Chapter 6 Circular Motion and Other Applications of Newton’s Laws

Uniform Circular Motion *on Horizontal Plane*

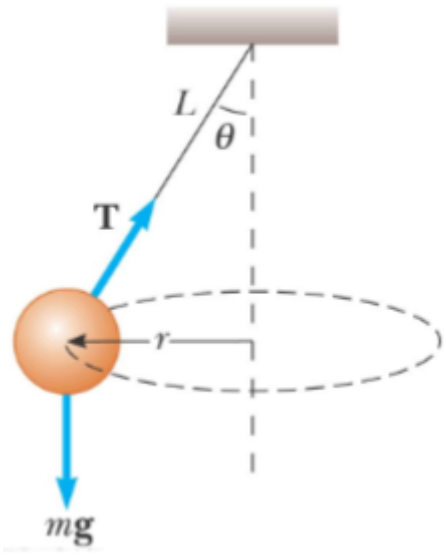
- A force F_r is directed towards the center of the circle
- This force is associated with an acceleration, a_c
- $\sum F = ma_c = m\frac{v^2}{r}$
- Causes a *centripetal acceleration* to act towards the center of the circle
- Causes a **change in the direction of the velocity vector**
- When this force vanishes, the object would move in a *straight-line* path tangent to the circle.

Centripetal Force

- The force causing the centripetal acceleration is called the **centripetal force**
- ***Centripetal force** causes circular motion**

Conical Pendulum

The object is in equilibrium in the vertical direction and undergoes uniform circular motion in the horizontal direction



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

v is independent of m

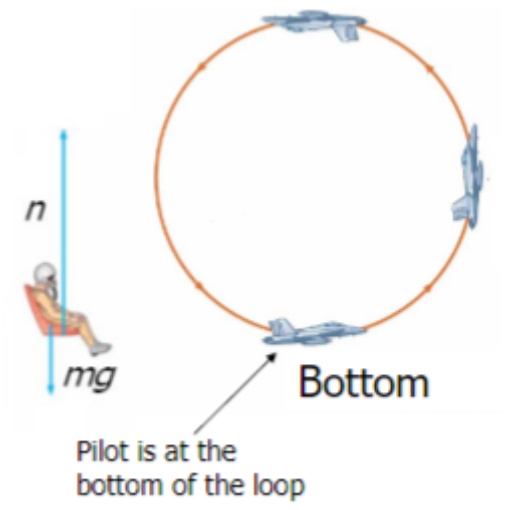
Horizontal *Flat* Curve

- $f_s = \mu_s mg = \frac{mv^2}{r}$
- The force of static friction supplies the centripetal force
- The maximum speed at which the car can negotiate the curve is $v = \sqrt{\mu_s gr}$

Banked Curve

- Designed to deal with very small or no friction situation
- A component of the normal force that supplies the centripetal force $\tan\theta = \frac{v^2}{rg}$

Loop-the-Loop in **Vertical Plan**



At the bottom of the loop, the upward force experienced by the object is greater than its weight

$$n_{bottom} = mg\,(1 + \frac{v^2}{rg})$$

At the top of the loop,

$$n_{top} = mg\,(\frac{v^2}{rg} - 1)$$

Black-out and **Red-out**

Black-out

- **Occurs**: When a pilot pulls out of an accelerated dive.

- **Mechanism**: The blood in the pilot's brain has a downward velocity due to inertia when pulling out of a dive. This causes the blood to move toward the legs, draining from the brain and potentially leading to unconsciousness (black-out). This situation is exacerbated if the pilot is not wearing a G-suit.
- **Condition**: The pilot experiences positive G-force ($G > 1$), meaning the force acting on the body is greater than its weight:
  $n = \frac{mv^2}{r} - mg > 0$
  where:
  - n is the net force on the pilot,
  - m is the pilot’s mass,
  - v is the velocity,
  - r is the radius of the vertical circle,
  - g is the acceleration due to gravity.

Red-out

- **Occurs**: When a pilot pulls out of an accelerated climb in an upright or inverted position.
- **Mechanism**: The blood rushes upward to the head, flooding the eyes and potentially rupturing capillaries, leading to blurred vision and a red tint—hence, "red-out."
- **Condition**: The pilot experiences negative G-force ((G < 0)), causing a potentially damaging upward force:
  $n = \frac{mv^2}{r} - mg < 0$
  This indicates an overload that directs blood toward the head, causing pressure in the eye capillaries.

Rules of Thumb about *+ve* and *-ve* G Force on a Person

1. **Positive G-force (*+ve* G)**:
   - Equations: $n_1 > 0$ and $n_2 = 0$
   - Result: **Black-out** (Possible)
2. **Standard 1G**:
   - Equations: $n_1 = mg$ and $n_2 = 0$
   - Note: This is normal gravitational force ($1G$ is positive G)
3. **Negative G-force (*-ve* G)**:
   - Equations: $n_1 = 0$ and $n_2 > 0$
   - Result: **Red-out** (Possible)
4. **Zero G-force (0G)**:
   - Equations: $n_1 = 0$ and $n_2 = 0$
   - Description: Free fall or weightlessness, no sensation of touch.

Non-Uniform Circular Motion

- The acceleration and force have tangential components
- F_r produces the centripetal acceleration
- F_t produces the tangential acceleration
- $\sum F = \sum F_r + \sum F_t$

Vertical Circle with Non-Uniform Speed

- The gravitational force exerts a tangential force on the object
  - Look at the components of F_g
- The tension at any point can be found
  - $T = m\left(\frac{v^2}{R} + g\,\cos\theta\right)$

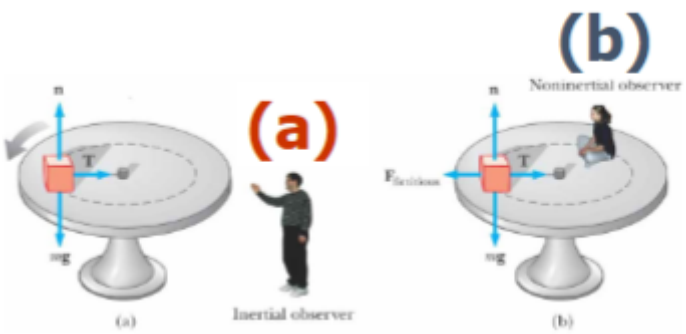
Top and Bottom of Circle

- The tension at the bottom is a maximum ($\cos 0^\circ = 1$)
- The tension at the bottom is a maximum ($\cos 180^\circ = -1$)
- If $T_{top} = 0$, then $v_{top} = \sqrt{gR}$

Motion in Accelerated Frames

- A *fictitious force* results from an accelerated frame of reference
  - A fictitious force appears to act on an object in the same way as a real force, but you cannot identify a second object that applies the fictitious force to the first object. **Therefore a fictitious force is not a real force that exhibits real effects**
- Although *fictitious forces* are not real
  - Objects in the car can slide
  - You can feel the push to the outside of a rotating platform
  - Circular motion of an object tied to a string

Fictitious Forces in a Rotating System



According to the inertial *observer (a)*, the block is circulating, the tension is the centripetal force

$$T = \frac{mv^2}{r}$$

The non-inertial *observer (b)* sees that the object is not moving,

$$T - F_{fictitious} = T - \frac{mv^2}{r} = 0$$

Centrifugal Force

- The outward force is called a *centrifugal* force
  - It is a **fictitious force** due to the acceleration associated with the car's change in direction