PDF File

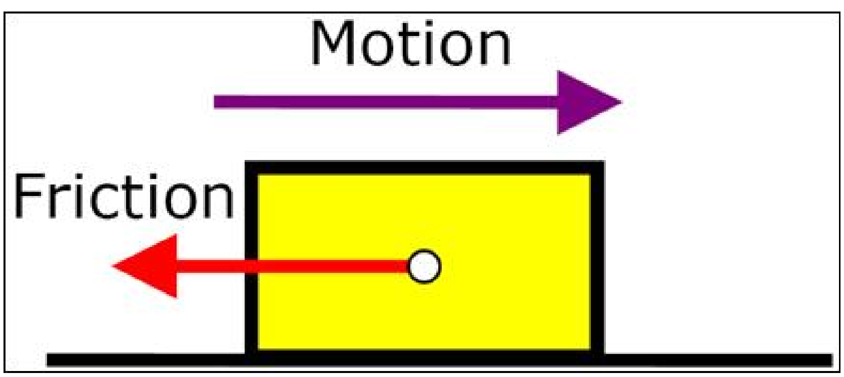
FORCES AND FRICTION

Unit Overview

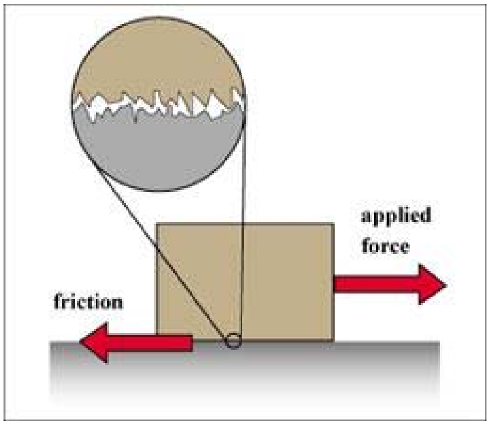
This unit will focus on the effects of friction, both one dimensionally and in two dimensions. You will see how friction opposes the motion of an object to slow it down, or make it impossible to move. We will also explore how other forces like a push or pull, gravity and friction all work together in Newton's second law of motion as learned about in units 6 and 7.

Friction

Friction is a force that acts in a direction parallel to the area of contact, and opposes the motion or the tendency to move. There are two kinds of friction, static and kinetic. *Static Friction* is the friction force that opposes motion and is equal to or greater than the force trying to move the object. So the object trying to move cannot, and it is at rest. Eventually the object will move when more force is added to the object, which tells us that static friction can only be so great. *Kinetic Friction* is the frictional force exerted on one surface by the other when the surfaces are in relative motion. Even if an object is able to move, there will still be friction between the object's surface and whatever the object is moving on top of. There are 6 simple principles about friction, which will be helpful to consider when dealing with problems to determine if friction will be a factor, and when it will not.

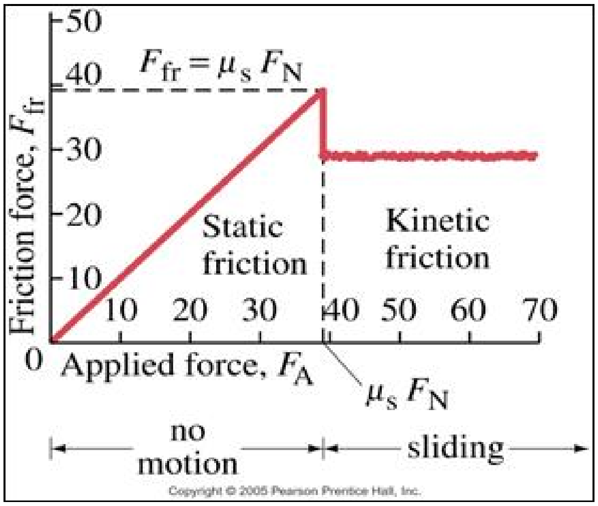
1. Friction acts parallel to the surfaces in contact and opposite the motion of the object. 
2. Friction depends on the nature of the materials in contact and the smoothness of their surfaces.

Even materials that appear to be smooth have microscopic irregularities on its surface causing friction.



3. Starting friction is greater than sliding/rolling friction.

The static frictional force increases as the applied force increases, until it reaches its maximum. Then the object starts to move, and the kinetic frictional force takes over. Therefore static friction is always greater than kinetic Friction

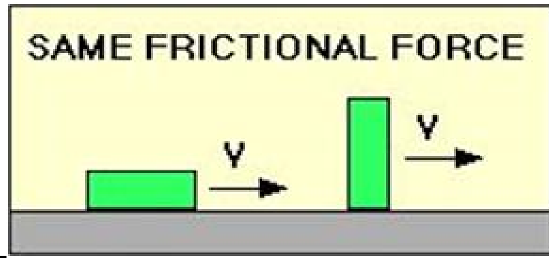


4. Sliding friction is practically independent of speed.

Once an object starts moving the only thing that really matters is the surface of the materials moving past one another

5. Friction is practically independent of the area of contact.

Surface area does not make something have more or less friction.



6. Friction is directly proportional to the force pressing the two surfaces together.

In other words; the heavier the object is, the more friction there will be opposing its motion.

(i.e., it's harder to push a truck than it is to push a sports car)

Solving for Friction in One Dimension

In order to solve for friction we must first look at whether the object is at rest or if it is moving. If it is at rest we are dealing with static friction. If it is moving, it is kinetic. Next we will consider what materials are in motion and what surface it is moving on top of. This will determine the *coefficient of friction* value for the problem. As the surface changes, the coefficient of friction changes. Below is a table that shows some common surfaces coming into contact with one another and then what the coefficient of static and kinetic friction would be.

Mass of the object that is moving is another factor in determining the amount of friction acting on the object. The heavier the object, the more friction there will be. The final factor to consider is gravity. Gravity is acting on an object to pull it down against the surface.

By looking at those factors concerning friction, it yields the equation:

$$F_{\mathrm{fr}} = \mu_{\mathrm{k}} F_{\mathrm{N}}$$

Where Ffr is the force of friction, μ_k is the coefficient of friction and Fn is the normal force or mass X gravity (mg)

TABLE 4–2 Coefficients of Friction†

Surfaces	Coefficient of Static Friction, μ_s	Coefficient of Kinetic Friction, μ_k
Wood on wood	0.4	0.2
Ice on ice	0.1	0.03
Metal on metal (lubricated)	0.15	0.07
Steel on steel (unlubricated)	0.7	0.6
Rubber on dry concrete	1.0	0.8
Rubber on wet concrete	0.7	0.5
Rubber on other solid surfaces	1–4	1
Teflon® on Teflon in air	0.04	0.04
Teflon on steel in air	0.04	0.04
Lubricated ball bearings	<0.01	<0.01
Synovial joints (in human limbs)	0.01	0.01

† Values are approximate and intended only as a guide.

Copyright © 2005 Pearson Prentice Hall, Inc.

QuickTime Kinetic and Static Friction (02:37)

Solving problem hints:

- When velocity is constant or zero, the force of friction is equal to the applied force.
- Always sum your forces on one side before solving for anything else
- Draw a force diagram for every problem
- Don't forget Newton's second law – F = ma as well as your kinematics equations from Unit 2

Examples:

1. A box with a mass of 20 kg is resting on a table. The coefficient of static friction is .4. What is the force of friction acting on the box?

Given
Mass = 20 Kg
μ_k = .4 (there are no units for coefficient of static friction)

Solving for
Ffr

Equation - Ffr = μ_k Fn

Ffr = .4(20)(9.8)
Ffr = 78.4 N

2. You are pushing your little brother at a constant speed on a sled horizontally with a force of 40N, he has a mass of 30 kg, what is coefficient of kinetic friction?

Given
Mass = 30 Kg
Fapplied = 40N

Solving for
μ_k = ?

Equation - Ffr = μ_kFn

Hint – Because the sled is traveling at a *constant speed* the force of friction is equal to the applied force.

40 = μ_k (30)(9.8)

μ_k **= .136**

3. A force of 55 N accelerates a 6 kg block at 3 m/s^2 across a horizontal surface. How large is the frictional force and what is the coefficient of friction?

Given
Mass = 6 Kg
Fapplied = 55 N
Acceleration = 3 m/s^2

Solving for
Ffr
μ_k

Equations - Ffr = μ_kFn and F = ma

When solving for Ffr we will use the equation F = ma. In order to do this you must use the sum of the forces for F on the left side of the equation. In this

problem we have an applied force and a force of friction. Because friction always acts in a direction opposite of motion we will subtract friction from the applied force to give us one F.

Yielding the equation:
Fa – Ffr = ma

55 – Ffr = (6)(3)
55 – Ffr = 18
-Ffr = -37 (the negative signs cancel out because they are present on both sides of the equation)
Ffr = 37

Now we can solve for μ_k

Ffr = μ_kFn

37 = μ_k(6)(9.8)
μ_k = .63 (notice that μ_k will always be equal to or less than 1)

4. You are ice skating and gliding with an initial speed of 7m/s and glide to a stop. How far will you go, given the coefficient of friction is .08?

Given
Vo = 7
V = 0
μ_k = .08

Solving for
distance

Equations – Ffr = μ_k Fn, F = ma and $V^2 = Vo^2 + 2ad$

Because the problem says that you are gliding with a velocity of 7 indicates that at this moment there are no applied forces acting on you to make you move. So the only force acting against your motion is friction.

F=ma

-Ffr = ma (Ffr is going to be negative because it is acting in the opposite direction of motion)

We will write what Ffr is, in its place in the equation (μ_kFn or $\mu_k$mg)

-$\mu_k$mg = ma

This allows us to cancel out mass since we do not know the mass of the skier.

-μ_kg = a

-.08(9.8) = a

a = -.784 m/s^2

Now we can solve for the distance of the skier

$V^2 = Vo^2 + 2ad$

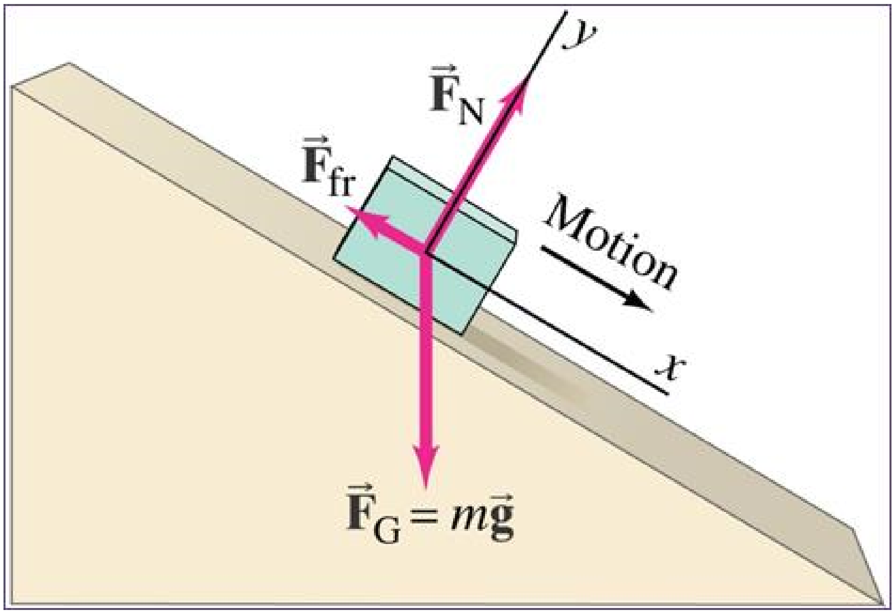
$0^2 = 7^2 + 2(-.784)(d)$

-49 = -1.568d

d = 31.25m

Friction in Two Dimensions

The above scenarios all depicted a situation where an object was moving along a flat horizontal surface, but what happens when the object is moving downhill or on a slope? In these types of situations gravity plays a huge role in accelerating the object downhill at an angle relative to a horizontal plane. In this case we need to come up with a coordinate system. We will say the slope of this hill or incline is the x axis and the y axis is perpendicular to the incline or hill. By looking at the picture below, you can see the direction of forces acting on the block: the normal force is perpendicular to the incline.



An object sliding down an incline has three forces acting on it: the normal force, gravity, and the frictional force.

- **The normal force is always perpendicular to the surface.**
- **The friction force is parallel to it, opposing gravity in the x direction**
- **The gravitational or weight force points straight down.**
- **There may also be an applied force acting on the object if something is pushing or pulling it**

Now that an object is moving "downhill" there will be a horizontal gravity component and a vertical gravity component. The natural acceleration of the object down an incline is due to gravity in the x direction.

<u>Weight components equations:</u>
Fgx (gravity in the x direction) = mg sin theta
Fgy (gravity in the y direction) = Fn = mg cosine theta – According to Newton's second law (F=ma) they are equal to one another because acceleration is zero in the y direction

Hints:
The angle of the incline given is the same angle between the normal force and the weight force. When you find Fn and Fgx this is the similar triangle that you will use to break it up into its components. Which is why in most cases we will use the sin trig function to find Fgx and the cosine trig function to find Fn.

Acceleration in the Y direction is always zero.

Examples:
1. A 5 kg block slides down a 26 degree inclined plane with a constant acceleration of .25 m/s 2. The block starts from rest at the top.
A. **What is the Force of Friction?**

Given

Mass = 5 kg
Angle of incline = 26 degrees
Acceleration = .25 m/s^2

Solving For

Ffr

Equations
Sum of Forces = ma
Fgx – Ffr = ma (gravity in the x direction is helping to accelerate the block down the incline and friction is trying to slow it down)

mgsinθ – Ffr = ma

5(9.8) SIN (26) – Ffr = 5(.25)
21.5 – Ffr = 1.25
-Ffr = -20.25 N
Ffr = 20.25N

B. What is the Coefficient of Friction

Equation

Ffr = μ_kFn

20.25 = μ_k(5)(9.8)(Cos26)

20.25 = μ_k44

μ_k **= .46**

2. **A skier with a mass of 65 Kg is going down a slope that has an incline of 30 degrees because her friend pushed her with a force of 5.3 Newton's. Assuming the coefficient of kinetic friction is .10, what is her acceleration?**

Given

Mass = 65 kg
Angle of incline = 30 degrees
Applied Force = 5.3 N

μ_k = .10

Solving For
Acceleration

Equations
Sum of Forces = ma
Fa + Fgx – Ffr = ma (Fa is the applied force which is the push of her friend. Gravity in the x direction is helping to accelerate the block down the incline and friction is trying to slow it down)

And Ffr = μ_kFn

Ffr = μ_kFn
Ffr = .10(65)(9.8)(Cos30)
Ffr = 55.2 N

Fa + mgsinθ – Ffr = ma
5.3 + 65(9.8) SIN(30) – 55.2 = 65a
268.6 = 65a
a = 4.13m/s²

3. A skier with a mass of 50 kg starts from rest and slides down an incline with an acceleration of 3 m/s2. If the force of friction acting against the skier is 22 N, what is the incline of the hill in degrees?

Given

Mass = 50 kg
Vo = 0
Acceleration = 3 m/s²
Ffr = 22 N

Solving For
Angle of the hill

Equations
Sum of Forces = ma
Fgx – Ffr = ma

50(9.8)sinθ - 22 = 50(3)
490sinθ - 22 = 150
490sinθ = 172
sinθ =172
θ = 20.5 degrees

Looking Ahead to Unit 9

In unit 9 you will explore friction in one dimension by completing a laboratory exercise. You will be able to manipulate the mass of an object, the materials of the surfaces and the initial velocity of the object.

Below are additional educational resources and activities for this unit.

Unit 8 Resource 1

Unit 8 Resource 2