# Kinematics

# Newton's Laws of Motion

- **1st Law**: The velocity of an object will not change unless acted upon by a force

$$\Sigma\vec{F}=0 \quad \Sigma\vec{\tau}=0$$

- **2nd Law**: The net force on an object is equal to the rate of change of momentum

$$\vec{F}=\frac{d\vec{p}}{dt}=m\vec{a} \qquad \vec{\tau}=\frac{d\vec{L}}{dt}=I\vec{\omega}$$

$$\int\vec{F}dt=\vec{J}=\Delta\vec{p} \qquad \int\vec{\tau}dt=Ang\vec{J}=\Delta\vec{L}$$

- **3rd Law**: For every force there is an equal but opposite force

# Newton's First Law -- Statics

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

$$\Sigma \vec{\tau} = 0$$

**Long Range Forces**

Act on the center of gravity

1) Gravitational Force
2) Electrical Force

**Contact Forces**

Act the point of contact

Consider every point of Contact

1) Normal Forces (Perpendicular to Surface)
   Can take any value needed
2) Frictional Forces (Parallel to surface)
   Can take any value up to $\mu_s N$
   Dynamic friction = $\mu_D N$

No Motion
or
Constant Motion

Do sample problems here

# Newton’s First Law -- Statics

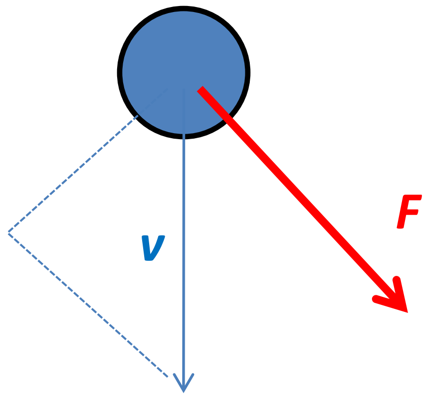

# Newton's Second Law -- Dynamics

$$\Sigma\vec{F} = \frac{d\vec{p}}{dt} = m\vec{a}$$

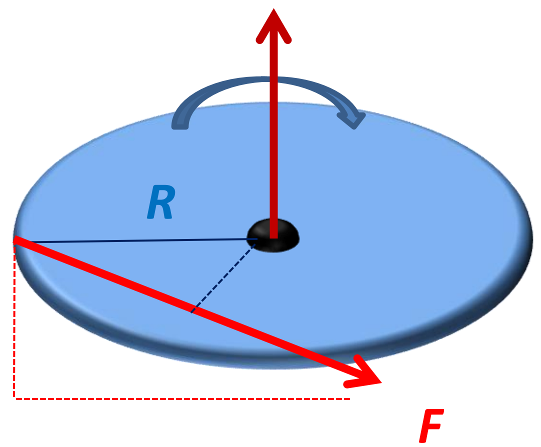
$$\Sigma\vec{\tau} = \frac{d\vec{L}}{dt} = I\vec{\omega}$$

$$\int \Sigma\vec{F}dt = \vec{J} = \Delta\vec{p}$$

$$\int \Sigma\vec{\tau}dt = Ang\vec{J} = \Delta\vec{L}$$




Talk about vectors




When do we use force/torque? When do we use impulse?

# Constant Acceleration

| Rotational Motion ($\alpha$ = constant) | Linear Motion (a = constant) |
|---|---|
| $\omega = \omega_0 + \alpha t$ | $v = v_0 + at$ |
| $\theta = (1/2)(\omega_0 + \omega)t$ | $y = (1/2)(v_0 + v)t$ |
| $\theta = \theta_0 + \omega_0 t + (1/2)\alpha t^2$ | $y = y_0 + v_0 t + (1/2)at^2$ |
| $\omega^2 = \omega_0^2 + 2\alpha\theta$ | $v^2 = v_0^2 + 2ay$ |

# Applying the Kinematics Equations

1) Make a drawing to represent the system being studied

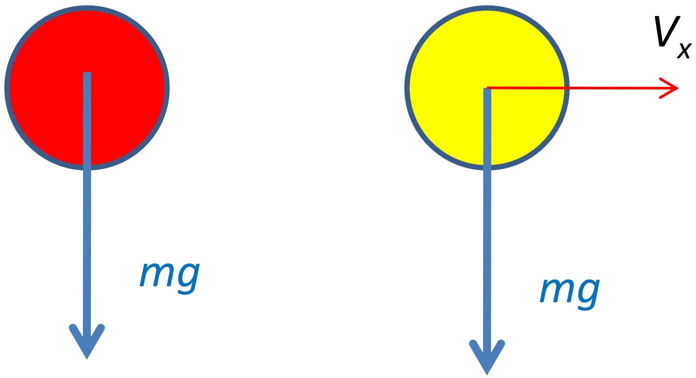
2) Decide which directions will be called positive and which negative

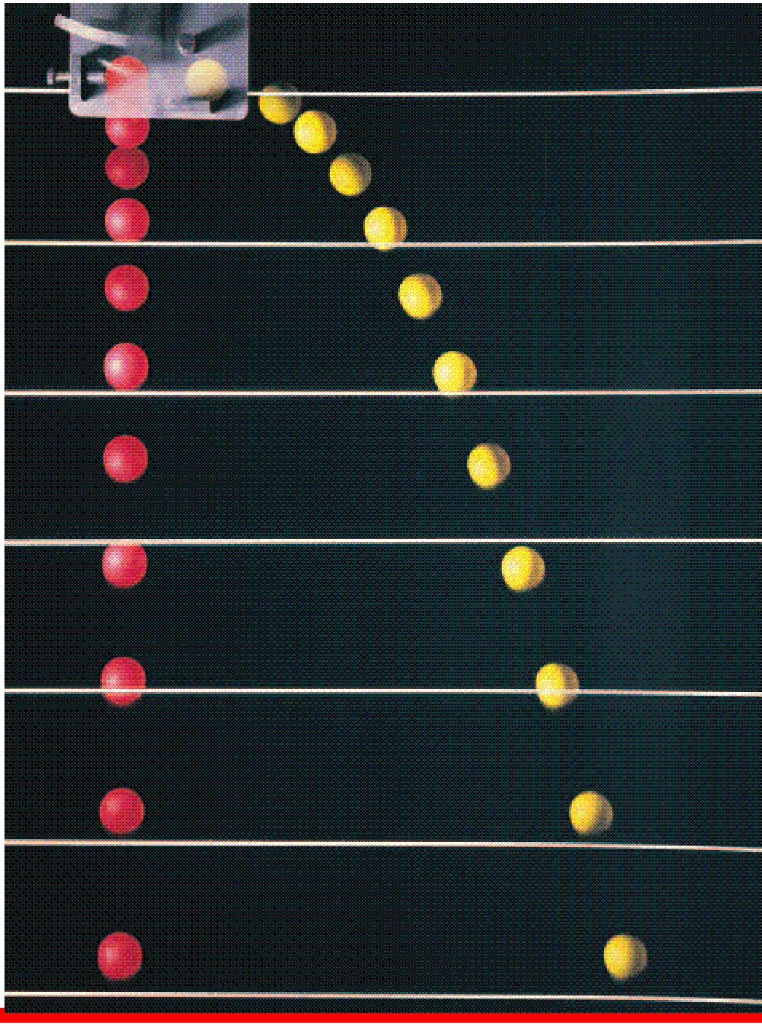
3) In an organized way, write down the values for any of the kinematic variables (*x, y, v , a, t* and initial values). Be alert for the *implied meaning* in the phrasing of the problem. For example, the phrase "starts at rest" implies that $v_0 = 0$.

4) Determine which equation will provide the required answer using the information given.

# Independence of Directions

Demo: Ball Drop



$$x = x_0 + v_{x0}t + (1/2)a_x t^2$$

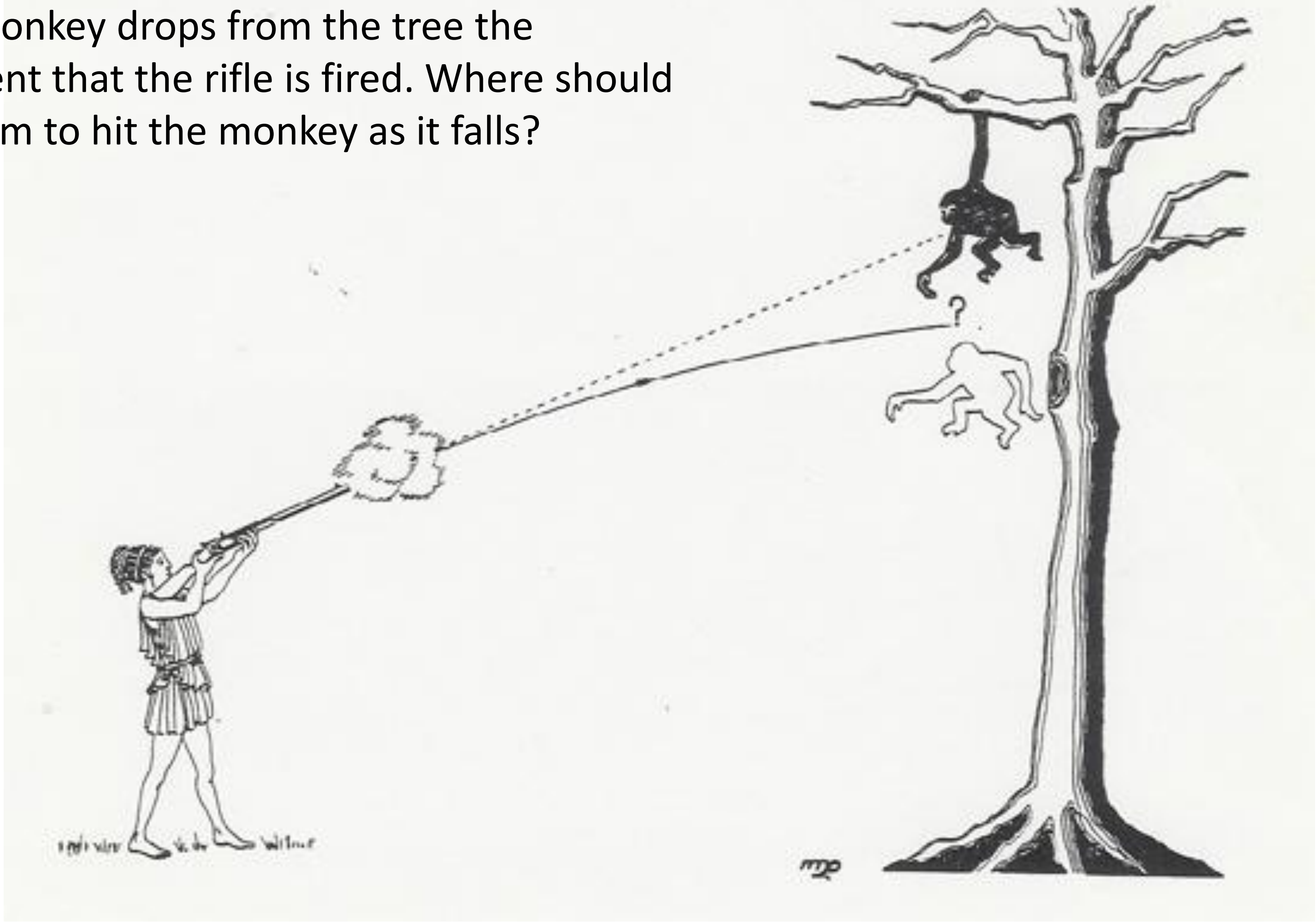
$$x = x_0 + v_{x0}t + (1/2)a_x t^2$$

$$y = y_0 + v_{y0}t + (1/2)a_y t^2$$

$$F = mg = ma_y$$

# The Monkey Hunter

The monkey drops from the tree the moment that the rifle is fired. Where should one aim to hit the monkey as it falls?

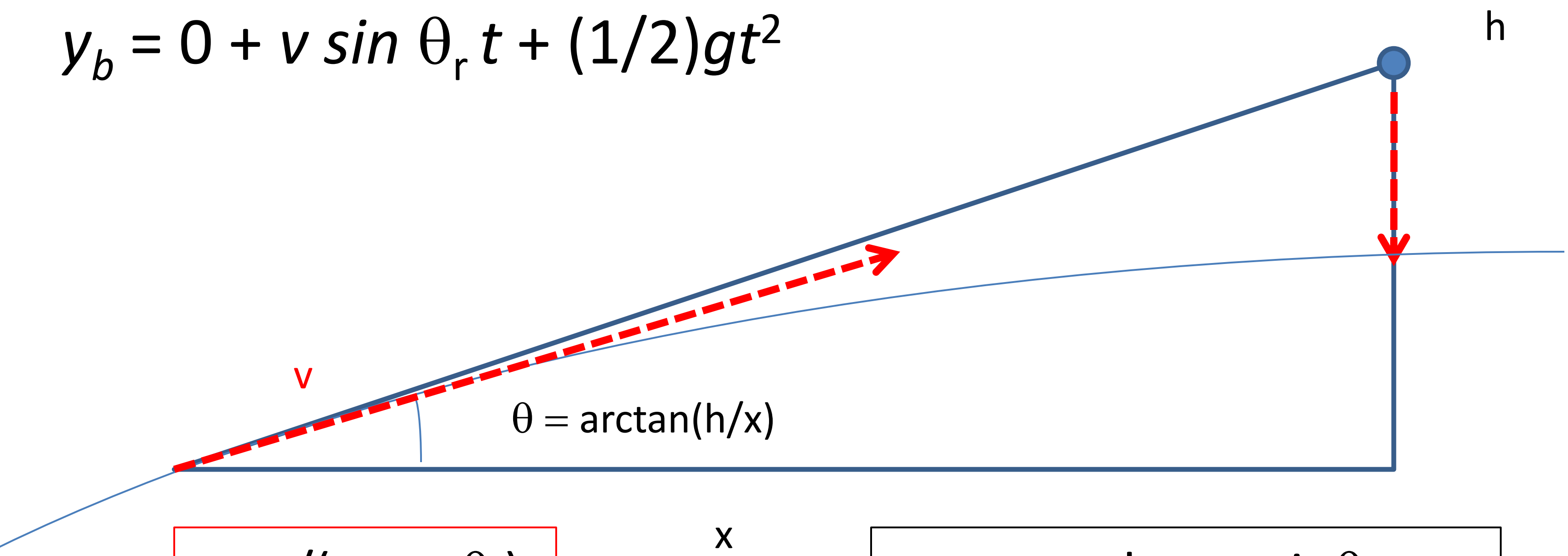


# The Monkey Hunter

$y_m = h + \cancel{v_{y0}} t + (1/2)gt^2$

DEMO: Monkey Hunter

$y_b = 0 + v \sin \theta_r t + (1/2)gt^2$




$t = x/(v \cos \theta_r)$

$y_b = y_m \rightarrow h = vt \sin\theta_r$
$\sin\theta_r = (h/vt) = (h/x)\cos\theta_r$
$\tan\theta_r = h/x$

# Maximum Trajectory

A projectile will follow a parabolic trajectory.
Which firing angle will travel the furthest?

Demo: Water Rockets

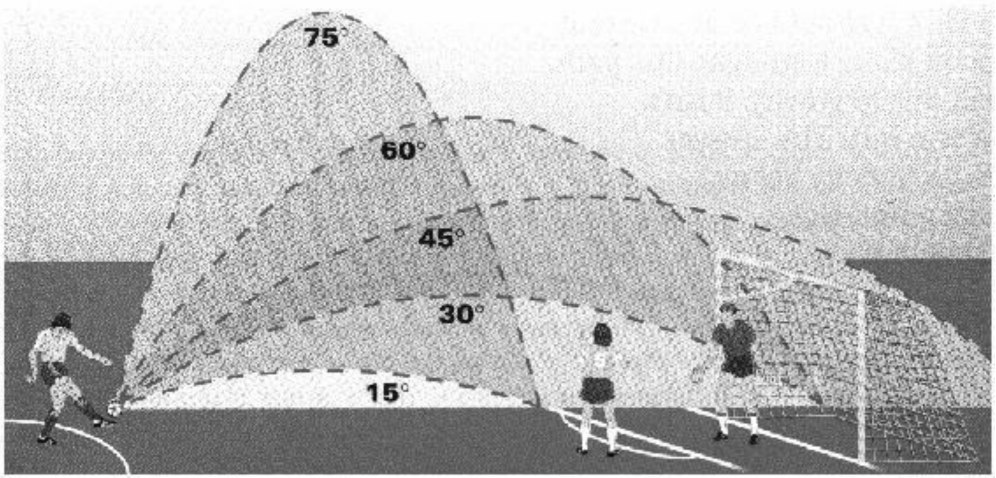
Flight time:

$$y = y_0 + v_{y0}t + (1/2)a_y t^2 \Rightarrow 0 = 0 + v \sin\theta\, t - (1/2)gt^2 \Rightarrow t = (2v/g)\sin\theta$$

Distance traveled:

$$x = x_0 + v_{x0}t + (1/2)a_x t^2 \Rightarrow$$
$$x = 0 + v \cos\theta\, t + 0$$
$$x = v^2\, 2\sin\theta\cos\theta/g$$
$$x = v^2 \sin(2\theta)/g$$

Maximum range when $\theta$=45

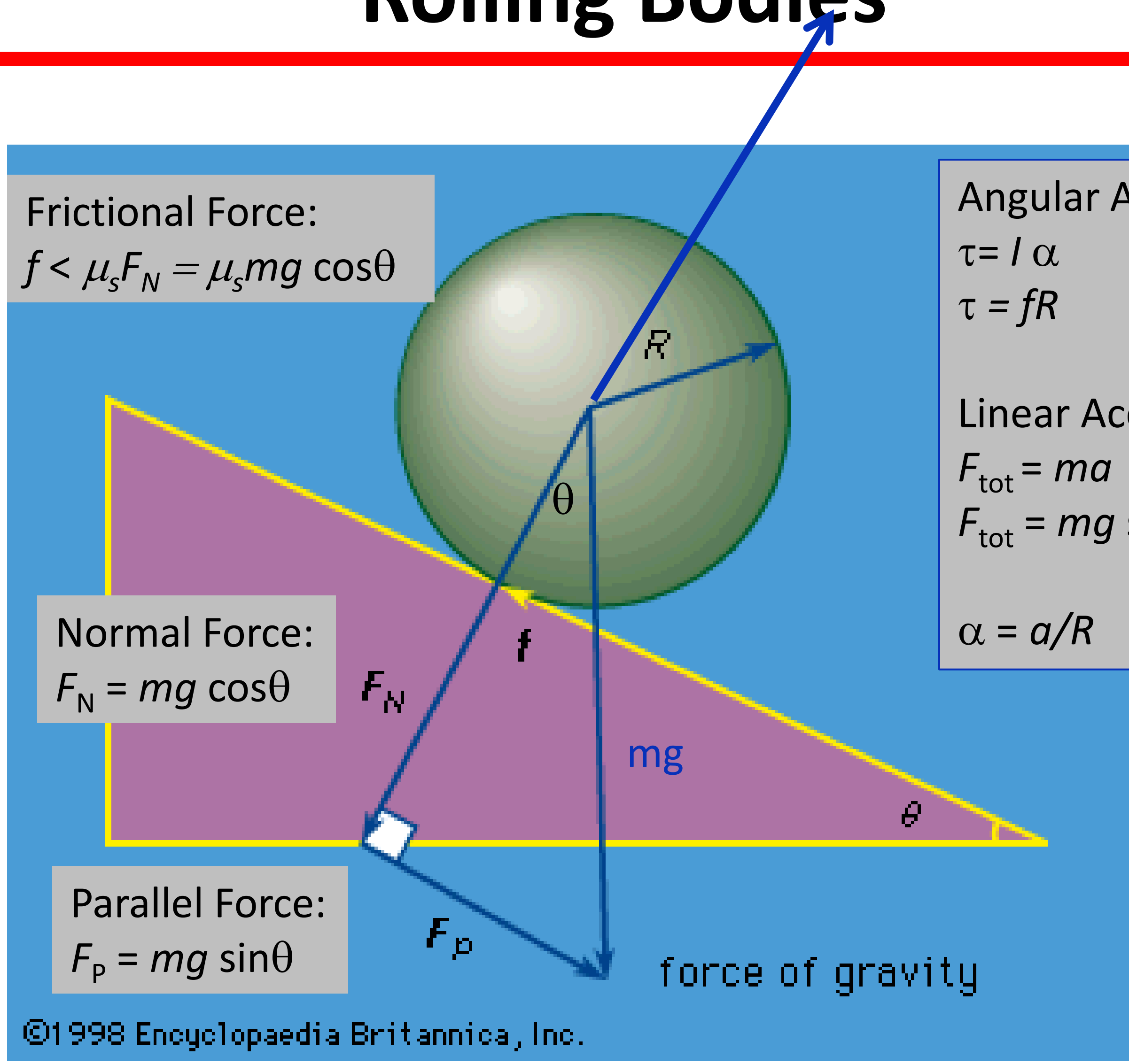


# Rolling Bodies

**Frictional Force:**
$f < \mu_s F_N = \mu_s mg \cos\theta$

**Normal Force:**
$F_N = mg \cos\theta$

**Parallel Force:**
$F_P = mg \sin\theta$




**Angular Acceleration**
$\tau = I\,\alpha$
$\tau = fR$

**Linear Acceleration**
$F_{tot} = ma$
$F_{tot} = mg \sin\theta - f$

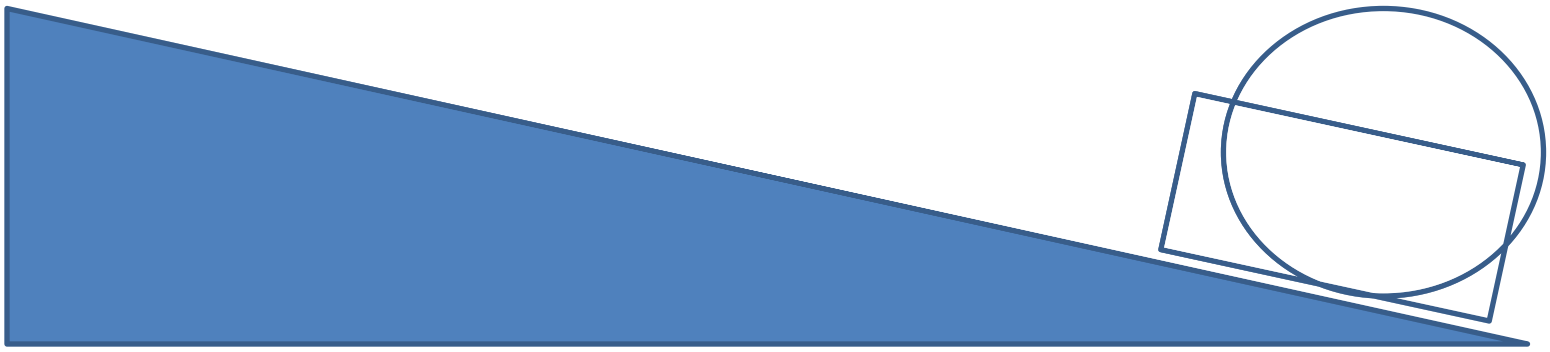
$\alpha = a/R$

# Inclined Planes

Which will go higher? A hoop or a frictionless puck?

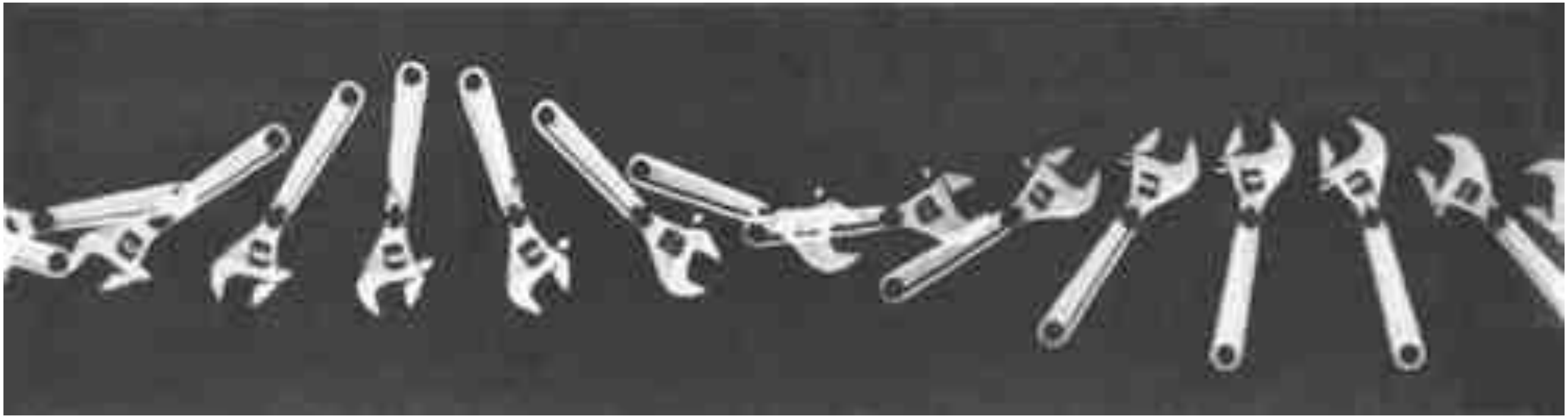
Linear motion: $s = 0 + v_0 t - (1/2)\,((mg \sin\theta - f)/m)\,t^2$

Demo: Inclined Planes



Consider conservation of energy

# Rotating Projectiles

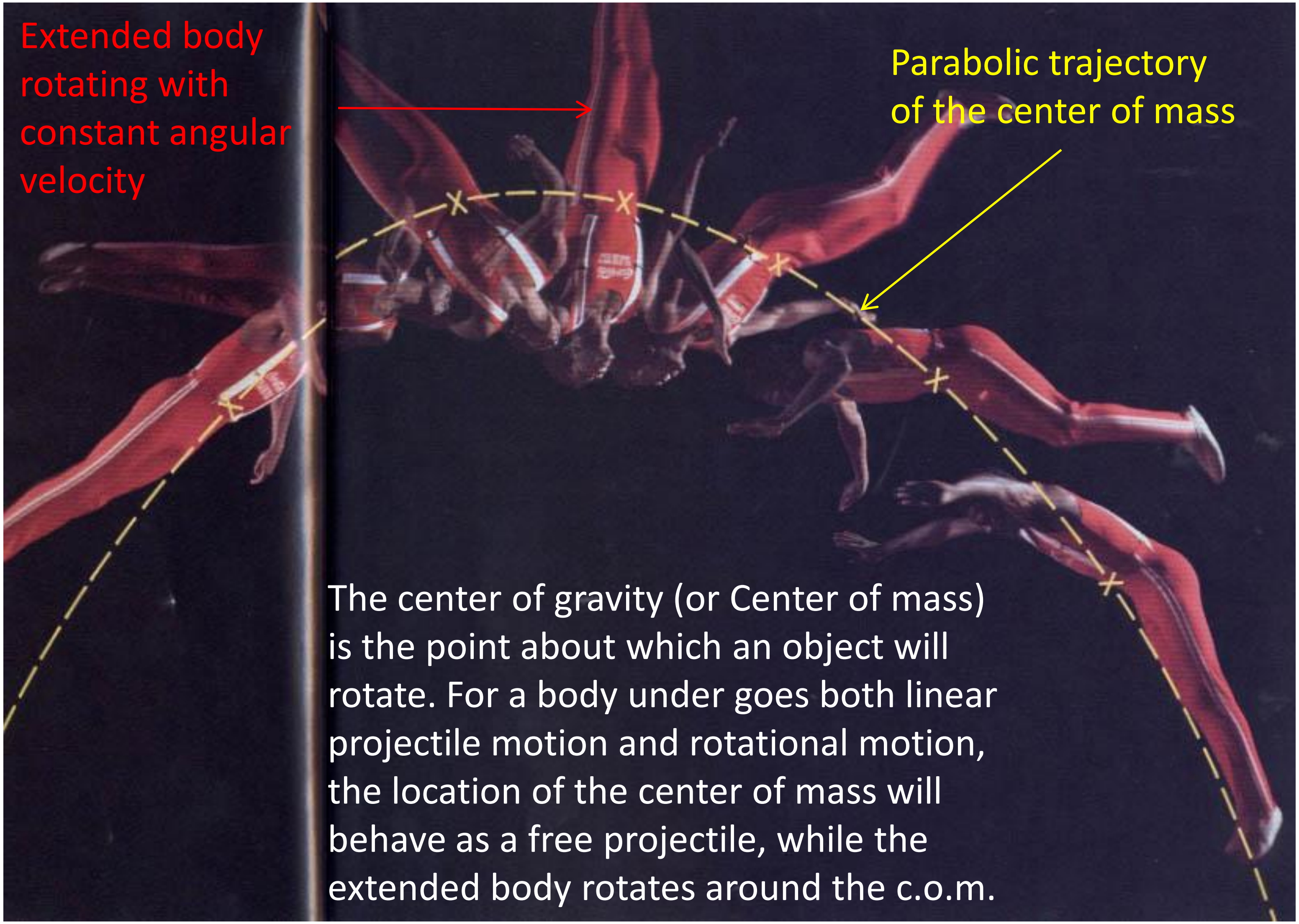


A body can rotate about a fixed pivot point.

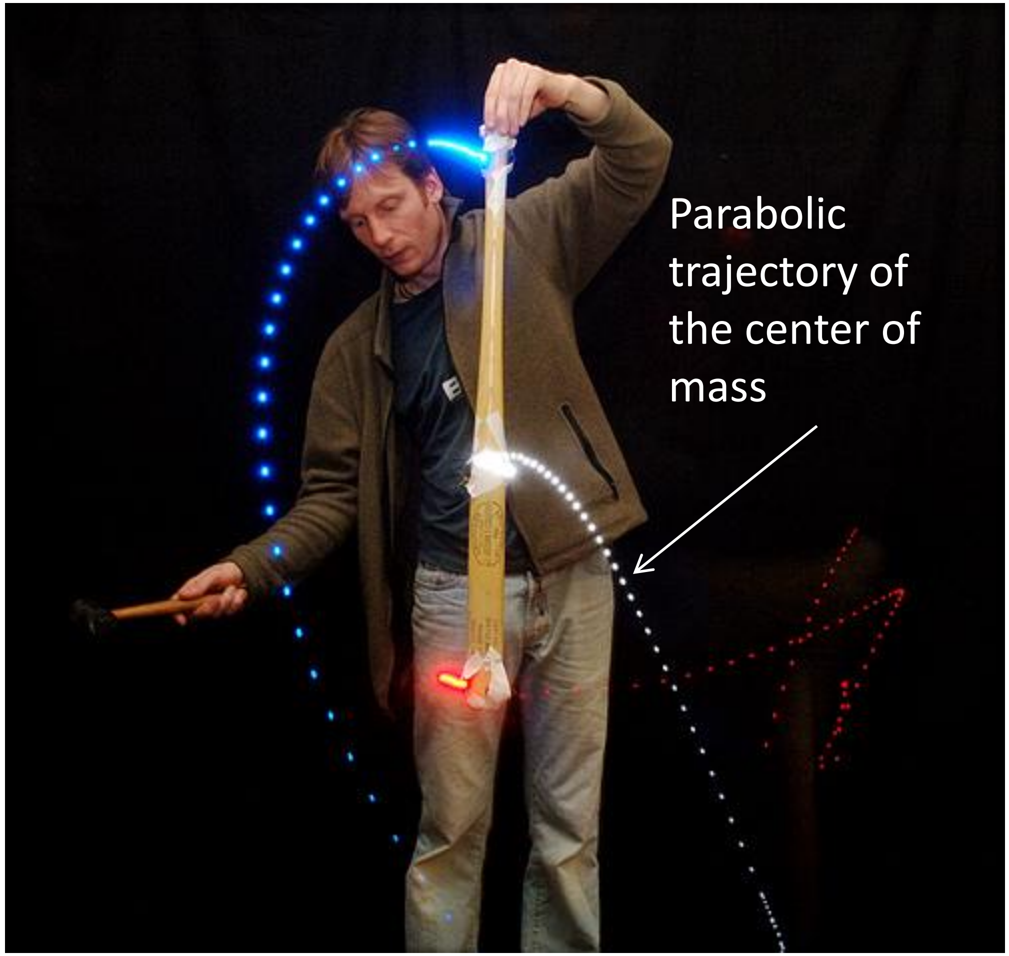
A free body rotates about it center of gravity

DEMO: Center of Gravity

# Center of Gravity

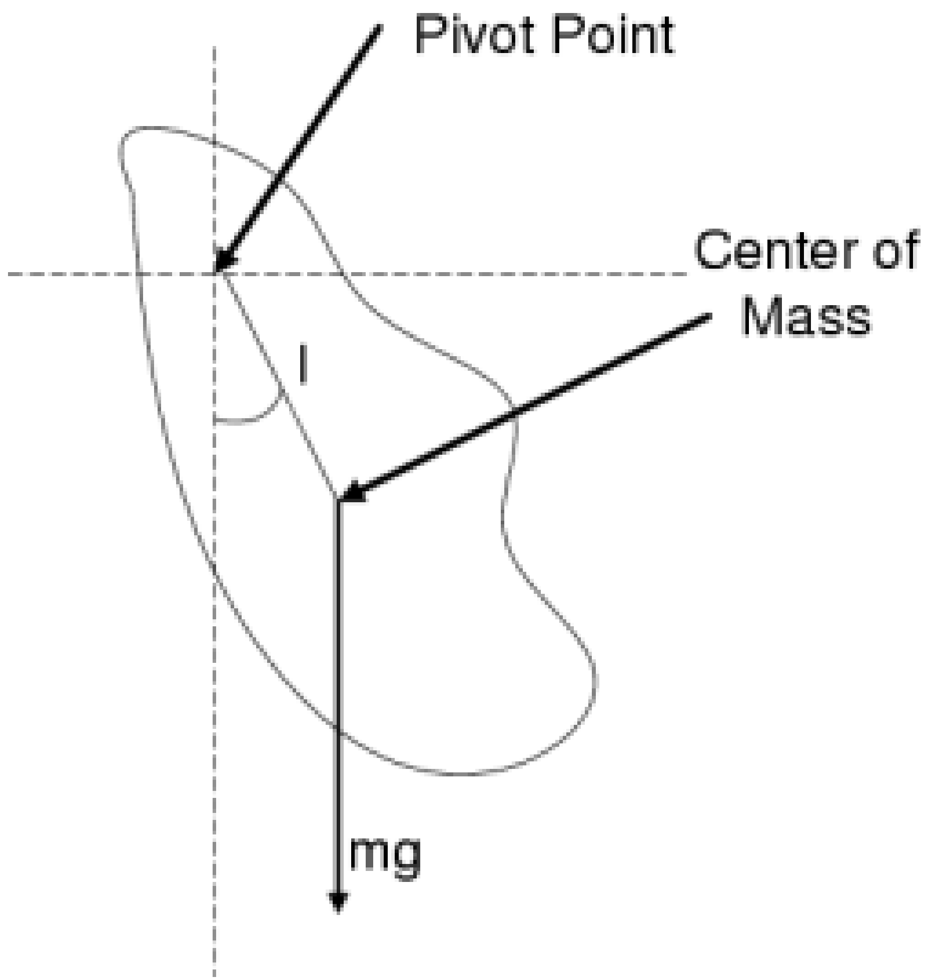


# Center of Gravity

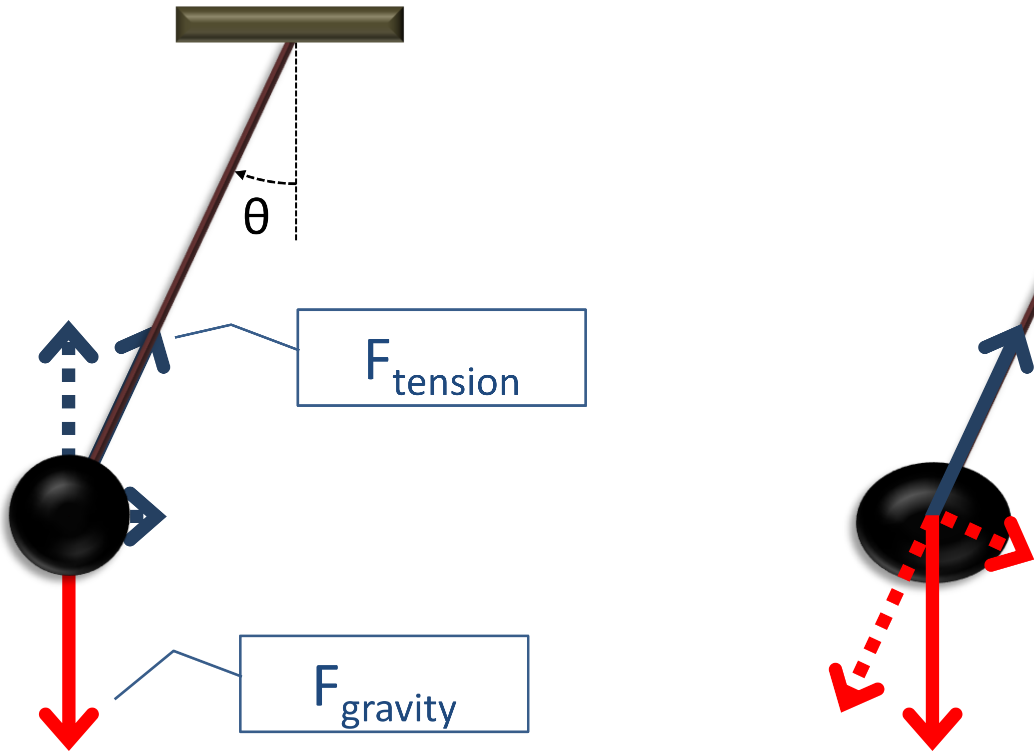



Angular impulse

# Rotating Off Axis



# Pendulum System




$$F_{Net} = mg\sin\theta$$

$$F_{tensionX} = F_{tension}\sin\theta$$

$$F_{tensionY} = F_{tension}\cos\theta$$

$$F_{gravityT} = F_{gravity}\sin\theta = mg\sin\theta$$

$$F_{gravityR} = F_{gravity}\cos\theta = mg\cos\theta$$

# Announcements

The final exam will be Wednesday March 17th 3:30 – 5:30

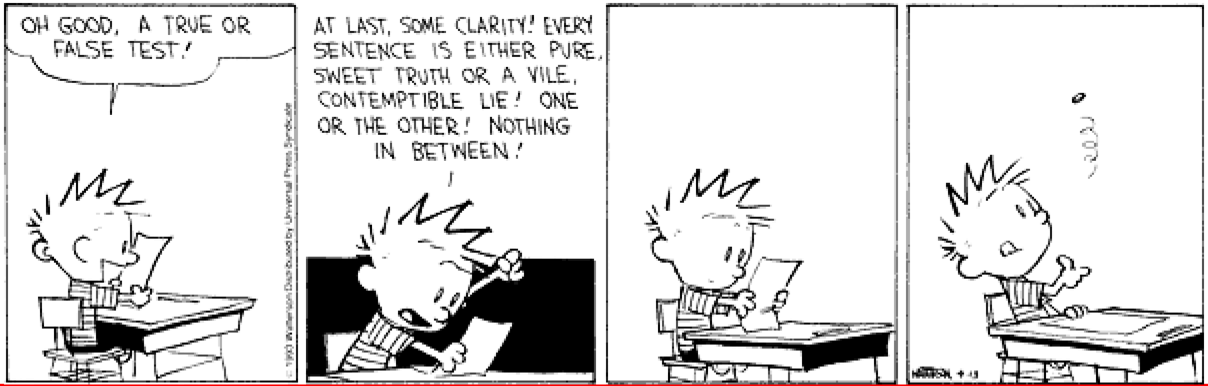
Bring a student ID with picture

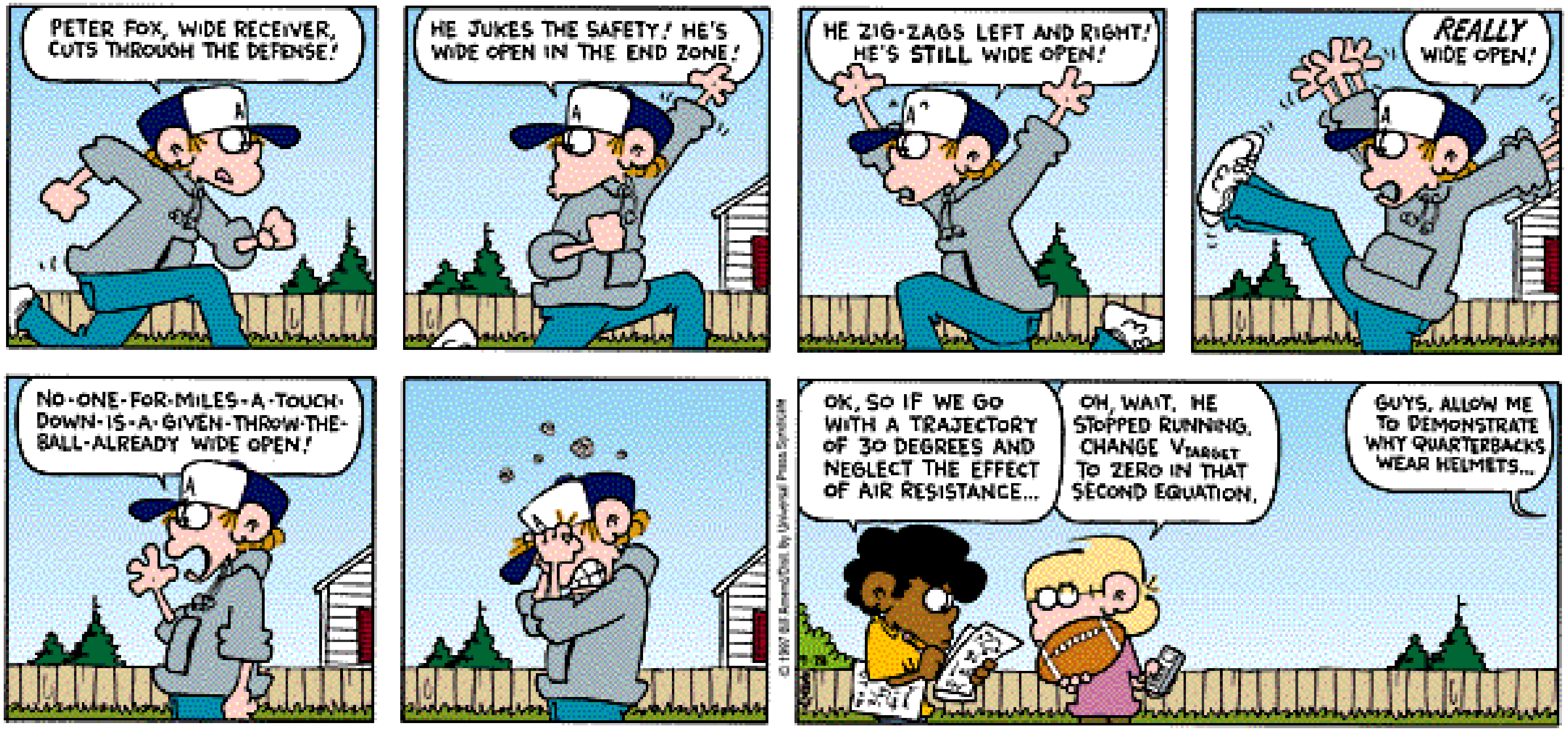
| Final Exam Room | Last Name Begins With: |
|---|---|
| 198 Young | N - Z |
| 1100 Social Sciences | C - M |
| 55 Roessler | A - B |

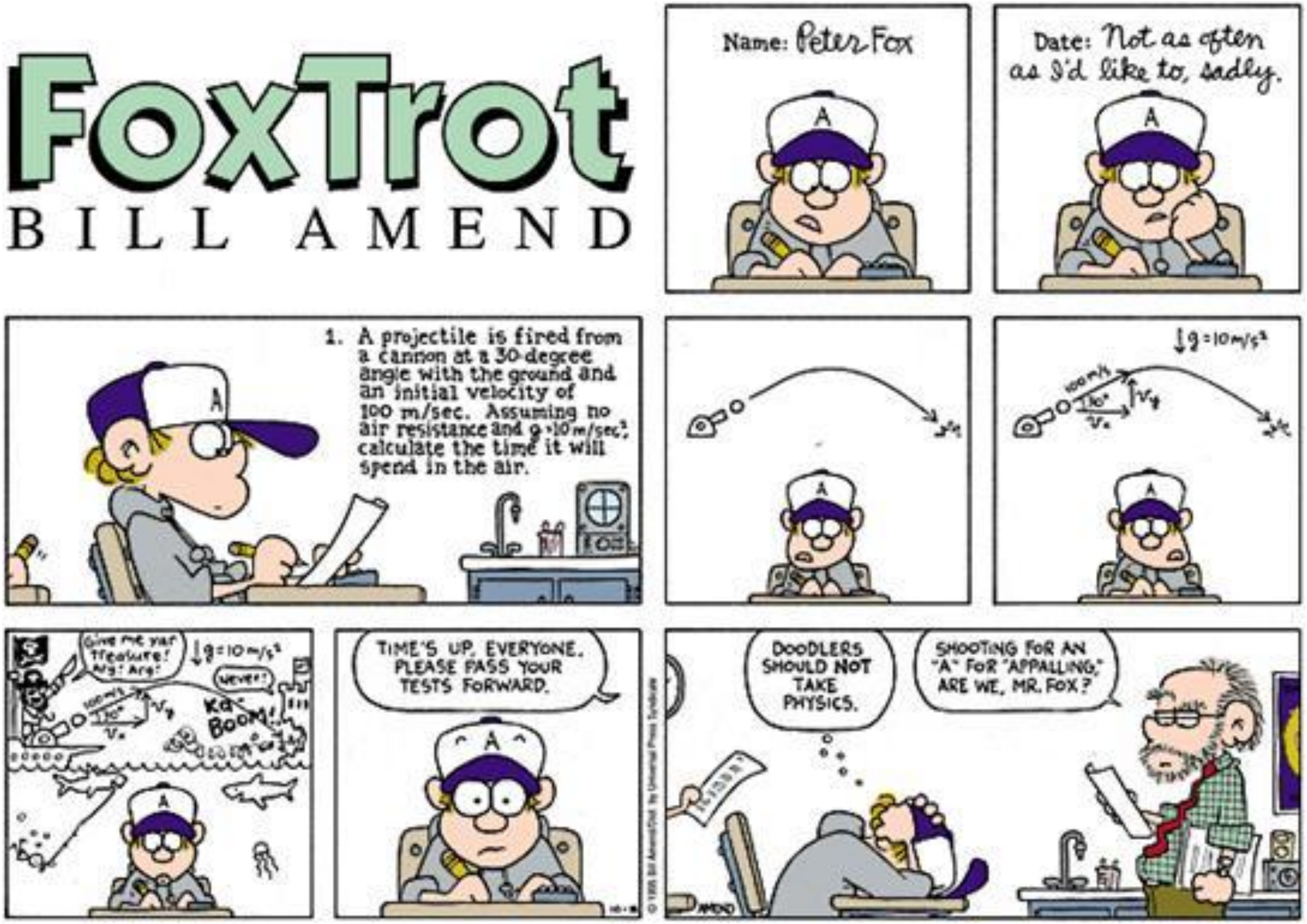
# DL Sections

## Winter 2010 7B-1 (A/B) D/L Assignments & Job Responsibilities

| | | | | |
|---|---|---|---|---|
| 1 | WF | 10:30-12:50 | 2317 EPS | Marcus Afshar |
| 2 | MW | 2:10-4:30 | 2317 EPS | Aaron Hernley |
| 3 | MW | 4:40-7:00 | 2317 EPS | Rylan Conway |
| 4 | MW | 7:10-9:30 | 2317 EPS | Rylan Conway |
| 5 | MR | 8:00-10:20 | 2317 EPS | Robert Lynch |
| 6 | TR | 10:30-12:50 | 2317 EPS | Aaron Hernley |
| 7 | R | 2:10-4:30 | 2317 EPS | Justin Dhooghe |
| 7 | M | 10:30-12:50 | 2317 EPS | Justin Dhooghe |
| 8 | TR | 4:40-7:00 | 2317 EPS | Britney Rutherford |
| 9 | TR | 7:10-9:30 | 2317 EPS | Britney Rutherford |
| 10 | TF | 8:00-10:20 | 2317 EPS | Emily Ricks |
| 11 | TF | 2:10-4:30 | 2317 EPS | Justin Dhooghe |




PETER FOX, WIDE RECEIVER, CUTS THROUGH THE DEFENSE!
HE JUKES THE SAFETY! HE'S WIDE OPEN IN THE END ZONE!
HE ZIG-ZAGS LEFT AND RIGHT! HE'S STILL WIDE OPEN!
REALLY WIDE OPEN!
NO-ONE-FOR-MILES-A-TOUCH-DOWN-IS-A-GIVEN-THROW-THE-BALL-ALREADY WIDE OPEN!
OK, SO IF WE GO WITH A TRAJECTORY OF 30 DEGREES AND NEGLECT THE EFFECT OF AIR RESISTANCE...
OH, WAIT, HE STOPPED RUNNING. CHANGE $V_{TARGET}$ TO ZERO IN THAT SECOND EQUATION.
GUYS, ALLOW ME TO DEMONSTRATE WHY QUARTERBACKS WEAR HELMETS...


FoxTrot
BILL AMEND
Name: Peter Fox
Date: Not as often as I'd like to, sadly.
1. A projectile is fired from a cannon at a 30-degree angle with the ground and an initial velocity of 100 m/sec. Assuming no air resistance and g=10 m/sec², calculate the time it will spend in the air.
↓g=10m/s²
100 m/s
30°
$V_x$
$V_y$
Give me yar Treasure! Arg! Arg!
Never!
Ka-BOOM!
TIME'S UP, EVERYONE. PLEASE PASS YOUR TESTS FORWARD.
DOODLERS SHOULD NOT TAKE PHYSICS.
SHOOTING FOR AN "A" FOR "APPALLING," ARE WE, MR. FOX?