Applications of Newton's Laws

Notes prepared by Megan L. Barry

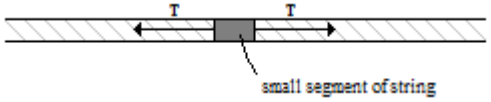
Based on Physics, 5th Ed. by Resnick, Halliday, Krane (Ch. 5)

1 Force Laws

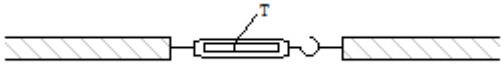
- Physicists have identified four "fundamental" types of forces that all known forces can be classified under:
  - Gravitational
  - Electromagnetic
  - Strong
  - Weak
- In introductory kinematics, we need only consider the first two. The Earth exerts gravitational force on all objects in its vicinity. All other forces in kinematics (contact forces, tension, spring forces, etc.) result from the interactions between atoms, which are ultimately electromagnetic in nature.

2 Tension and Normal Forces

- Tension - the force exerted by a string/rope
- The force due to tension is the same anywhere throughout an individual string.



- A scale placed in the middle of a string will read the value of the tension force.



- Normal force - the force exerted by a surface that keeps an object from being pulled to the center of the Earth. Always directed perpendicular to the surface.

  - Note: The magnitude of the normal force is only equal to the magnitude of the gravitational force when an object is on a horizontal surface, and no other vertical forces are being applied

3 Frictional Forces

- Friction - a force resulting from the surface of an object sliding against the surface of another object. Always directed in the opposite direction of the object's motion.
- Static friction - forces acting between surfaces at rest with respect to one another
- Coefficient of static friction - the ratio of the magnitude of the maximum force of static friction to the magnitude of the normal force. $\mu_s = \frac{f_{s,max}}{N}$ (dimensionless)
  - $f_{s,max}$ corresponds to the minimum force necessary to start motion
- Kinetic friction - forces acting between surfaces moving with respect to each other
- Coefficient of kinetic friction - the ratio of the magnitude of the force of kinetic friction to the magnitude of the normal force. $\mu_k = \frac{f_k}{N}$

4 The Dynamics of Uniform Circular Motion

- Newton's second law can also be applied to objects undergoing uniform circular motion. In this case, the sum of the forces in the radial direction are $\sum F_{rad} = m\frac{v^2}{r}$. The quantity $\frac{v^2}{r}$ is known as centripetal acceleration (a_C)
  - Keep in mind that centripetal forces act in the negative radial direction (inward)
- For every banked curve angle, there is an optimum velocity at which no friction is required to keep a vehicle from slipping.

5 Time-dependent Forces

- For time-dependent forces, $a_x(t) = \frac{F_x(t)}{m}$ can be integrated to get $v_x(t) = v_{0,x} + \frac{1}{m}\int_0^t F_x(t)dt$ and $x(t) = x_0 + v_{0,x} + \int_0^t v_x(t)dt$.

6 Noninertial Frames and Pseudoforces

- Noninertial frame - a frame that is accelerating, as viewed from an inertial frame (ex: an accelerating car, a merry-go-round, etc.)
- Pseudoforces - a source of an object's acceleration due to the acceleration of the reference frame it's in

- Centrifugal force - a pseudoforce directed away from the center of an object's circular path (depends on an object's position)
- Coriolis force - a pseudoforce related to an object's velocity while moving through a rotating frame

7 Limitations of Newton's Laws

- Newton's laws become invalid at very high speeds and near very massive objects
- Chaos theory can be used to predict the motion of systems too complex to apply Newton's laws