Newton's Laws

Name: _____

Video 403 (7:30)

kinematics: the describing of HOW things move

dynamics: the study of…

The Beginnings of Dynamics

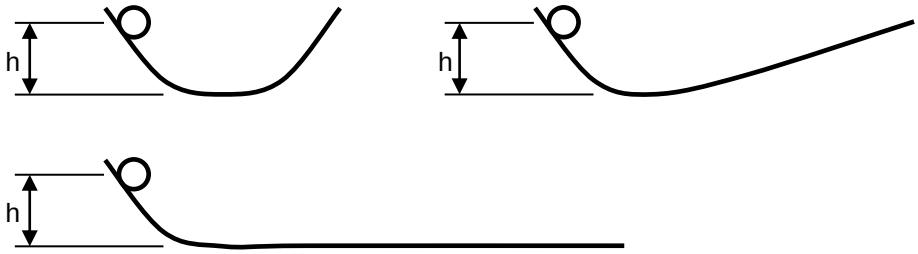
Aristotle (384–322 B.C.E.) didn't experiment, but claimed…

--

-- forces arise from matter…

e.g.,

Galileo Galilei (1564–1642): Among other things, he rolled spheres down inclined planes.



Newton's First Law of Motion (Law of Inertia) An object at rest tends to stay at rest – and an object in motion tends to stay in motion at constant velocity – unless the object is acted upon by an unbalanced, external force.

Video 406 (4:35)

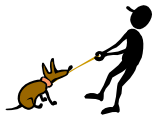
An Introduction to Forces

force: a push or pull; forces are vectors

contact forces

field forces

e.g.,



e.g.,

Springs exert forces, but ONLY when they are stretched or compressed.

If stretched, springs…

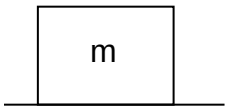
If compressed, springs…

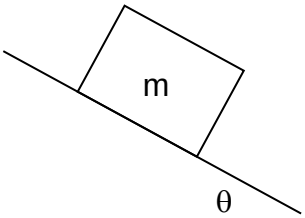
The FARTHER they are **stretched** (or *compressed*), the _____ the elastic force with which they **pull** (or *push*) back.

Springs conform to Hooke's law:

Video 408 (7:01)

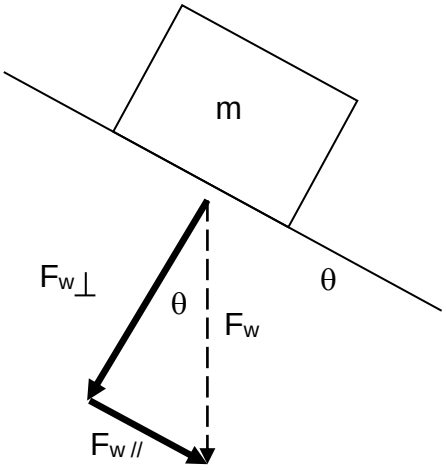
weight (F_w): gravity's effect on object; always acts ↓



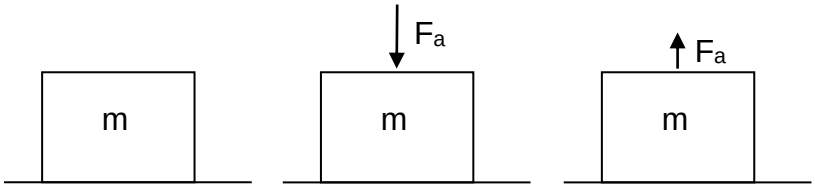


Equation for weight:

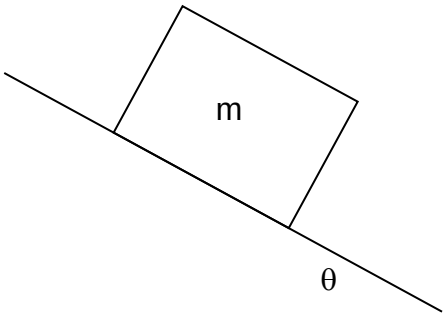
On "incline" problems, it is convenient to resolve all forces into ⊥ and // components. For weight F_w…



normal force (F_n): the force a surface exerts on object normal (i.e., ⊥) to surface



F_n changes ^{w}/surface angle and ^{w}/applied force (dir. & mag.), but remains at right angles to surface.



Video 410 (6:37)

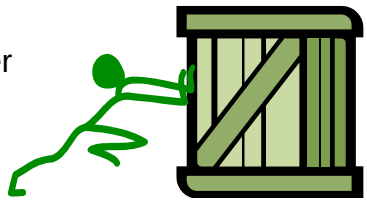
Friction --

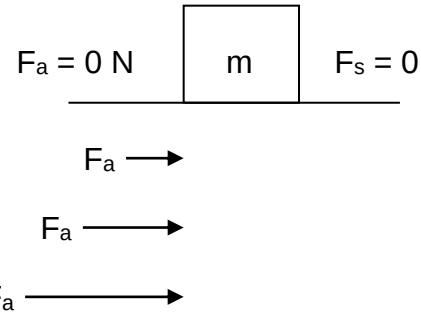
-- depends on: 1. nature of contact surfaces

2. the normal force, i.e.,

Static Friction

-- when objects are NOT moving relative to each other





F_s can take any value from zero to $F_{s,max}$.

Kinetic Friction

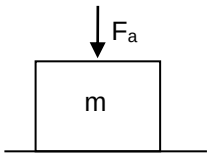
--

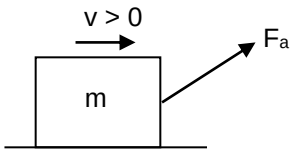
-- has only one value for a given set of conditions

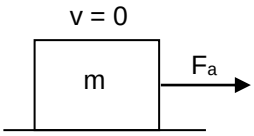
Video 412 (7:58)

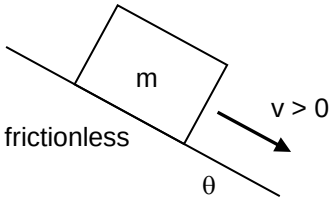
free body diagram (FBD):

-- For now, we will assume that all forces act at the body's center of mass.



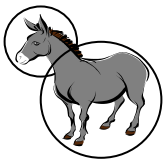
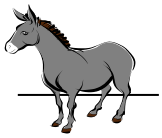
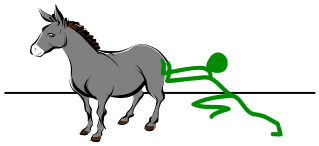






Video 415 (8:01)

Equilibrium On an object in equilibrium...

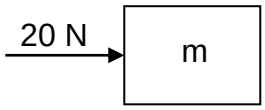
	Situation:	FBD:
In deep space...		
On Earth...		
Still on Earth...		

An object in equilibrium is either… 1.

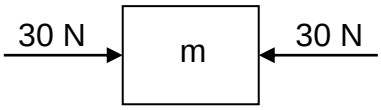
2.

i.e.,

The net force on such an object is...

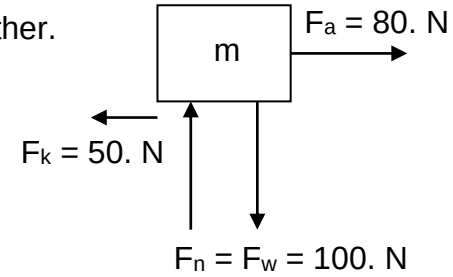


At moment force is applied, box is…	What happens?
at rest	
moving 20 m/s →	
moving 20 m/s ←	



What if box is…	What happens?
at rest	
already moving	

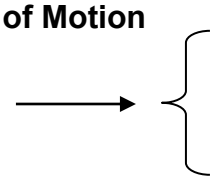
Sometimes, net force is zero in one direction but NOT zero in another.



-- _____ equilibrium ONLY

Video 418 (8:09)

Newton's Second Law of Motion



By Newton's 2nd Law, objects…

…in equilibrium (i.e., experiencing NO net force)...

…experiencing a net force...

i.e.,

To solve Newton's 2nd law problems (i.e., "force problems"):

1. Draw a correct FBD. Don't forget any forces.
2. For direction "A," write $\Sigma F_A = m\, a_A$. If there is a surface, direction "A" should generally be the one perpendicular to the surface. Solve for whatever you can.
3. For direction "B," write $\Sigma F_B = m\, a_B$. Solve for whatever you need to. You will probably be able to substitute in something you solved for in the $\Sigma F_A = m\, a_A$ part.
4. You should be done. Round your answer properly and make sure it has the correct unit (if any).

EX. A ____ kg mass moving along horiz. surface is acted upon by a ____ N force in direction of its motion. If coeff. of kinetic friction is _____, find mass's acceleration.

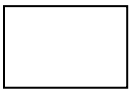
$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

Video 421 (9:59)

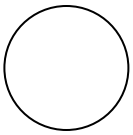
A ____ kg mass moving ⟶ horizontally is acted upon by a ____ N force inclined up and to-the-right at ___° above horizontal. Coeff. of kinetic friction is ____. Find mass's acceleration.

$\Sigma F_{\perp}$:



$\Sigma F_{//}$:

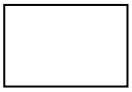
EX. A ____ kg mass hangs vertically at rest from a spring. If the spring displaces ____ cm, find the force constant.



$\Sigma F_{\updownarrow}$:

EX. A ____ kg mass is at rest on horizontal surface. Rope tied to mass has tension ____ N and is angled ____° above horizontal. Also, a ____ N force presses mass into surface. Find normal & friction forces.

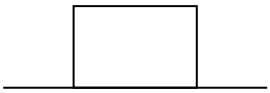
$\Sigma F_{\perp}$:



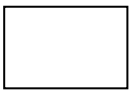
$\Sigma F_{//}$:

Video 424 (7:05)

A ___ kg mass at rest on horiz. surface requires a ___ N applied horiz. force to make it begin moving. Find coeff. of static friction between mass and surface.



$\Sigma F_{\perp}$:



$\Sigma F_{//}$:

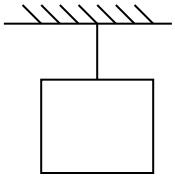
EX. To keep ___ kg mass moving at constant velocity, only ___ N $\longrightarrow$ is req'd. Find coeff. of kinetic friction.

$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

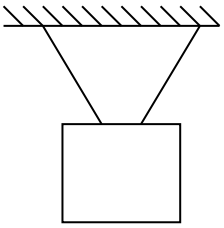
Video 427 (4:08)

A ___ kg mass hangs from ceiling by a single rope. Find tension in rope.



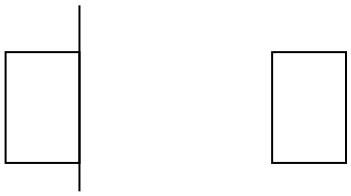
ΣF:

EX. Same ___ kg mass hangs now from two ropes, each having angle of ___^{o} above horiz. Find tension in each rope.



Video 430 (8:18)

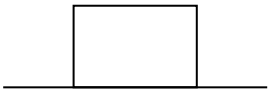
A ___ kg mass is being pushed upwards along a vert. surface by a force of ___ N at an angle of ___^{o} above the horizontal. If the coeff. of kinetic friction is ___, find the mag. of the mass's acceleration.



$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

EX. A ___ kg mass moving $\rightarrow$ along horiz. surface is acted upon by a ___ N force (down and to-the-right) at __^{o} below horizontal. Coeff. of kinetic friction is ___. What applied horiz. force is req'd for acceleration to be ___ m/s^2 $\rightarrow$?

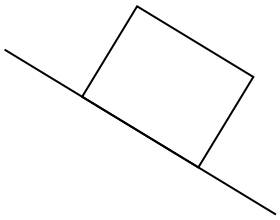


$\Sigma F_{\perp}$:

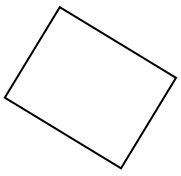
$\Sigma F_{//}$:

Video 433 (7:18)

A block of mass ___ kg is at rest on an incline of ___^{o}. Also, a ___ N force is pulling on the mass down the ramp and a ___ N force is pressing the mass into the surface. Find the normal force and the friction force on the mass.

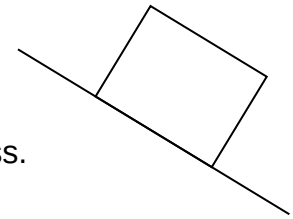


$\Sigma F_{\perp}$:

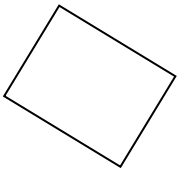


$\Sigma F_{//}$:

EX. A ___ N force acts downward along a ___^{o} inclined plane on a ___ kg mass. The force is parallel to the plane, the coefficient of kinetic friction is ___, and the mass is already moving. Find the acceleration of the mass.



$\Sigma F_{\perp}$:



$\Sigma F_{//}$:

Video 436 (6:16)

A ___ kg mass at rest on a horizontal surface is acted upon by two external applied forces: a ___ N force at ___^{o} up and to-the-left and a ___ N force at ___^{o} up and to-the-right. The coefficient of static friction is ___. Will the mass move?

$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

NOW, WE'LL SOLVE PROBLEMS WITH NUMBERS…

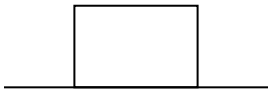
Video 439 (8:52)

A 13 kg mass moving along horiz. surface is acted upon by an 87 N force in direction of its motion. If coeff. of kinetic friction is 0.22, find mass's acceleration.

$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

EX. An 18 kg mass moving ⟶ horizontally is acted upon by a 165 N force inclined up and to-the-right at 33° above horizontal. Coeff. of kinetic friction is 0.26. Find mass's acceleration.

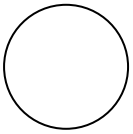


$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

Video 442 (5:57)

A 2.30 kg mass hangs vertically at rest from a spring. If the spring displaces 15.4 cm, find the force constant.

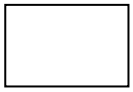


$\Sigma F_{\updownarrow}$:

EX. An 8.4 kg mass is at rest on horizontal surface. Rope tied to mass has tension 73 N and is angled 43° above horizontal. Also, a 58 N force presses mass into surface. Find normal & friction forces.

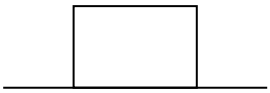
$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

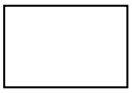


Video 445 (7:14)

A 38 kg mass at rest on horiz. surface requires a 153 N applied horiz. force to make it begin moving. Find coeff. of static friction between mass and surface.

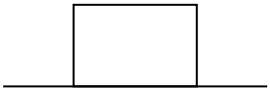


$\Sigma F_{\perp}$:



$\Sigma F_{//}$:

EX. To keep 38 kg mass moving at constant velocity, only 87 N $\longrightarrow$ is req'd. Find coeff. of kinetic friction.

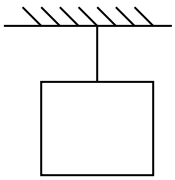


$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

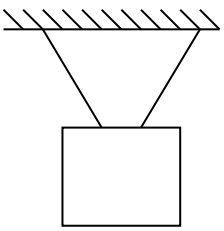
Video 448 (5:44)

A 55 kg mass hangs from ceiling by a single rope. Find tension in rope.



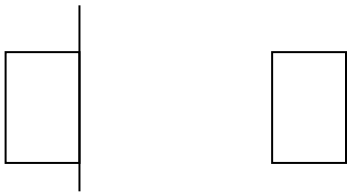
ΣF:

EX. Same 55 kg mass hangs now from two ropes, each having angle of $60.^{o}$ above horiz. Find tension in each rope.



Video 451 (9:54)

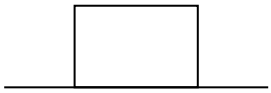
A 7.82 kg mass is being pushed upwards along a vert. surface by a force of 175 N at an angle of 55.0^o above the horizontal. If the coeff. of kinetic friction is 0.142, find the mag. of the mass's acceleration.



$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

EX. A 31 kg mass moving $\longrightarrow$ along horiz. surface is acted upon by a 218 N force (down and to-the-right) at 40.^{o} below horizontal. Coeff. of kinetic friction is 0.24. What applied horiz. force is req'd for acceleration to be 3.32 m/s^2 $\longrightarrow$?

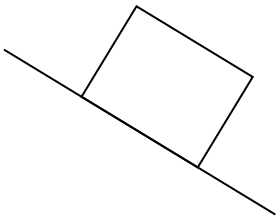


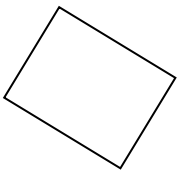
$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

Video 454 (8:00)

A block of mass 17 kg is at rest on an incline of 25^o. Also, a 21 N force is pulling on the mass down the ramp and an 82 N force is pressing the mass into the surface. Find the normal force and the friction force on the mass.

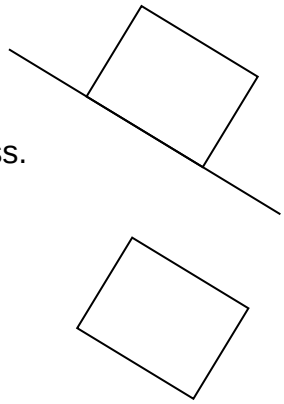




$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

EX. A 52 N force acts downward along a 41^o inclined plane on a 22 kg mass. The force is parallel to the plane, the coefficient of kinetic friction is 0.49, and the mass is already moving. Find the acceleration of the mass.

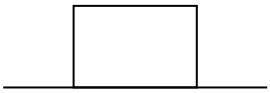


$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

Video 457 (8:37)

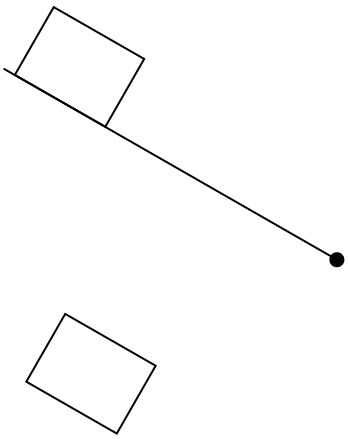
A 56 kg mass at rest on a horizontal surface is acted upon by two external applied forces: a 275 N force at 18^o up and to-the-left and a 418 N force at 42^o up and to-the-right. The coefficient of static friction is 0.31. Will the mass move?



$\Sigma F_{\perp}$:

$\Sigma F_{//}$:

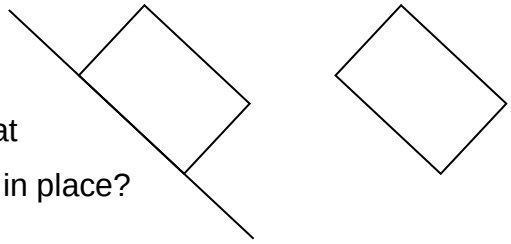
EX. A 26 kg mass is on an adjustable incline. Mass is at rest when incline is horiz. and remains at rest as incline is angled more steeply. It is found that max. angle for which mass stays put is 28^o. Find the coeff. of static friction between mass and incline.



Video 460 (8:21)

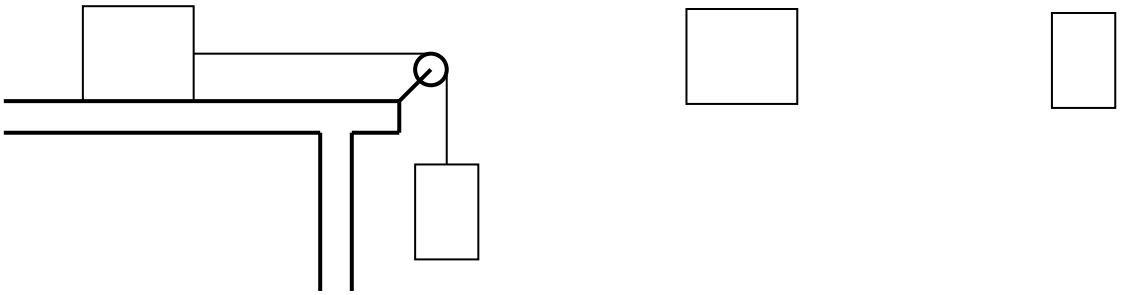
Newton's 2nd Law and Systems of Equations

A 58 kg mass must remain at rest along a 48° inclined plane. The coefficient of static friction is 0.14 and the coefficient of kinetic friction is 0.08. What applied horizontal force is required to keep the mass in place?



Video 463 (6:22)

A 3.9 kg mass (Mass 1) hangs from a string that is looped over a pulley projecting out from a tabletop. The other end of the string is attached to a 6.5 kg mass (Mass 2) on the tabletop such that, between the pulley and Mass 2, the string is horizontal. Assuming that both masses are already moving together and that the coefficient of kinetic friction between Mass 2 and the table is 0.21, find the acceleration of Mass 1.



Video 466 (9:01)

Terminal Velocity

Why do objects fall at the same rate in the absence of air resistance?

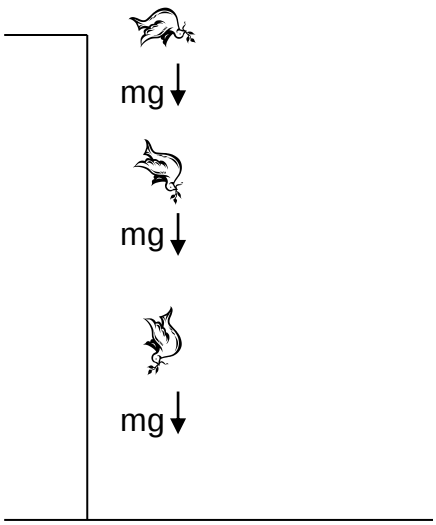
From Newton's 2nd Law ($\Sigma F = ma$)... SMALL OBJECT LARGE OBJECT

What if air resistance isn't negligible?

Air resistance (F_{air}) depends on:

1.

2.



Because air resistance depends on an object's speed, the more mass it has, the longer it will have to fall before the air resistance equals the weight,

i.e.,

In general, then…

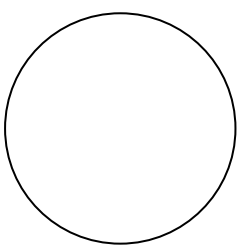
Video 469 (7:17)

Newton's Third Law of Motion Newton recognized that forces always occur in pairs.

"If object A exerts a force on object B, then B exerts an equal force on A, but in the opposite direction."

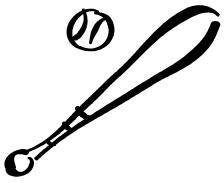
<u>or</u>

"For every action, there is an equal and opposite reaction."

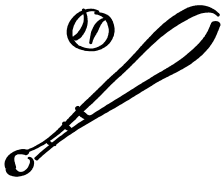


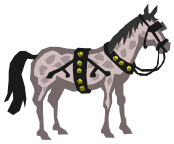
** <u>The action and reaction forces</u>…

Before impact…



After impact…

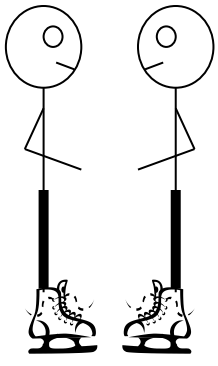




Video 472 (2:22)

Consider ice-skating twins, each of mass 50. kg. Find acceleration of A if…

1) ...A pushes on B with 50. N.



2) ...each pushes on the other w/50. N.