: object at rest

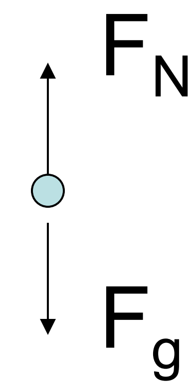
- Ex 3: What is the normal force acting on the 2.5 kg book resting on your desk?
  - What forces act on the book?
    - Gravity and Normal force
  - Free body diagram
  - Apply 2nd law



$$F_{net} = ma = 0$$

$$F_g + F_N = 0$$

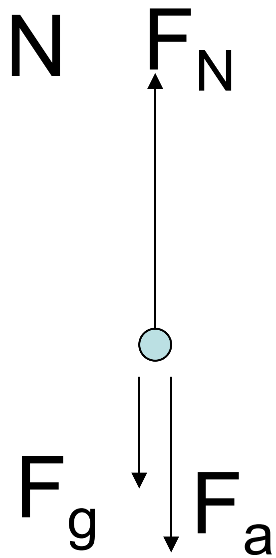
$$F_N = -F_g = -mg$$



$$F_N = -2.5kg \times -9.8 \, {}^{N}\!/\!_{kg} = 24.5N$$

Extended object at rest

- Ex 3: what is the normal force acting on your book as you lean on it with a 35 N force?
  - What forces act on the book?
    - Gravity, Applied and Normal force
  - Free body diagram
  - Apply 2nd law



$$F_{net} = ma = 0$$

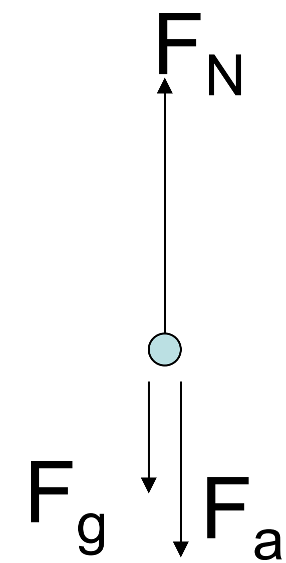
$$F_{net} = ma = 0$$

$$F_g + F_a + F_N = 0$$

$$F_N = -F_g - F_a$$

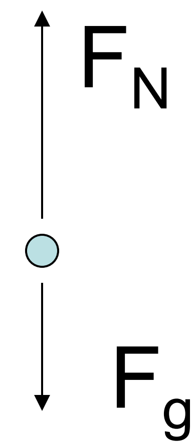
$$F_N = -(-24.5N) - (-35N)$$

$$F_N = 60N$$



Accelerating object

- Ex 4: find the apparent weight of a 50 kg student accelerating upwards at 3.4 m/s^2
  - What forces act on the student?
    - Gravity and Normal force
  - Free body diagram
  - Apply 2nd law

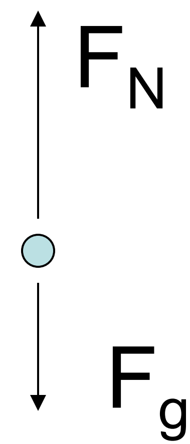


$$F_{net} = ma$$

$$F_N + F_g = ma$$

$$F_N = -F_g + ma$$

$$F_N = -mg + ma$$



$$F_N = -50(-9.8) + 50(3.4)$$

$$F_N = 660N$$

p. 41 #32

GRF “Mini” Quiz

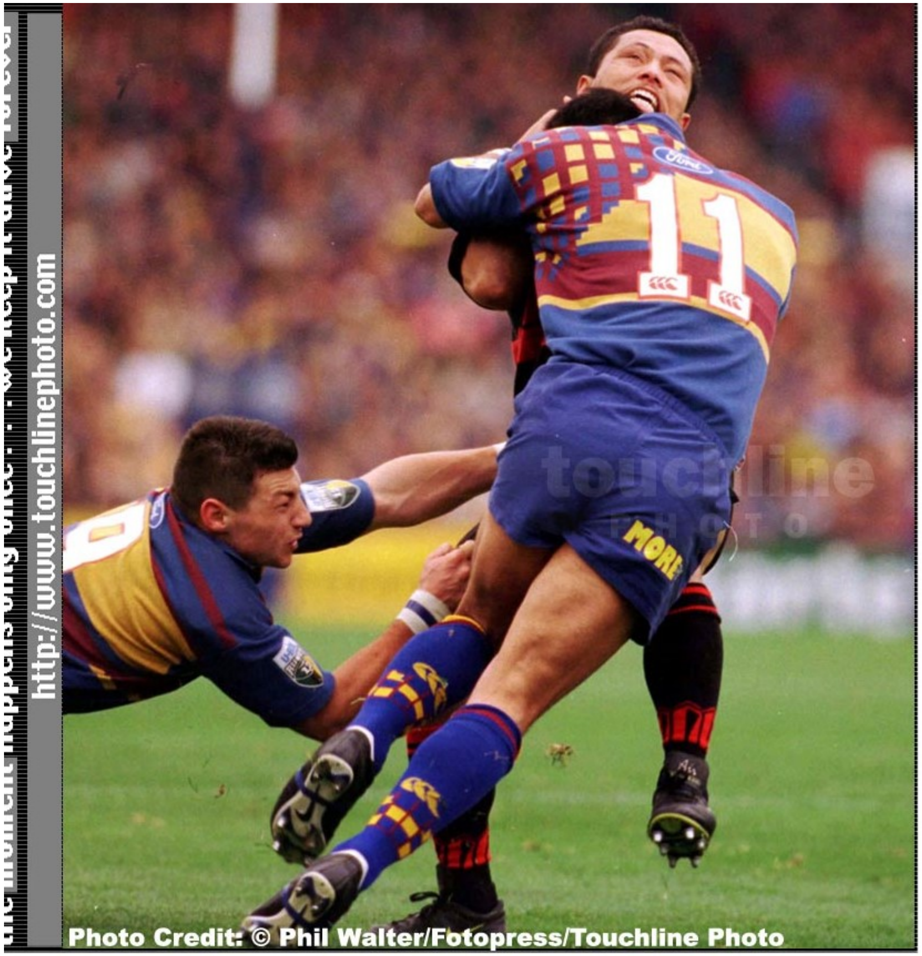
- Use the graph from the force platform to a) identify regions of positive, negative and zero acceleration (4 marks)
- b) Solve for the maximum positive acceleration (3 marks)
- c) What differences would you see on the graph if this hefty fellow gained even more mass over the holidays? (3 marks)

Principle of Momentum Conservation:

- Total momentum before is equal to total momentum after the collision
- This is true for all closed, isolated systems

No one allowed in or out

No net external force



Chabal: timing is everything

Can we use momentum to analyze this collision?

Momentum is conserved so p before must equal p after

- Rokocoko has a mass of 105 kg and runs at 7.5 m/s into 92 kg Betson
- How fast are they moving after the collision?

$$\Delta p = 0$$

$$p = p'$$

$$p_1 + \cancel{p_2} = p_1' + p_2'$$

$$p_1 = p'$$

$$m_1 u_1 = m_T v$$

$$v = \frac{m_1 v_1}{m_T}$$

$$v = 4.0 \, {}^{m}\!/\!{}_{s}$$

Most common physics 11 collision: moving object collides with stationary one; they move off together

Ex: a student with a mass of 105 kg runs at 7.5 m/s into a 92 kg classmate, find v

$$p = p'$$

$$m_1 u_1 = m_T v$$

$$v = \frac{m_1 v_1}{m_T}$$

$$v = 4.0 \, {}^{m}\!/_{s}$$

Same steps every time!

- Variables
- $m_1=$
- $u_1=$
- $m_2=$
- $u_2=$
- $v'=$

$p_i=p_f$

$p_{1+}\ p_2 = p_1'{}_+\ p_2'$

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$m_1u_1 + m_2u_2 = (m_1 + m_2)v?$

$0 = m_1v_1 + m_2v_2?$

For an explosion? Ex: bottle rocket

- Variables
- m_1=0.320 kg
- v_1=?
- m_2=0.850 kg
- v_2=-25 m/s

$p_i=p_f$

$0 = m_1v_1 + m_2v_2$

$m_1v_1 = -m_2v_2$

$v_1 = -m_2v_2/m_1$

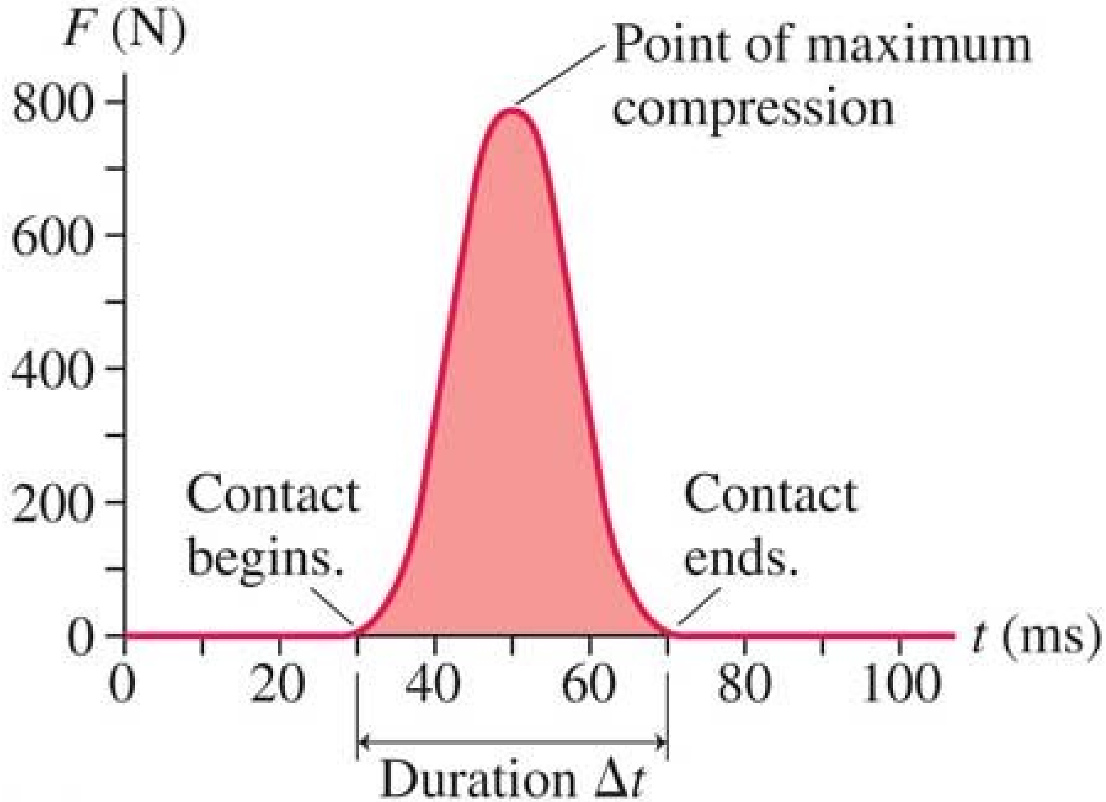
$v_1 = -0.850\text{kg}(-25\text{m/s})/0.320\text{kg}$

$v_1 = 66$ m/s

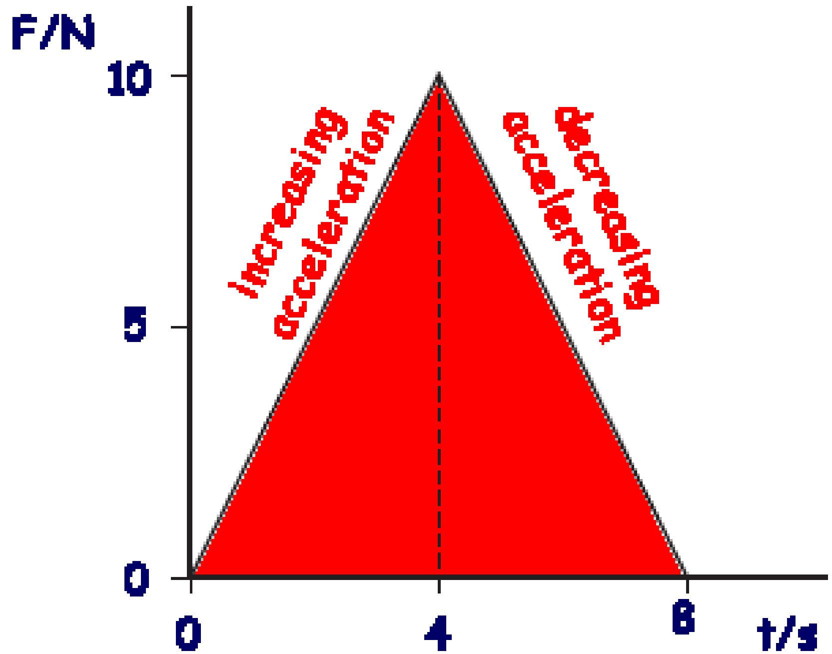
- Try p. 46 #33, 34

Area under the graph

- This should give impulse



Ex: a) Find the impulse



b) Find the change in velocity of the 0.32 kg ball

- Finish p. 46 #33, 34