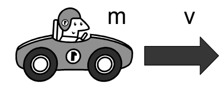
L-9 Conservation of Energy, Friction and Circular Motion

- Kinetic energy, potential energy and conservation of energy
- What is friction and what determines how big it is?
- Friction is what keeps our cars moving
- What keeps us moving in a circular path?
- <u>centripetal</u> *vs.* <u>centrifugal</u> force

Kinetic energy (KE)

- If something moves in any way, it has **kinetic energy**
- **kinetic energy (KE) is energy of motion**
- If I drive my car into a tree, the kinetic energy of the car can do work on the tree – it can knock it over



$$KE = \tfrac{1}{2} m v^2$$

KE does not depend on which direction the object moves

Potential energy (PE)

- If I lift an object, I do work (F x d), and this work is stored as PE
- The PE that an object gets when it is lifted is called by an amount h is called

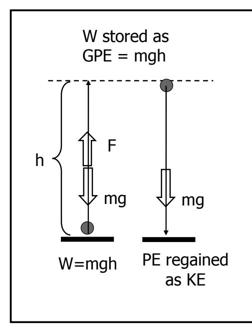
  Gravitational Potential Energy

  GPE= m x g x h = m g h

  m in kg, g = 10m/s², h in m, GPE in **Joules (J)**
- the higher I lift the object the more GPE it has
- When an object falls, the PE is converted to KE
- I must do work to compress a spring → PE is created
- When the spring is released PE → KE

conservation of energy

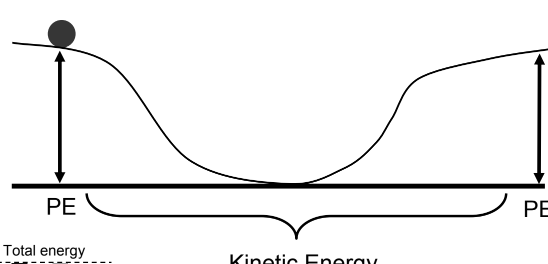
- if something has energy it doesn't loose it
- It may change from one form to another (potential to kinetic and back)
- KE + PE = constant
- example – roller coaster
- when we do work in lifting the object, the work is stored as potential energy.

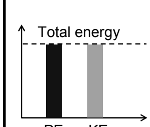


Amusement park physics

- the roller coaster is an excellent example of the conversion of energy from one form into another
- work must first be done in lifting the cars to the top of the first hill.
- the work is stored as gravitational potential energy
- you are then on your way!

Up and down the track



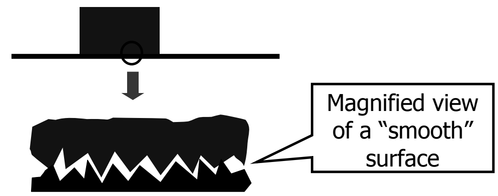


If friction is not too big the ball will get up to the same height on the right side.

What is friction?

- Friction is a force that acts between two surfaces that are in contact
- It always acts to **oppose** motion
- It is different depending on whether or there is motion or not.
- It is actually a force that occurs at the microscopic level.

A closer look at friction



At the microscopic level even two smooth surfaces look bumpy → this is what produces friction

Static friction

If we push on a block and it doesn't move then the force we exert is less than the friction force.

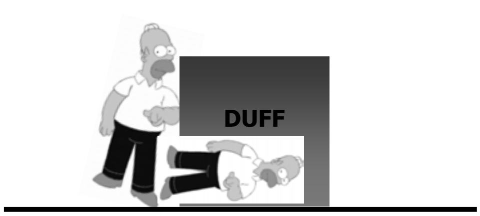
This is the **static friction** force at work

If I push a little harder, the block may still not move → the friction force can have any value up to some maximum value.

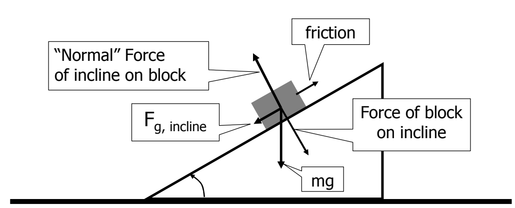
Kinetic friction

- If I keep increasing the pushing force, at some point the block moves → this occurs when the push P exceeds the maximum static friction force.
- When the block is moving it experiences a smaller friction force called the **kinetic friction force**
- It is a common experience that it takes more force to get something moving than to keep it moving.

Homer discovers that kinetic friction is less than static friction!

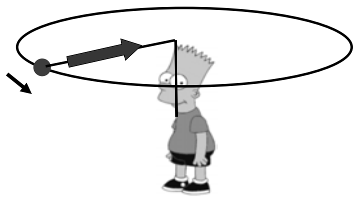


Measuring friction forces



At some point as the angle if the plane is increased the block will start slipping.
At this point, the friction force and gravity are equal.

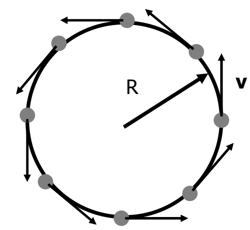
Going in circles



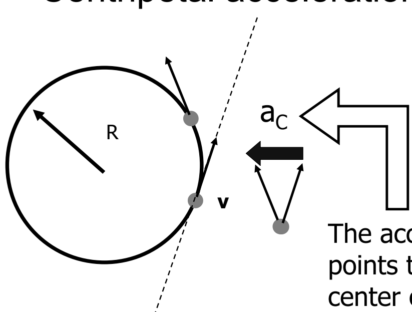
Bart swings the tennis ball around his head in a circle. The ball is accelerating, what force makes it accelerate? The tension in the string!

Uniform circular motion

- Velocity means both the *speed* and *direction*
- *Uniform* here means that the speed is constant as the objects goes around
- The direction of v is changing constantly, so there is an acceleration a
- For this type of motion we call this acceleration centripetal acceleration



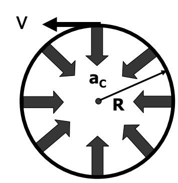
Centripetal acceleration, a_C



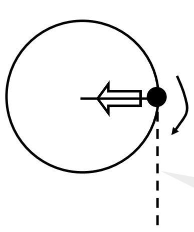
The acceleration points toward the center of the circle

Centripetal force and acceleration

- centripetal acceleration
- magnitude $a_C = \frac{v^2}{R}$
- in the direction toward the *center* of the circle
- since F = ma , some force is necessary to produce this centripetal acceleration,
- we call this a *centripetal force* ➔ we must identify this in each situation



Ball on a string



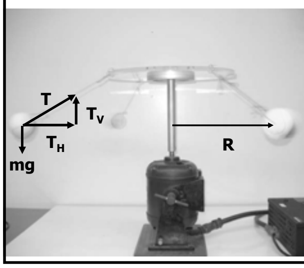
The tension in the string provides the necessary centripetal force to keep the ball going in a circle.

path of ball if the string breaks

Magnitude of centripetal acceleration

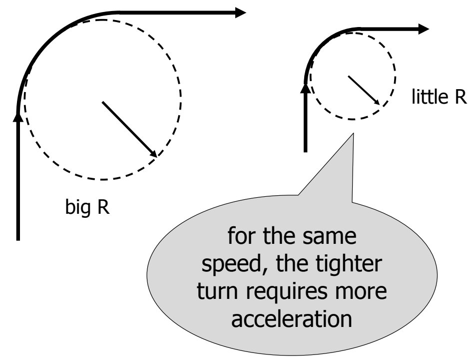
- The centripetal acceleration depends on two factors → the speed with which you take the turn and how tight the turn is
- More acceleration is required with a higher speed turn
- more acceleration is required with a tighter turn→ smaller radius of curvature

Carnival Ride

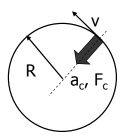


- There are 2 forces on the tennis ball- weight, mg and the tension, T
- The vertical part of the tension force T_V supports the weight
- The centripetal force is provided by the horizontal part, $T_H = mv^2/R$

Wide turns and tight turns



Centripetal acceleration

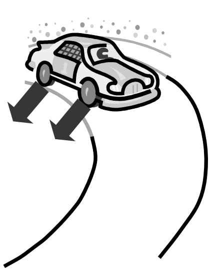


- centripetal acceleration: $a_C = \frac{v^2}{R}$
- for some turns, the “safe” speed is posted
- a force is needed to produce this centripetal acceleration→
- **CENTRIPETAL FORCE**
- where does this force come from?

Example

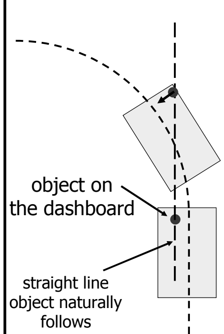
- What is the tension in a string used to twirl a 0.3 kg ball at a speed of 2 m/s in a circle of 1 meter radius?
- Force = mass x acceleration [$m \times a_C$]
- acceleration $a_C = v^2 / R = (2\ m/s)^2 / 1\ m$
  $= 4\ m/s^2$
- force = $m\, a_C = 0.3 \times 4 = 1.2$ N
- If the string is not strong enough to handle this tension it will break and the ball goes off in a straight line.

making a turn



- A turn is a part of a circle, and thus a centripetal force is needed to turn the car
- The centripetal force is provided by the **friction** force between the road and tires.
- this force is reduced if the road is wet or icy

What is centrifugal force ?



- The red object will make the turn only if there is enough friction between it and the dash, otherwise it moves in a straight line
- The car actually slides out from under the object
- the apparent outward force (as seen by someone in the car) is called the **centrifugal force**
- it is **NOT A REAL force!** It is a fictitious force
- an object will not move in a circle until something makes it!