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 through chapter 6. Chapter 7 material (work, energy, ...) will not be on the first midterm.
- Mention again at end of lecture
Fluid Drag Forces

- Nonviscous flow = no drag force
- Viscous but laminar
  - $\eta =$ viscosity
- Viscous and turbulent

\[ F_d = -K \eta v \]

\[ F_d = \frac{1}{2} C \rho A v^2 \]
Terminal Speed

- In either case, 
  \[ D \propto -v^1 \text{ or } 2 \ldots \]
  - Object will attain a terminal speed
  - Text does the turbulent flow case
  - Laminar flow case:
    \[
    D = -K\eta v
    \]

\[ D = mg \text{ when } v = v_{\text{term}} = \frac{mg}{K\eta} \]

Between \( 0 \leq v \leq v_{\text{term}} \):
\[
 m \frac{dv}{dt} = mg - K\eta v
\]

with solution for start at rest
\[
v = v_{\text{term}} \left( 1 - e^{-\frac{K\eta t}{m}} \right) \quad [\text{culture}]
**Centripetal Force**

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

\[
T = m \frac{v^2}{R}
\]
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!
F=ma better than using “fake forces”

Accelerometer Problem

- We found $\tan \theta = \frac{a}{g}$ ... 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!

\[
T = Mg
\]
\[
T = m\frac{v^2}{r}
\]

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 below the hand

\[ F_T \cos \theta = mg \]
\[ F_T \sin \theta = m \frac{v^2}{r} \]
\[ \tan \theta = \frac{v^2}{rg} \]

\[ v = \sqrt{Lg \sin \theta \tan \theta} \]

Note \( r = L \sin \theta \)
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 $\mu_s$
- 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, level track.
- What is the static coefficient of friction required? (so it won’t skid!)

\[
N = mg \\
f_s = m \frac{v^2}{R} \\
f_s^{\max} = \mu_s^{\text{critical}} mg \\
\mu_s^{\text{critical}} = \frac{v^2}{Rg}
\]
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

- No friction...what speed \( (v_c) \) is required to keep car from sliding!
- Let's work it out!

\[
F_N \cos \theta = mg \quad F_N \sin \theta = m \frac{v_c^2}{R} \\
\tan \theta = \frac{v_c^2}{Rg} \quad v_c = \sqrt{Rg \tan \theta}
\]

- What happens if \( v \) is
  - Bigger than \( v_c \)?
  - Smaller than \( v_c \)?

Physics 1401 - L 6
Frank Sciulli
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

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (x)</td>
<td>Meters (m)</td>
</tr>
<tr>
<td>Time</td>
<td>Seconds (s)</td>
</tr>
<tr>
<td>Velocity</td>
<td>Meters/second (m/s)</td>
</tr>
<tr>
<td>Acceleration</td>
<td>m/s/s (m/s²)</td>
</tr>
<tr>
<td>Mass</td>
<td>Kilogram (kg)</td>
</tr>
<tr>
<td>Force</td>
<td>Newton (N) = kg-m/s²</td>
</tr>
<tr>
<td>Work (Energy)</td>
<td>Joule (j) = N-m</td>
</tr>
</tbody>
</table>
Quantitative Definition of Work

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

Work done = $W$

$W = F \cdot \left\{ \begin{array}{l} \text{displacement} \\ \text{in same direction} \end{array} \right\}$

$\Delta W = F \cdot \Delta r$
Bead on a Wire with constant Force (and acceleration) - no friction

\[ a_x = \frac{F_x}{m} \]

\[ W = F_x d \]

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

\[ W \equiv F_x d \]

\[ W = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 \]

\[ W = K - K_0 \]

\[ K \equiv \frac{1}{2}mv^2 \quad \text{(Kinetic energy - new concept)} \]

- 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 $F$ in $x$-direction and $F$ dependent on $x$:
Each increment in $\Delta x$ produces $\Delta W = F \Delta x$
Add up all the work to get total work: $W$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$$

$W = K - K_0$

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

\[
\text{Work done (by grav)} = \text{Chg K}
\]

\[
-mgy = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2
\]

\[
v^2 = v_0^2 - 2gy
\]
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