Force And Motion II

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Phys 211, Lecture 9

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Clicker Question 1 (30 s)

- CMB as related to physics stands for
  - A. Cosmetic Makeup Brand
  - B. Coastal Mortar Board
  - C. Cell and Molecular Biology
  - D. Cosmic Microwave Background

Clicker Question 2 (30 s)

- CMB was discovered in what decade?
  A. In the 1940's
  B. In the 1950's
  C. In the 1960's
  D. In 1990's

Clicker Question 3 (30 s)

- What is CMB ?
  A. Microwave radiation of the Earth
  B. Microwave radiation of the Sun
  C. Faint glow (remnants) of the big bang
  D. None of the above

Clicker Question 4 (30 s)

- What temperature does CMB correspond to ?
  - A. About 273 Kelvin
  - B. About 373 K (100 C)
  - C. About 10K
  - D. About 3 K

Friction

- Dissipative Force
  - Friction is a force. It opposes impending (about to happen) motion
  - Direction is opposite to that of impending motion. It is electromagnetic in nature
- Static Friction
  - When an object is at rest, it requires a certain minimum external force to get it moving (sliding) across the contact surface.
  - During this time, the force that opposes the motion is due to static friction
- Kinetic Friction
  - When the (sum of external) applied forces causes the object to move, there can still exist friction opposing motion, this force is dynamic friction
- Contact Force
  - Friction force can exist between any two (or more) surfaces in contact and moving (or at rest) relative to each other.

Friction Formulae

- Frictional force is proportional to normal force
  - The constant of proportionality is called the coefficient of friction
  - Coefficient of friction can have a value that could be zero or greater

$$F_{fr} \propto N$$

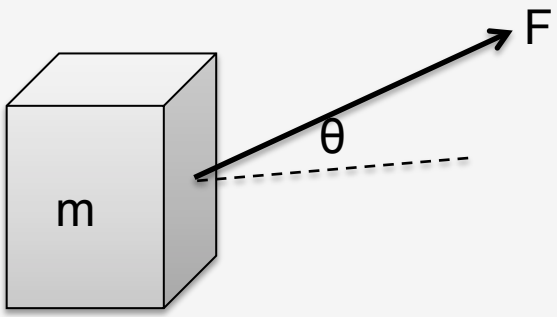
$$\Rightarrow \boxed{\frac{F_{fr}}{N} = \mu\,, \quad \mu \geq 0}$$

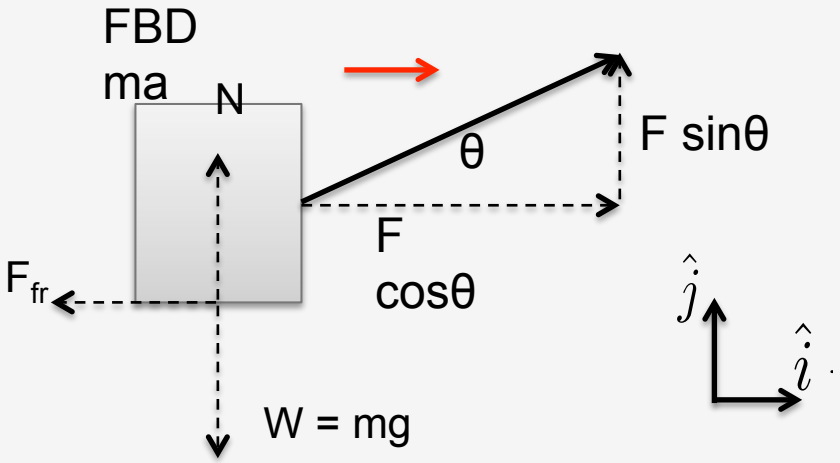
- F_s (static) and F_k (kinetic) Friction

$$F_s = \mu_s N$$

$$F_k = \mu_k N$$

Problem 1





Given m = 4 kg, F = 20 N, θ = 20°
Case 1: Assume object is at rest and find coefficient of static friction μ_s
Case 2: If applied force increases to F = 25 N and μ_k = 0.2, find the acceleration of the block

Equations of Motion

$$(F\cos\theta - F_{fr})\,\hat{i} = ma\,\hat{i}$$

$$(N + F\sin\theta - mg)\,\hat{j} = 0$$

$$|\vec{F}_{fr}| = \mu N$$

Case 1

$$F\cos\theta = F_s$$

$$N = mg - F\sin\theta$$

$$F_s = \mu_s N$$

$$\mu_s = \frac{F\cos\theta}{mg - F\sin\theta}$$

$$\Rightarrow \boxed{\mu_s = 0.58}$$

Case 2

$$ma = F\cos\theta - F_k$$

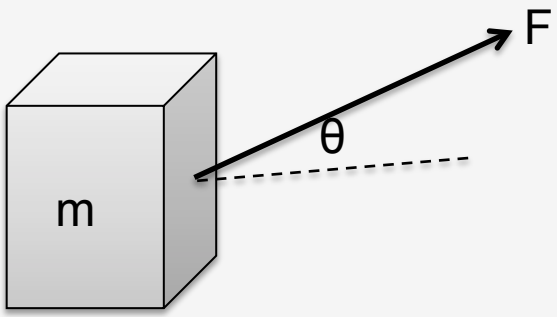
$$N = mg - F\sin\theta$$

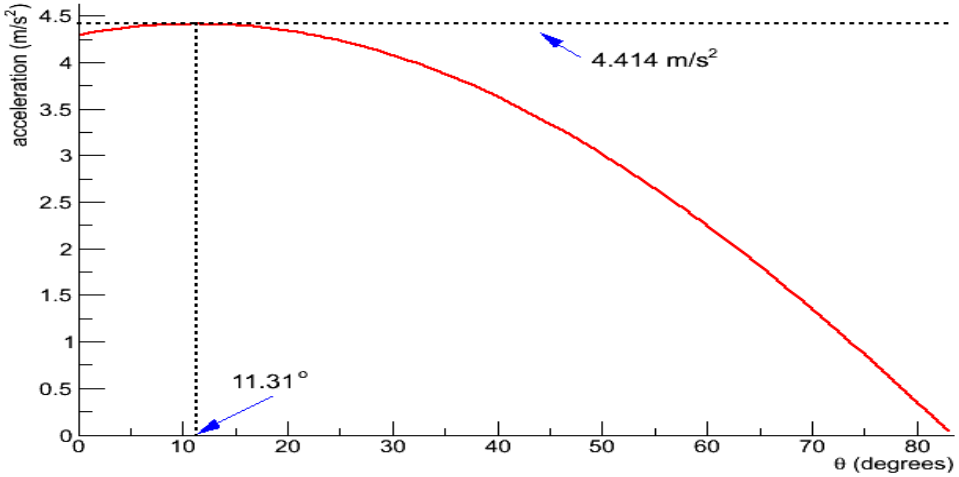
$$F_k = \mu_k N$$

$$a = \frac{F}{m}(\cos\theta + \mu_k \sin\theta) - \mu_k g$$

$$\Rightarrow \boxed{a = 4.34\ m/s^2}$$

Problem 1 (continued)





1) Find normal force and force of friction for Cases 1 and 2
2) For Case 2, what angle (call it θ_{max}) does the block attain maximum acceleration?

Equations of Motion

$$(F\cos\theta - F_{fr})\,\hat{i} = ma\,\hat{i}$$

$$(N + F\sin\theta - mg)\,\hat{j} = 0$$

$$|\vec{F}_{fr}| = \mu N$$

Problem 1

Force	Case 1	Case 2
Normal	32.36 N	30.65 N
Friction	18.79 N	6.13 N

Problem 2

$$a = \frac{F}{m}(\cos\theta + \mu_k \sin\theta) - \mu_k g$$

$$\frac{da}{d\theta} = \frac{F}{m}(\sin\theta - \mu_k \cos\theta) = 0$$

$$\tan\theta_{max} = \mu_k$$

$$\Rightarrow \boxed{\theta_{max} = \tan^{-1}(0.2) \approx 11.31^\circ}$$

Centripetal Force

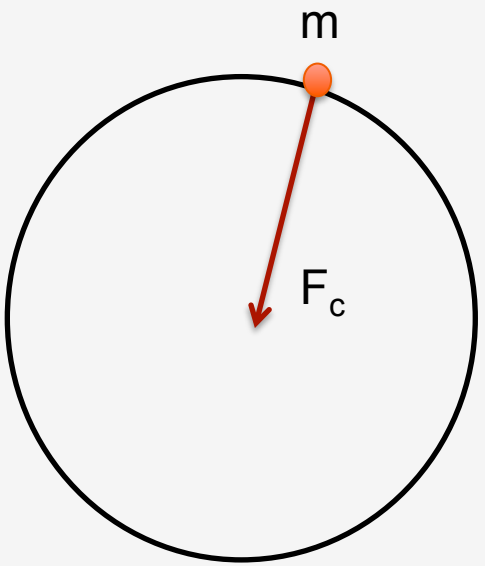
- For an object moving at a constant speed (v) along a circular arc of radius (r), the acceleration is

$$a_c = \frac{v^2}{r}$$

- If the object has a mass m, then applying Newton's second law gives

$$\boxed{F_c = ma_c = \frac{mv^2}{r}}$$

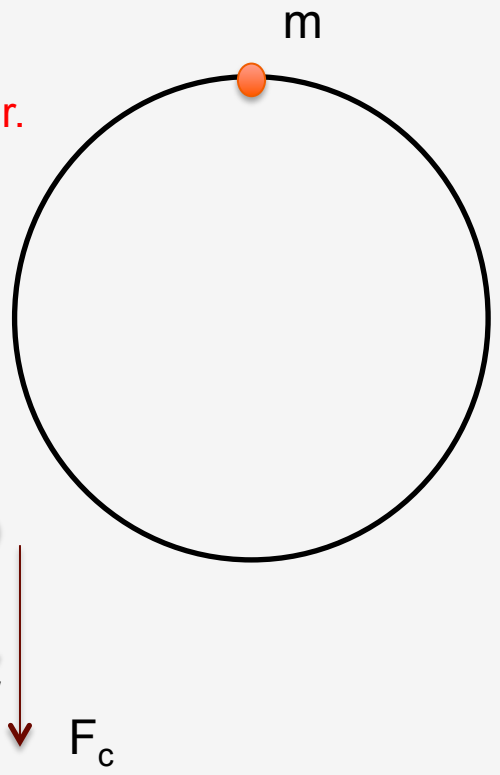
- The force is directed toward the center of the circle and is called the centripetal (center seeking) force.



Example (Vertical Loop)

- What is the minimum speed at which an object of mass m traveling along the circumference of a vertical circle not lose contact at the highest point?

The object will lose contact with the surface when the normal force becomes zero. The minimum speed at which this happens is v = √gr. At any larger speed than that, the object will stay put and not lose contact with the circular path at the highest point.



$$N + mg = ma = \frac{mv^2}{r}$$

$$mg \approx \frac{mv_{min}^2}{r}, \quad N \to 0$$

$$\boxed{v_{min} = \sqrt{rg}}$$