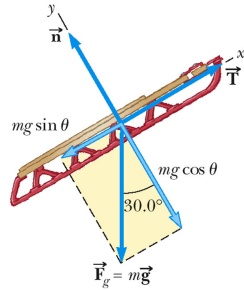


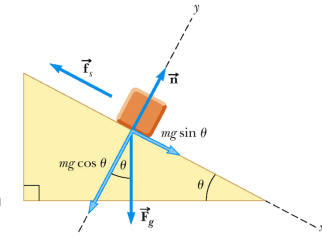
Inclined Planes

- Choose the coordinate system with x along the incline and y perpendicular to the incline
- Replace the force of gravity with its components



Block on a Ramp, Example

- Axes are rotated as usual on an incline
- The direction of impending motion would be down the plane
- Friction acts up the plane
 - Opposes the motion
- Apply Newton's Laws and solve equations



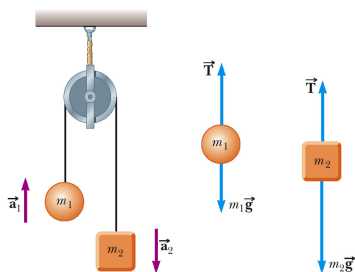
Friction/Inclined Plane Example

A 4000 kg truck is parked on a 15° slope. How big is the frictional force on the truck?

Multiple Objects – Example

- When you have more than one object, the problem-solving strategy is applied to each object
- Draw free body diagrams for each object
- Apply Newton's Laws to each object
- Solve the equations

Multiple Objects – Example, cont.



A 5-kg block hangs vertically by a massless string from a pulley. The string is connected over the pulley to a 7-kg block on a ramp inclined at a particular angle. If the angle of the ramp is 28° and there is no friction, what is the acceleration of the blocks?

Springs & Hooke's Law

- Springs can supply forces (similar to strings & tension)
- These are *restoring* forces: the spring wants to be in its equilibrium position
- Force due to a spring depends on how "strong" the spring is: spring constant k
- Also depends on how much the spring is stretched/compressed: x

$$\mathbf{F}_{\text{spring}} = -kx$$

The spring constant

- k tells you something about the physical properties of the spring
- Big value of k : spring is difficult to stretch/compress
- Small value of k : spring is easy to stretch/compress, very flexible

Uniform Circular Motion

- When moving at a constant speed in a circular path, acceleration is non-zero because direction of velocity changes

$$a_c = v^2/r$$

a_c = centripetal acceleration (m/s²)

v = speed of object (m/s)

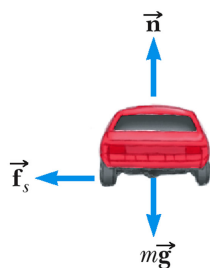
r = radius of circle (m)

Centripetal Acceleration

- An object traveling in a circle, even though it moves with a constant speed, will have an acceleration
- The centripetal acceleration is due to the change in the *direction* of the velocity

Level Curves

- Friction is the force that produces the centripetal acceleration



Examples of centripetal acceleration:

- Ball-on-a-string
- Car on a banked circular road
- Car on a circular track
- Planet orbiting a star
- Car driving over a circular hill
- Car driving through circular valley
- Roller coaster loop

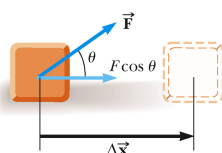
Example: A 1500kg car takes a sharp turn with a radius of 20.0 m. If the coefficient of friction between the tires and the road is 0.80, what's the fastest speed at which the car can take the turn?

Period & Frequency

- Period (T): Time to complete one full rotation
- Frequency (f): Number of rotations completed per second.
- $f = 1/T$, $T = 1/f$
- $v = 2\pi R/T$

Work and Energy

- Work: $W = F \cdot d$ (picks out parallel components)
- $F \rightarrow$ Force on object
- $d \rightarrow$ displacement
- **Direction** of force relative to motion matters!
- Units: 1 Joule = 1 kg m²/s²



Energy

- Several different varieties of energy, depending on what the object is doing, where it is located, what it interacts with, etc.
- Kinetic Energy (motion): $KE = \frac{1}{2} mv^2$
- Rolling Kinetic Energy: $KE_{rot} = \frac{1}{2} I\omega^2$
- Gravitational Potential Energy: $U_g = mgh$
- Elastic Potential Energy (springs): $U_{sp} = \frac{1}{2} kx^2$
- All have the same units as work (Joules)

Methods of Energy Transfer:

- By work from a force
- By radiating heat
- By wave propagation (either physical waves or electromagnetic waves)
- All energy comes from/goes SOMEwhere! It's never destroyed, but can become less "useful".

Work-KE Theorem

- Work is done on or by objects/systems
- Energy is an internal property that objects/systems possess

$$W = \Delta KE$$

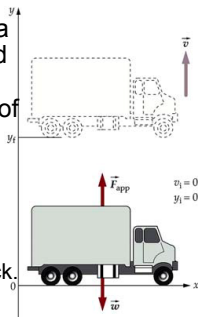
$$F \cdot d = \frac{1}{2} m_f v_f^2 - \frac{1}{2} m_i v_i^2$$

Work (+ or -) done on an object causes changes in its KE (increase or decrease).

Example: Loading a Ship

A 3,000 kg truck is loaded onto a ship by crane that exerts upward force of 31,000 N on truck. This force is applied over a distance of 2.0 m.

- Find work done on truck by crane
- Find work done on truck by gravity.
- Find net work done on the truck.



Types of Forces

- There are two general kinds of forces
 - Conservative: Work and energy associated with the force can be recovered (Example: Gravity)
 - Nonconservative: forces are dissipative and work done against it cannot easily be recovered (Example: Friction)

Conservative Forces

- A force is conservative if the work it does on an object moving between two points is **independent of the path** the objects take between the points
 - The work depends only upon the initial and final positions of the object
 - Any conservative force can have a potential energy function associated with it

More About Conservative Forces

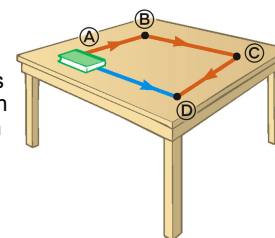
- Examples of conservative forces include:
 - Gravity
 - Spring force
 - Electromagnetic forces
- Potential energy is another way of looking at the work done by conservative forces

Nonconservative Forces

- A force is nonconservative if the work it does on an object depends on the path taken by the object between its final and starting points.
- Examples of nonconservative forces
 - kinetic friction, air drag, propulsive forces

Friction Depends on the Path

- The blue path is shorter than the red path
- The work required is less on the blue path than on the red path
- Friction depends on the path and so is a non-conservative force



Work-Energy Theorem, Extended

- The work-energy theorem can be extended to include potential energy:

$$W_{nc} = (KE_f - KE_i) + (PE_f - PE_i)$$

- If other conservative forces are present, potential energy functions can be developed for them and their change in that potential energy added to the right side of the equation

Conservation of Energy, cont.

- Total mechanical energy is the sum of the kinetic and potential energies in the system

$$E_i = E_f$$

$$KE_i + PE_i = KE_f + PE_f$$

- Other types of potential energy functions can be added to modify this equation

Problem Solving with Conservation of Energy

- Define the system
- Select the location of zero gravitational potential energy
 - Do *not* change this location while solving the problem
- Identify two points the object of interest moves between
 - One point should be where information is given
 - The other point should be where you want to find out something

Problem Solving, cont

- Verify that only conservative forces are present
- Apply the conservation of energy equation to the system
 - Immediately substitute zero values, then do the algebra before substituting the other values
- Solve for the unknown(s)