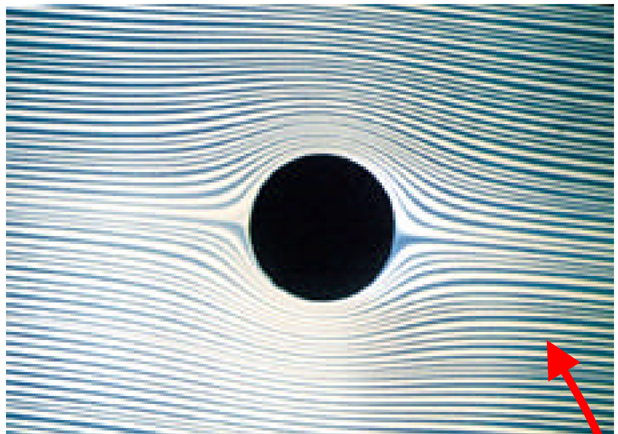
Information

- **Lecture today**
  - ◆ **Complete Ch 6 on Force and Motion**
  - ◆ **Begin Ch 7 on Work and Energy**
- **Exam in one week will emphasize material up <u>through chapter 6</u>. Chapter 7 material (work, energy, …) will <u>not</u> be on the first midterm.**
- **Mention again at end of lecture**

review

Fluid Drag Forces

- **Nonviscous flow = no drag force**
- **Viscous but laminar**
  - η=viscosity
- **Viscous and turbulent**

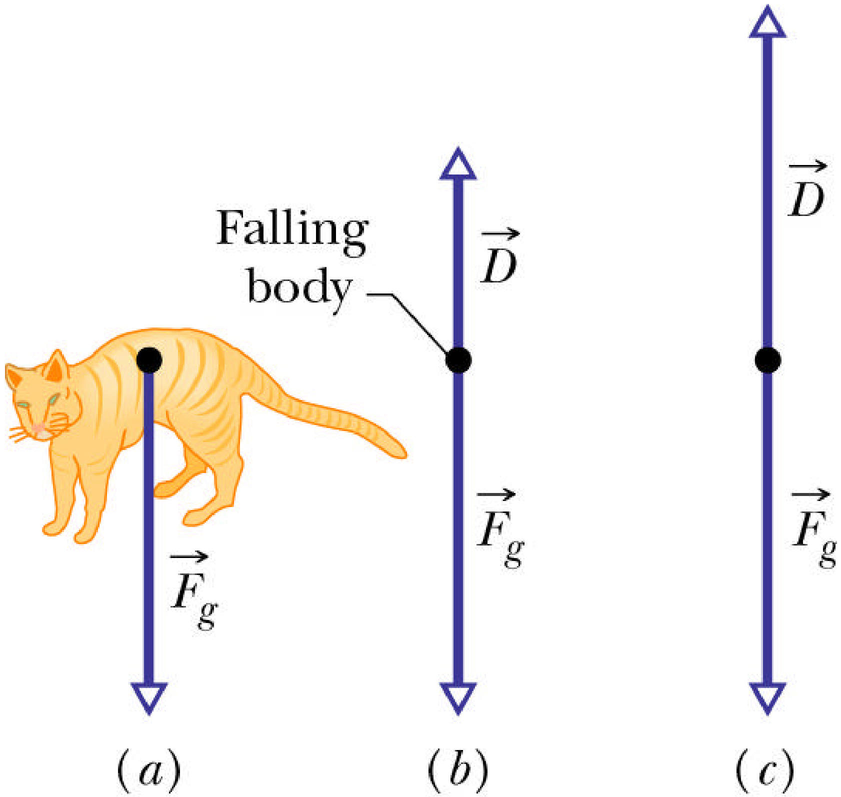


$$F_d = -K\eta v$$

$$F_d = \frac{1}{2} C \rho A v^2$$

review

Terminal Speed



- **In either case,**
  D µ - $v^{1 \text{ or } 2}$ …
  - **Object will attain a <u>terminal speed</u>**
  - **Text does the turbulent flow case**
  - **<u>Laminar flow case</u>:**

$$D = -K h v$$

$$D = mg \quad \text{when } v = v_{term} = \frac{mg}{K h}$$

Between $0 \le v \le v_{term}$**:**

$$m\frac{dv}{dt} = mg - K h v$$

with solution for start at rest

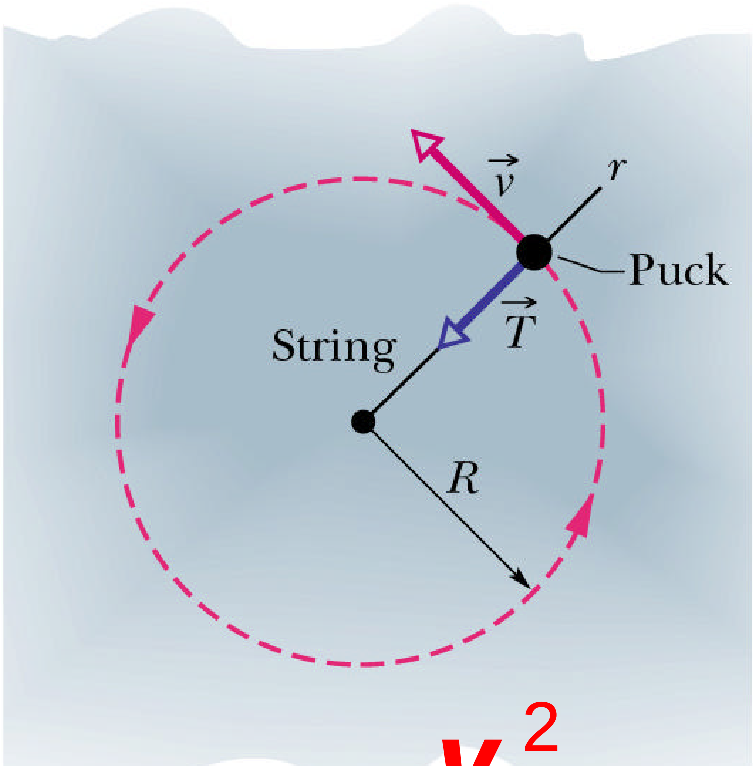
$$v = v_{term}(1 - e^{-\frac{K h}{m}t})$$

[culture]

review

<u>Centripetal</u> Force

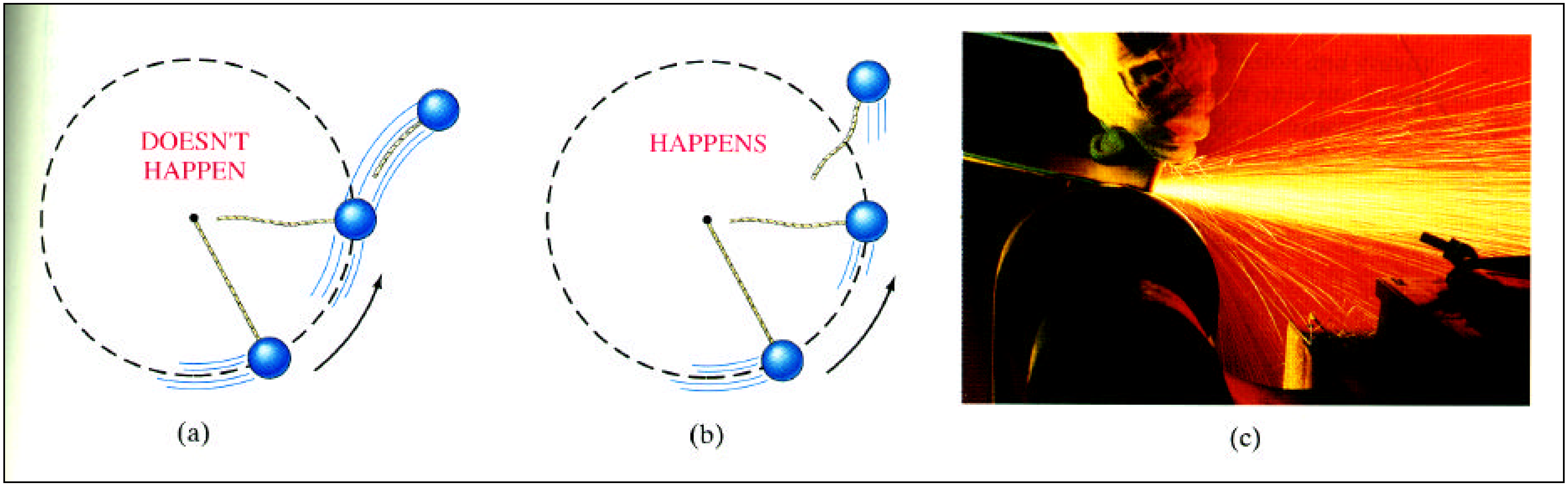
- Must <u>always</u> be a force to hold an object in circular motion
- This force supplies the centripetal acceleration!
- Hey! What happened to <u>centifugal force</u>?



$$T = m\frac{v^2}{R}$$

review

Centrifugal Force is a FICTION! (Fake Force)

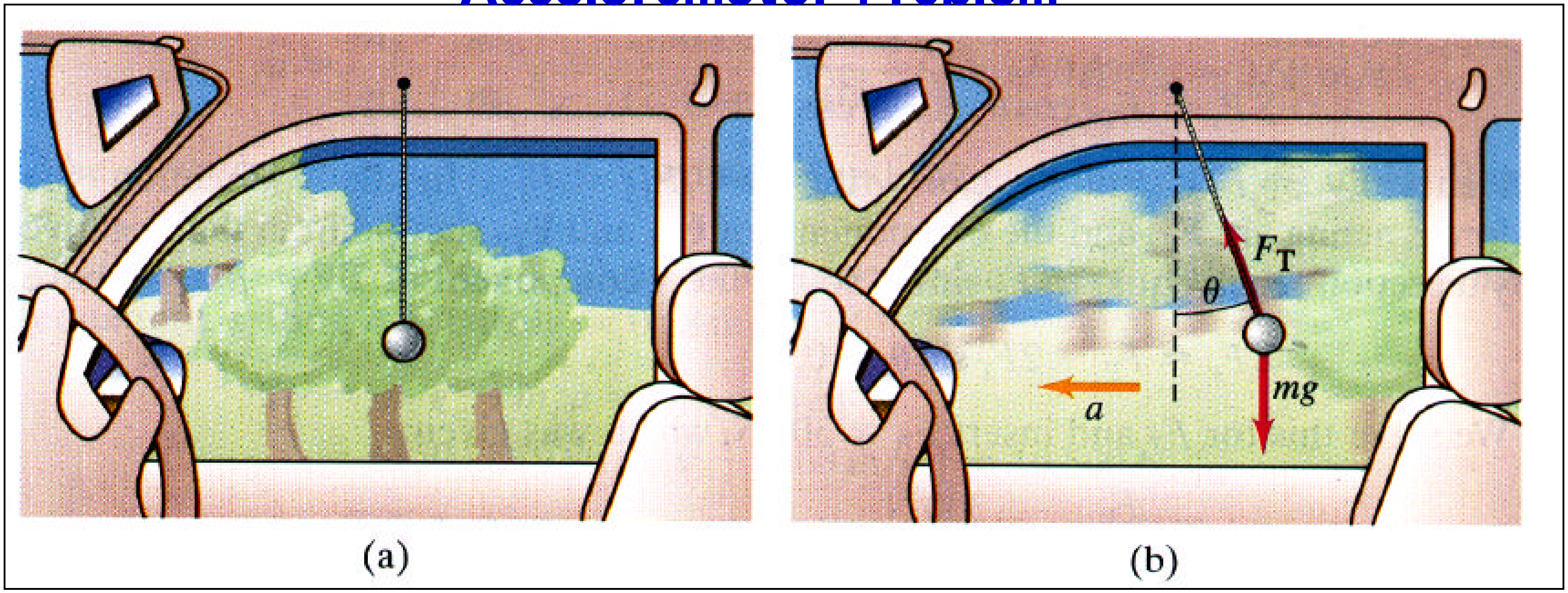


- **Real life experiences that make clear … objects without force travel in a straight line at the velocity with which they started!**
- **We use "fake forces" to explain real sense because we are not recognizing acceleration!**

review

F=ma better than using "fake forces"

Accelerometer Problem



- We found $\tan\theta = a/g$ … from $F_x = ma$
- But if postulated "fictional force" in direction of *a*, this would "explain" the angle, but would not be correct
  - ◆ Same rationale holds for centrifugal forces

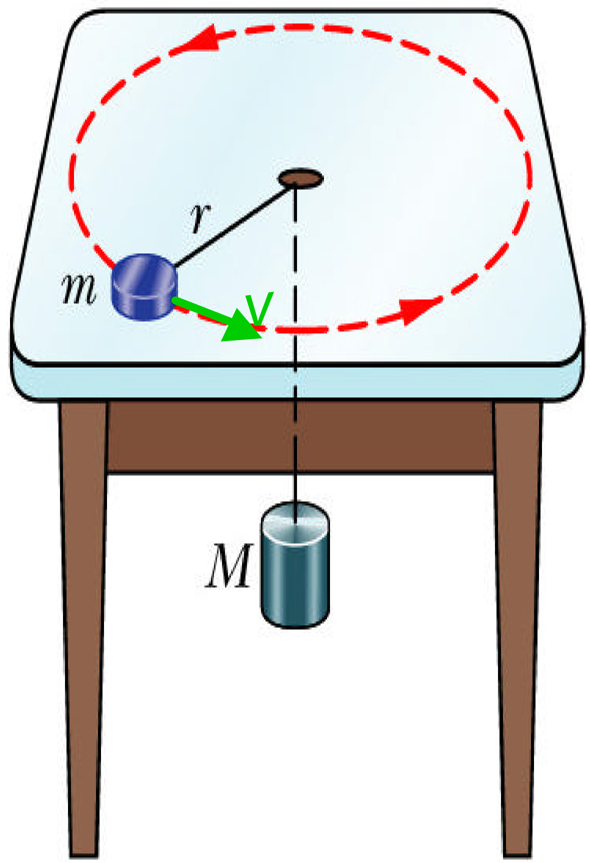
Prob. 6-41 (unassigned)

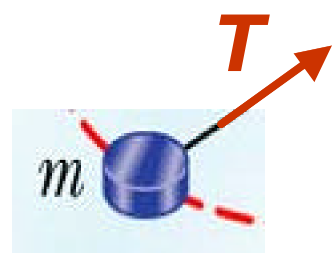
- **What speed will *m* travel at, so as to maintain circular motion of radius, *r* ?**
- **For given *M* and *r*, specific *v* works!**

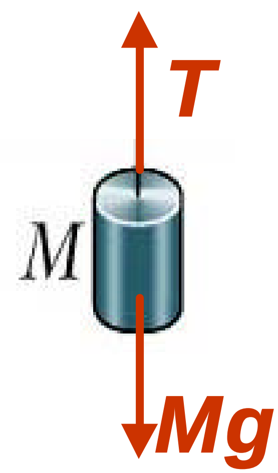
$$T = Mg$$

$$T = m\frac{v^2}{r}$$

$$\text{so } v = \sqrt{rg\frac{M}{m}}$$

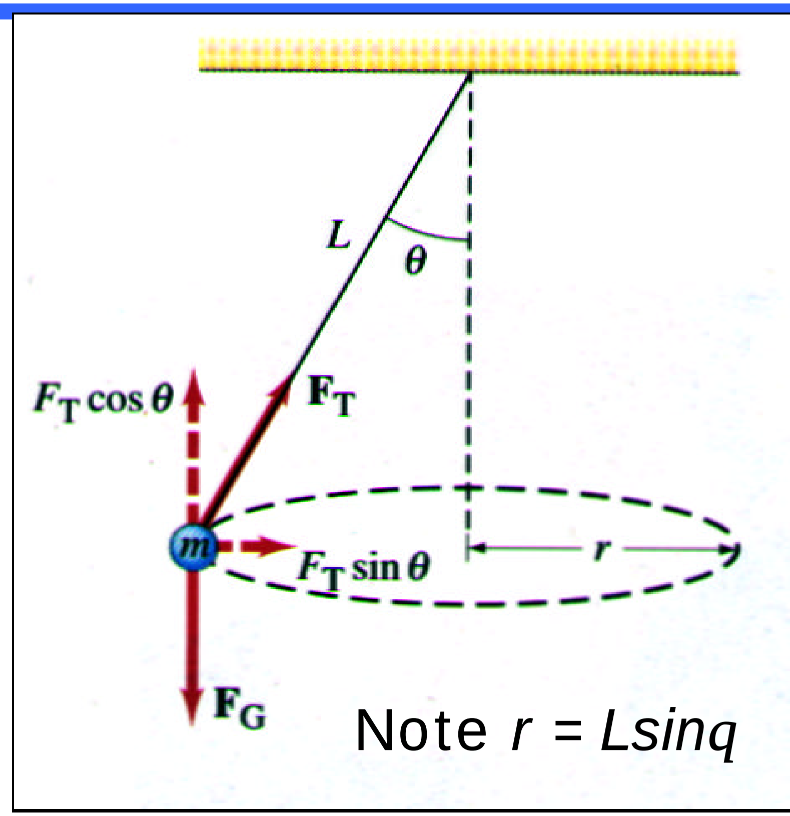






Conical Pendulum

- **Ball rotating stably in fixed circle**
- **Rotate the ball, tension in string supplies centripetal force**
- **Notice that circle is always <u>below</u> the hand**

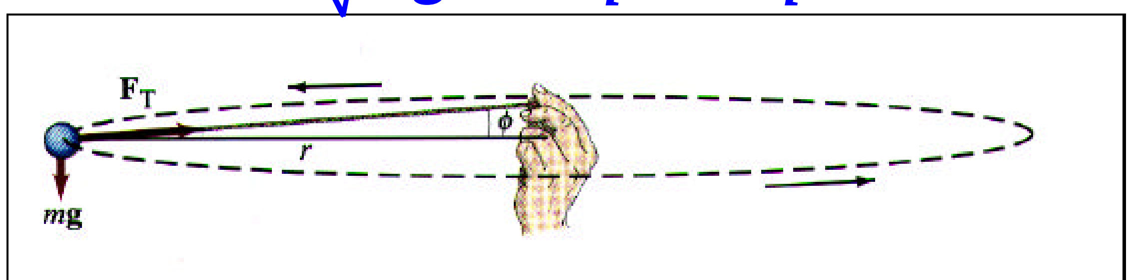


$$F_T \cos q = mg$$

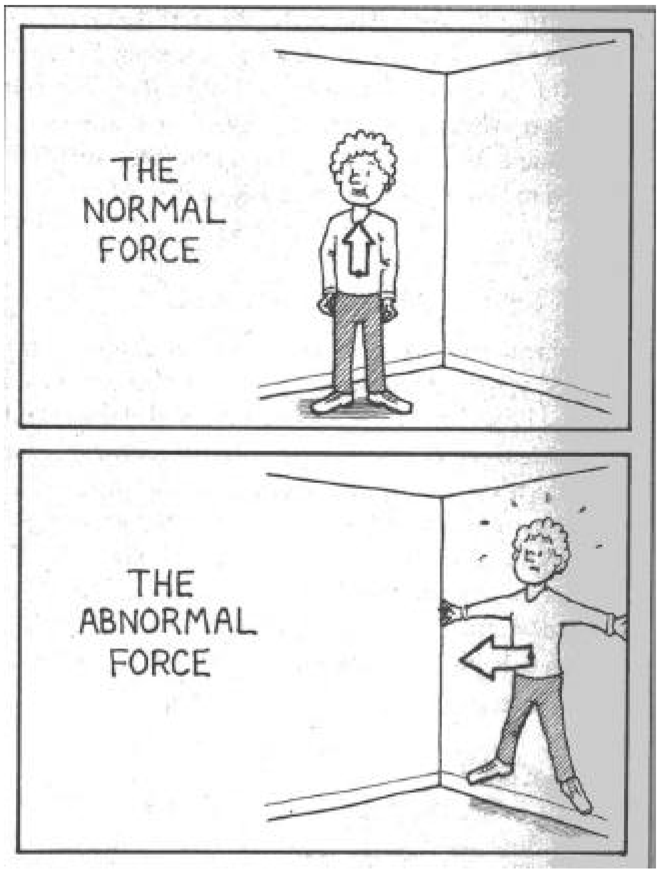
$$F_T \sin q = m\frac{v^2}{r}$$

$$\tan q = \frac{v^2}{rg}$$

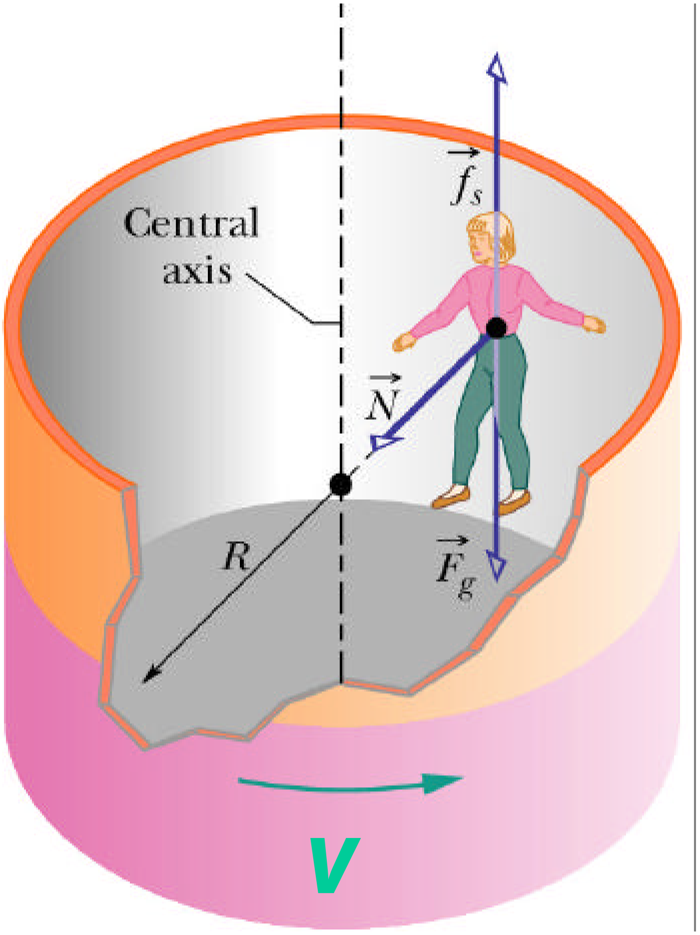
$$v = \sqrt{Lg \sin q \tan q}$$



An Abnormal Normal Force

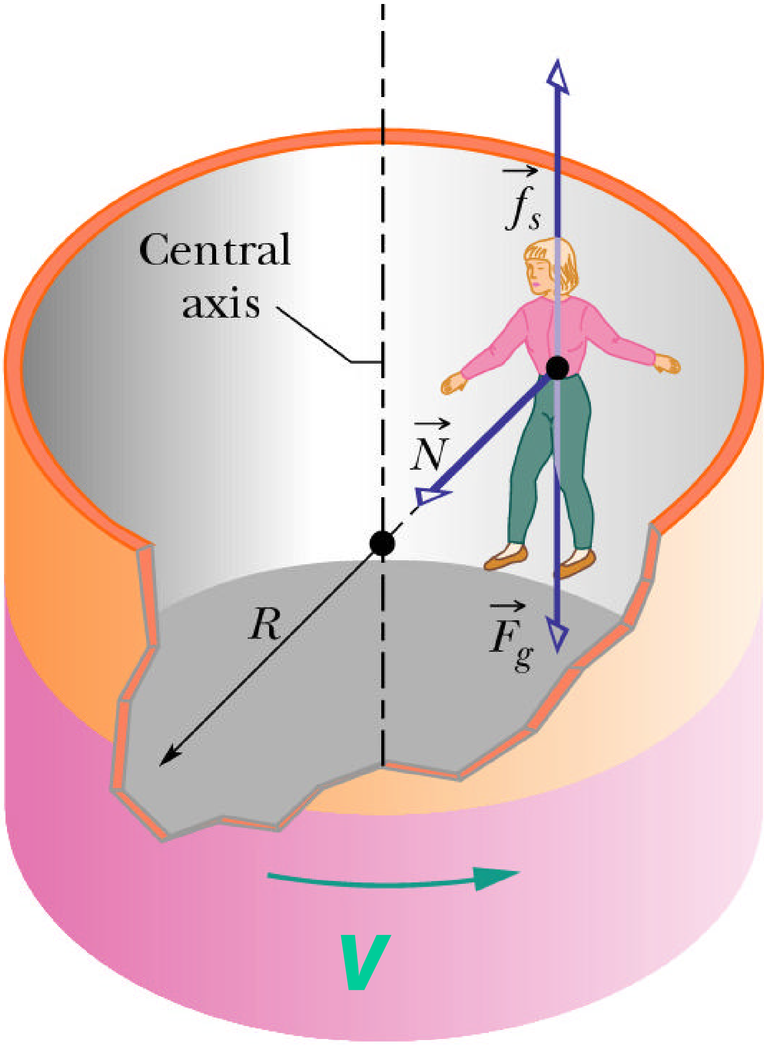


Go to the amusement park!

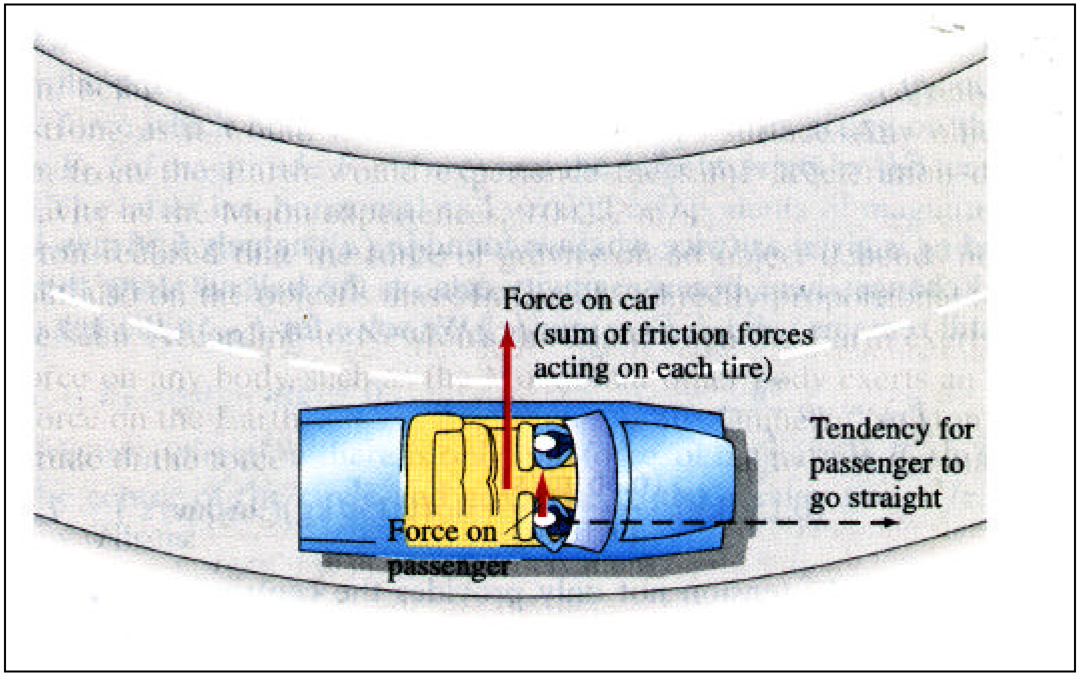


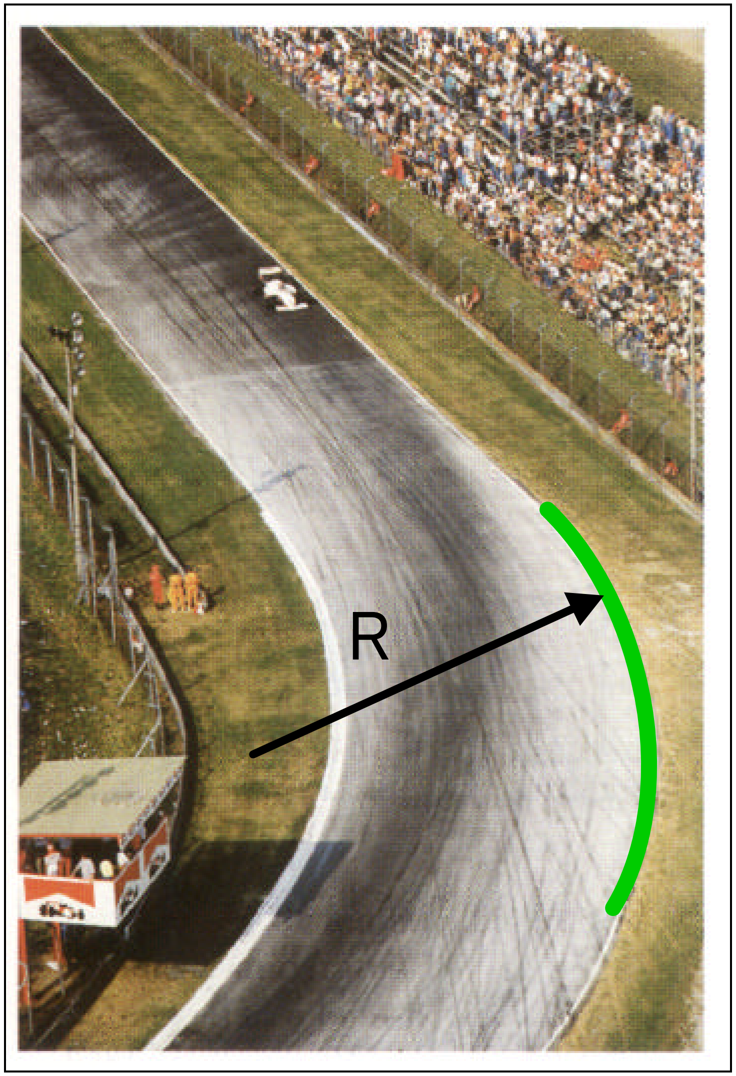
Sample Problem 6-8

- The ROTOR
- Rotates fast giving rider speed tangential speed v at the outer wall
- Floor falls
- Rider stays up
- Needed: friction at the wall
- Given: *R* and m_s
- What must *v* be ?



Race cars on a track



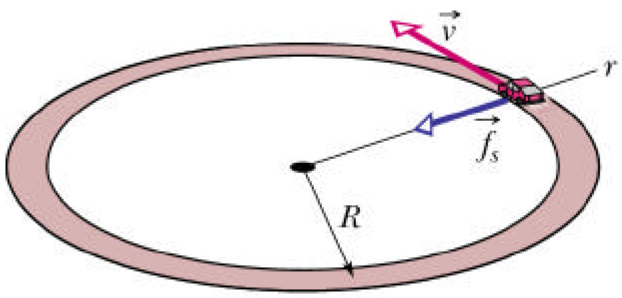


Note

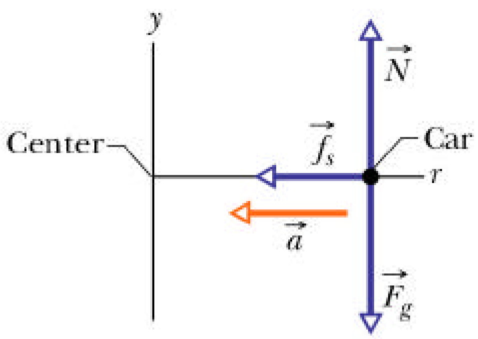
- required force on car (tires) from friction
- forces on people!
- all turns are arcs of circles

Sample Problem 6 - 9

- **Problem: driving in car on a circular, <u>level</u> track.**
- **What is the static coefficient of friction required? (so it won't skid!)**



(a)



(b)

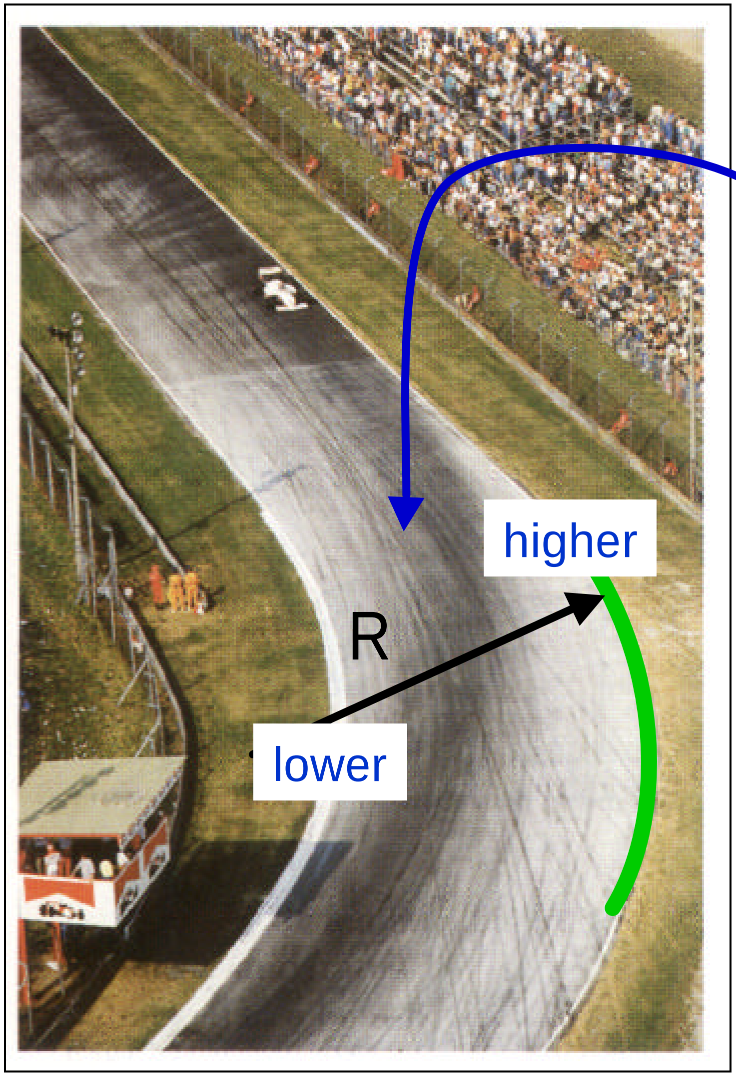
$$N = mg$$

$$f_s = m\frac{v^2}{R}$$

$$f_s^{\max} = \mu_s^{critical} mg$$

$$\mu_s^{critical} = \frac{v^2}{Rg}$$

Make life easier - Bank the track!



- Elevate outer ring of track relative to inner ring
- Look at it from the front (next slide)

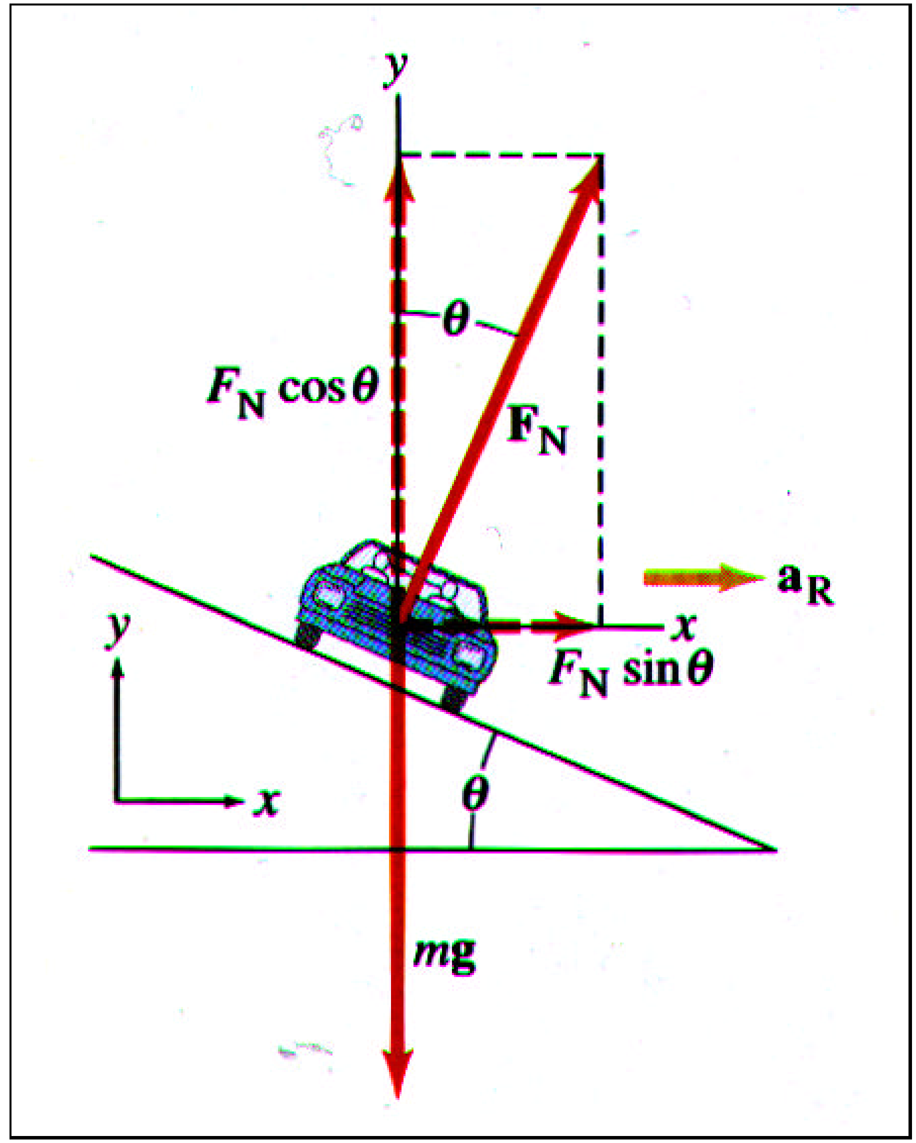
Car on banked track – circle center to right

- <u>No friction</u>...what speed (v_c) is required to keep car from sliding!
- Lets work it out!

$$F_N \cos\theta = mg \qquad F_N \sin\theta = m\frac{v_c^2}{R}$$

$$\tan\theta = \frac{v_c^2}{Rg} \qquad v_c = \sqrt{Rg\tan\theta}$$

- What happens if v is
  - Bigger than v_c?
  - Smaller than v_c?



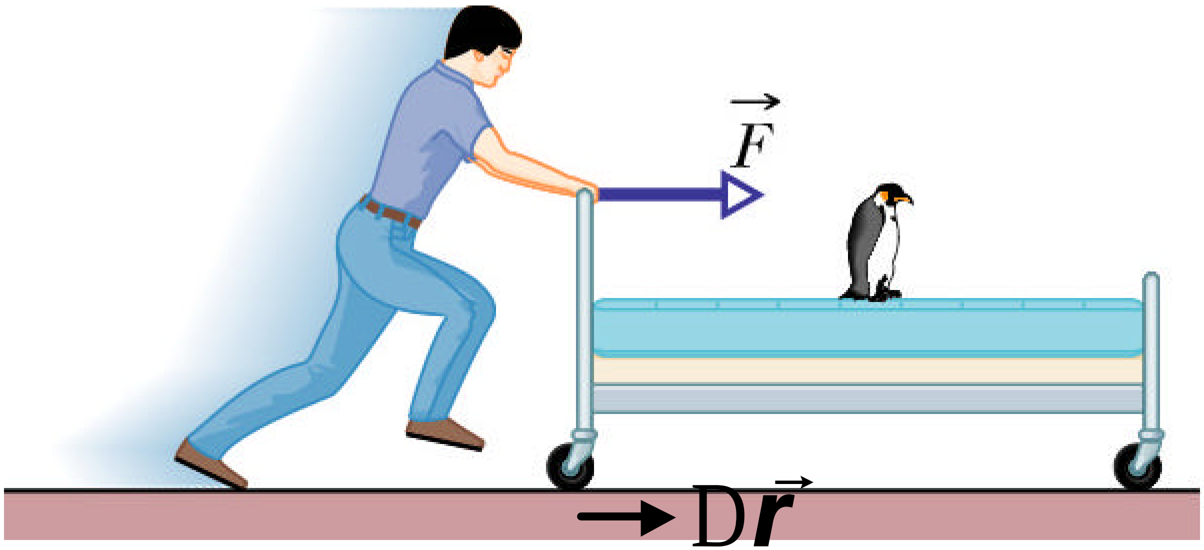
Work and Energy

- Highly useful concept (Newton missed it)
  - work & energy scalars, rather than vectors
- Work is performed whenever force is applied to an object with some component along or opposite the direction of displacement
  - Work done=Force ´ distance moved in the direction of the force
- Energy of several general types:
  - kinetic: energy involved in motion (often recoverable)
  - potential: energy available by virtue of availability to do work; recoverable in future as "kinetic"
  - dissipated energy: lost, converted to heat
- Work creates energy … energy convert between kinetic (motion) and potential (eg gravity)

Quantities and Units

Quantity	***Unit***
Displacement (x)	Meters (m)
Time	Seconds (s)
Velocity	Meters/second (m/s)
Acceleration	m/s/s (m/s^2)
Mass	Kilogram (kg)
Force	Newton (N) = $kg\text{-}m/s^2$
Work (Energy)	Joule (j) = N-m

Quantitative Definition of Work



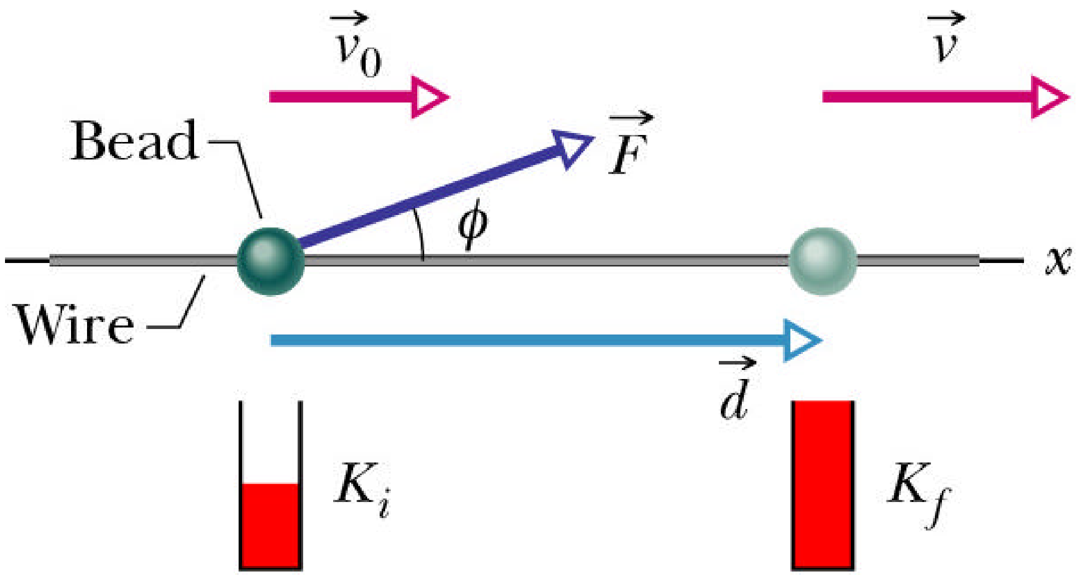
Work done = W

$$W = F \bullet \left\{ \begin{matrix} \text{displacement} \\ \text{in same direction} \end{matrix} \right\}$$

$$\Delta W = \vec{F} \bullet \Delta\vec{r}$$

- **Man does work on <u>system</u> of bed and penquin**
- **Note that normal and gravitational do NO work in this case.**
- **Only the force component moving the system in the <u>same</u> direction as the displacement does work**

Bead on a Wire with constant Force (and acceleration) – no friction



$$a_x = \frac{F_x}{m} \qquad W = F_x d$$

$$v^2 = v_0^2 + 2\frac{F_x}{m} d$$

$$W \equiv F_x d$$

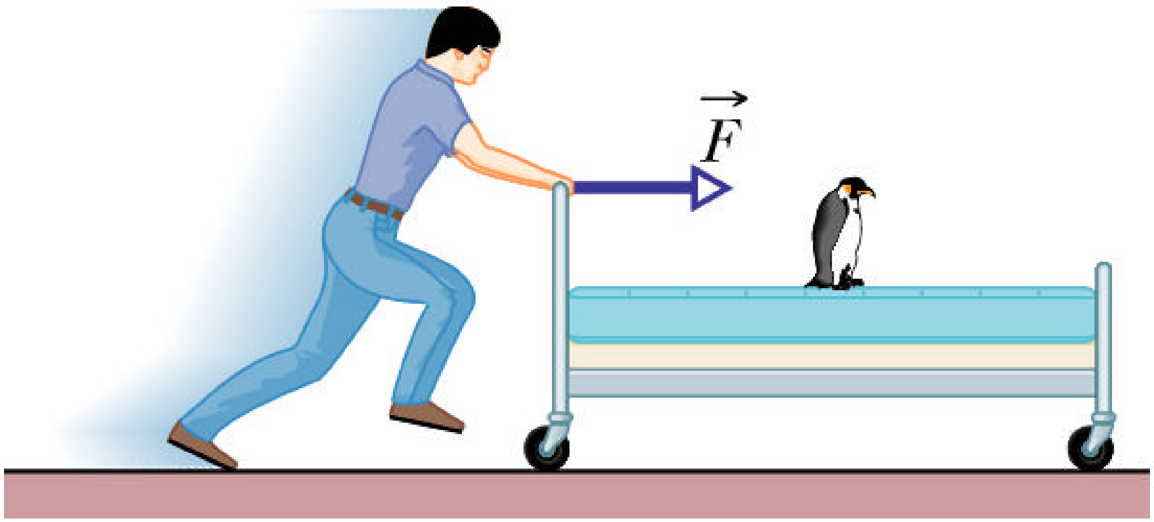
$$W = \tfrac{1}{2} m v^2 - \tfrac{1}{2} m v_0^2$$

$$W = K - K_0$$

$K \equiv \tfrac{1}{2} m v^2$ (Kinetic energy - new concept)

- **Work is + or -, depending on whether force has component in the same direction as displacement or opposite to the displacement**
- **Positive work increases Kinetic Energy**

Work-Energy Theorem



Take $\boldsymbol{F}$ in $\boldsymbol{x}$-direction and $\boldsymbol{F}$ dependent on $\boldsymbol{x}$:

Each increment in $\Delta \boldsymbol{x}$ produces $\Delta \boldsymbol{W} = \boldsymbol{F} \Delta \boldsymbol{x}$

Add up all the work to get total work: $\boldsymbol{W}$

$$W = \tfrac{1}{2} m v^2 - \tfrac{1}{2} m v_0^2$$

$$W = K - K_0$$

Work=change in Kin. Energy

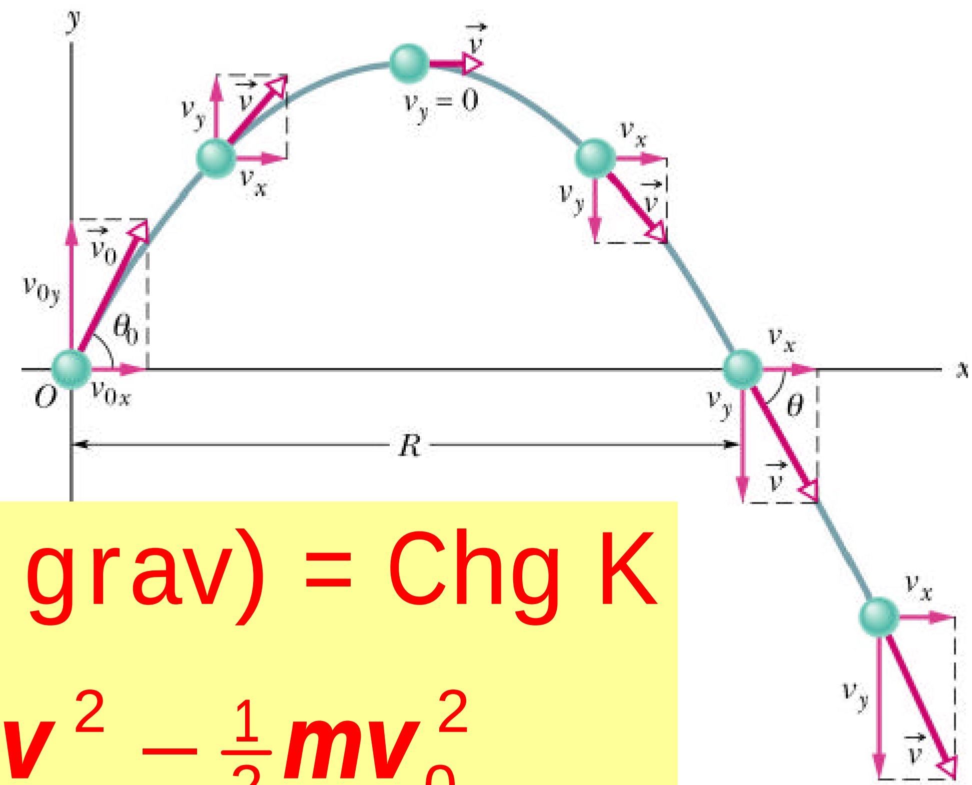
General Theorem is valid

so long as no energy dissipated

Consistent with what you know … get it easier!

Simpler way to get many of the answers got before (with grav force)

Note for any height y, then



Work done (by grav) = Chg K

$$-mgy = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_0^2$$

$$v^2 = v_0^2 - 2gy$$

Conclusions

- Begun to discuss important topic of work and energy
- Next time, we use it for several cases
- HW 2 solutions posted today
- Sample exam and solution for MT1 will be posted today
- "General exam guide" posted at the "Exam Specifics" web page
  - What to expect on exam day is described there … please read
  - We will go over it quickly in the next lecture