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Teach Yourself MCAT Physics in 24 Hours

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MCAT Physics

Force and Motion

MCAT Rapid Learning Series

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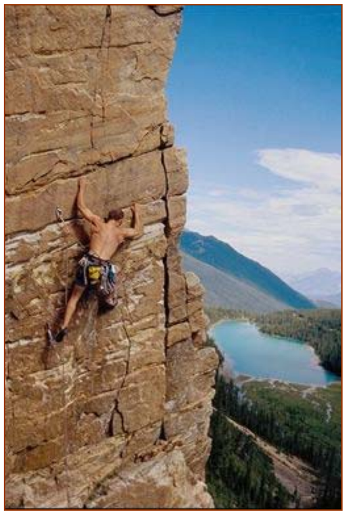
Learning Objectives

By completing this tutorial, you will:



- Understand Newton's three laws of motion.
- Explain the role of forces like friction and air resistance.
- Apply these laws to dynamics problems.

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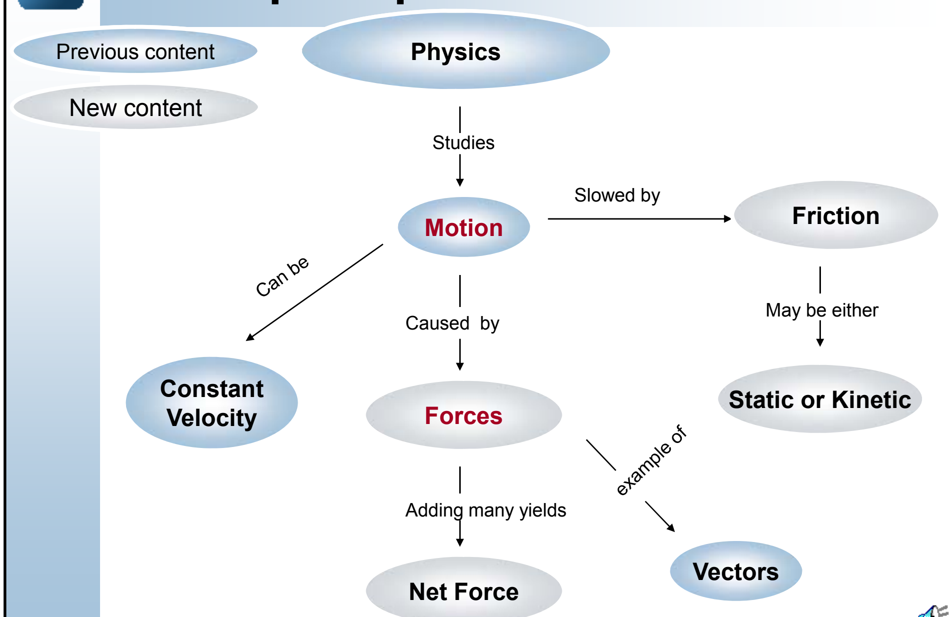
Concept Map: Forces and Motion



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Newton's Laws

Three basic laws formulated by Isaac Newton describe the forces acting on objects.

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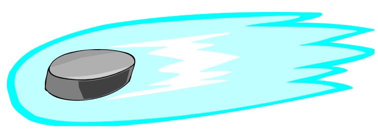
Newton's First Law

Every object continues in a state of rest, or uniform motion in a straight line,



unless it is acted upon by an outside force.

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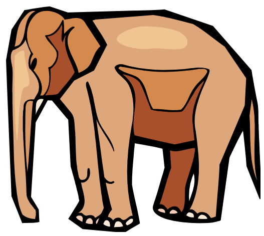
Inertia

This tendency to continue in a given state,

Newton's 1st law, is called inertia.

The more mass an object has, the more inertia it has.



Large amount of inertia!

Small amount of inertia!

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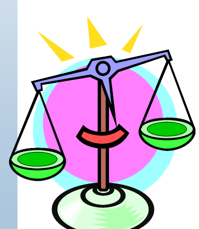
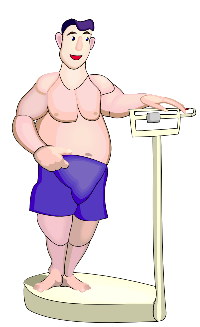
Mass vs. Weight

Mass: The amount of matter in an object.
Unit: kg, g

Weight: The force upon an object due to gravity.
Unit: Newtons, N.



Don't confuse mass & weight! They might be similar, but they are not the same.



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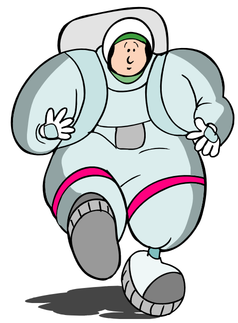
Mass Question

If you travel deep into space, does your mass change?

No!



Your location doesn't change the amount of matter present in your body. Even if you are floating in space, you still possess the same number of atoms and molecules.

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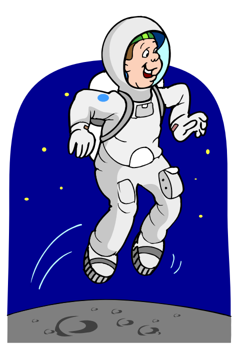
Weight Question

If you travel deep into space, does your weight change?

Yes!



In space, there may be less gravitational pull on you. Thus your weight, a force, will be less.

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Force Units

Some are familiar with the English unit for force, the pound, lb.

However, the typical metric unit for force is the Newton, N.

One Newton = 1 kg m/s².

On earth, 1 kg of mass would weigh 9.8N.

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Newton's Second Law

$$F_{net} = ma$$

net force, N

mass, kg

acceleration, m/s²

The acceleration of an object is directly proportional to the net force, and inversely proportional to the mass.

It may also be seen as $F_{net}=\Sigma F$. This indicates that the net force is the sum of all the forces acting on an object.

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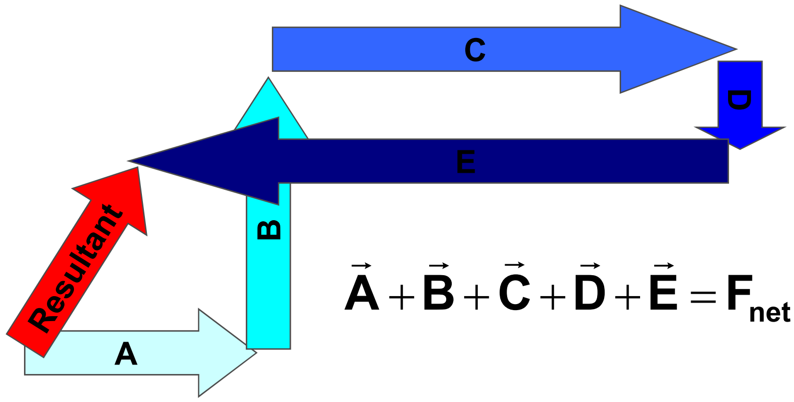
The Net Force

The net force is simply the resultant of all the forces acting on an object.



$$\vec{A} + \vec{B} + \vec{C} + \vec{D} + \vec{E} = F_{net}$$

It can be considered the leftover, or sum of all forces.

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Paycheck Analogy

You may work 10 hours at $10 per hour, but your pay at the end of the period is definitely not $100.

After all taxes and deductions are accounted for, what you actually get is your net pay. This is similar to the net force.

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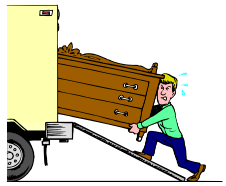
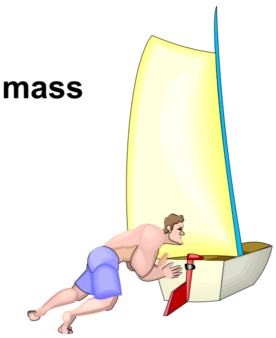
Second Law Observations

A larger mass is more difficult to accelerate than a smaller one! This is common sense!



Also, a larger force accelerates a mass more than a smaller one!



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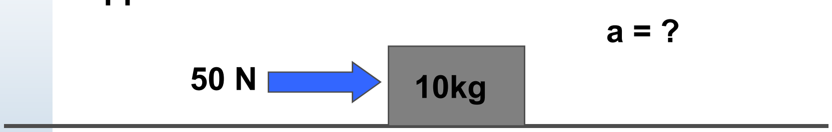
Second Law Example

If a 10kg block rests on a friction-less surface, how much will it accelerate if a 50N force is applied to it?



$$F_{net} = ma$$

$$a = F_{net}/m$$

$$a = 50N / 10kg$$

$$a = 5 m/s^2$$

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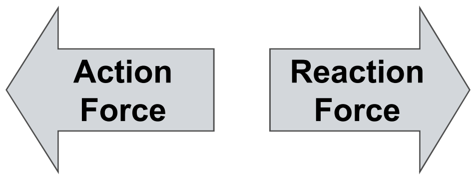
Newton's Third Law

For every force, there is an equal and opposite force.

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



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Newton's Third Law Example

The exhaust gasses from a rocket are forcefully pushed downward out the rear of the nozzle.

An equal and opposite force is exerted upwards on the rocket itself.

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The Normal Force

The chair supports, or pushes up on you. This reaction force is called the **normal force**.

Your weight due to gravity pulls you down.

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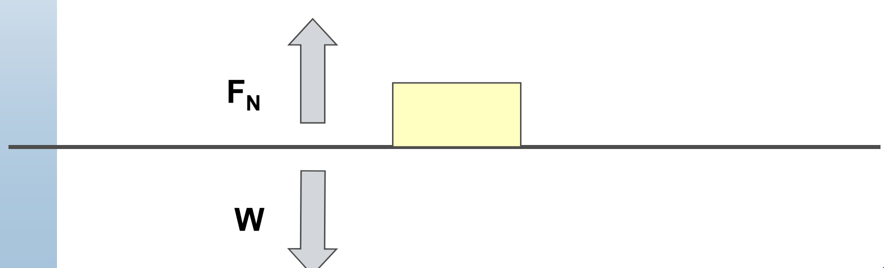
The Normal Force Direction

This normal force is always **perpendicular** to the surface.

If the surface is horizontal (flat), it is equal in magnitude to the weight of the object.



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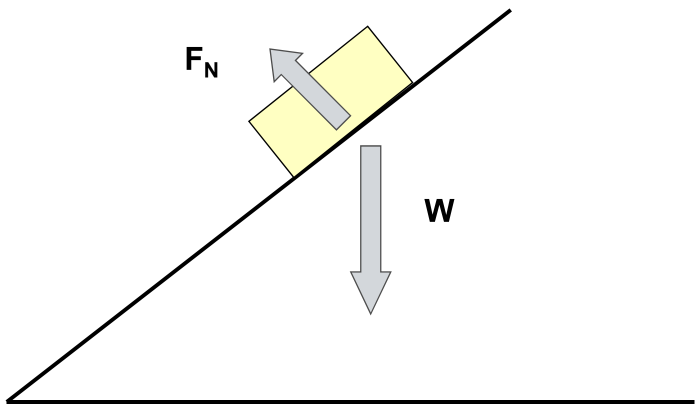
Normal Force on an Incline

If there is an incline, the normal force is still perpendicular to the surface, but it isn't equal in magnitude to the weight.



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Friction

Since it tries to slow all motions, one of the most important forces to study is friction.

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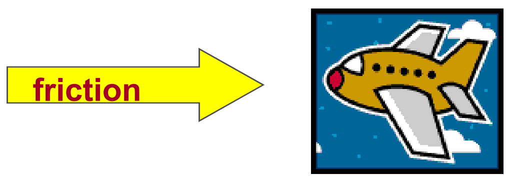
Direction of Friction

As previously mentioned, friction is a force that always opposes motion.

Air drag/air resistance are examples of friction between an object and the air.



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Types of Friction

There are two types of friction:

***static* (stationary) and *kinetic* (moving).**

Static friction keeps him from sliding off the chair.

Kinetic friction slows him as he slides.

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Simple Friction Example

Imagine a man is pushing a 20 kg sled along a floor at a constant velocity by applying a force of 40 N.

What is the weight of the sled?

F_{net}=ma   weight = (20 kg)(9.8 m/s²) = 196N

Here we consider the pull from gravity, not the horizontal motion due to the man's push.

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Frictional Force on Sled

What is the force from friction on the sled?

Since it has a constant velocity, F_{net} = 0. Friction must also be 40N

F_{net}= 0 N, dynamic equilibrium

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Coefficient of Friction

There is a way to mathematically describe the amount of friction between any two given surfaces.

$$\mu = \frac{F_f}{F_N}$$

Coefficient of friction, Greek letter mu

Force from friction, N

Normal force, N

μ (mu) is a unit-less ratio.

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Static and Kinetic Friction

Because the amount of friction depends on whether the object is moving or still, there are two possible μ values:

μ_s= static coefficient of friction

μ_k = kinetic coefficient of friction

The one you use depends on the situation!

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Kinetic Friction Example

Previously, a man pushed a 20 kg sled at a constant velocity with a force of 40N. What is the coefficient of kinetic friction, μ_k in this case?

$$\mu_k = \frac{F_f}{F_N}$$

Since it moves at a constant velocity, the frictional force must equal the pushing force.

$$\mu_k = \frac{40N}{(20kg)(9.8m/s^2)}$$

The normal force is equal in size to the weight

$$\mu_k = \frac{40N}{196N}$$

$$\mu_k = .20$$

No units for μ

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Dynamics Problems

The study of the forces acting on an object is called dynamics. These forces produce motion!

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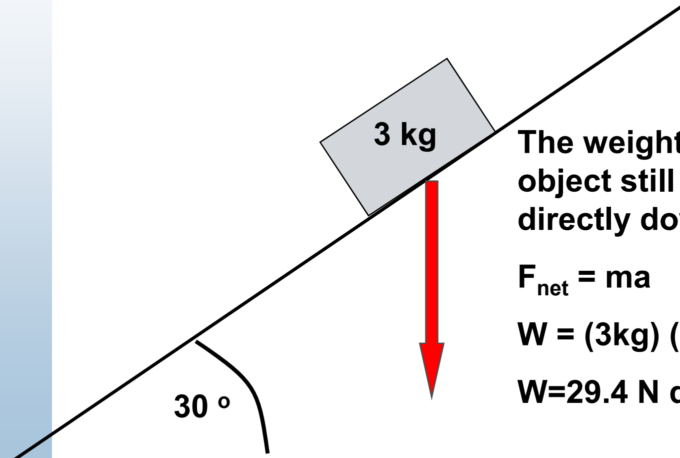
Inclined Plane Example

Calculate the acceleration of this block sliding down a frictionless inline.



The weight of the object still points directly down:

$F_{net} = ma$

W = (3kg) (9.8 m/s²)

W=29.4 N down

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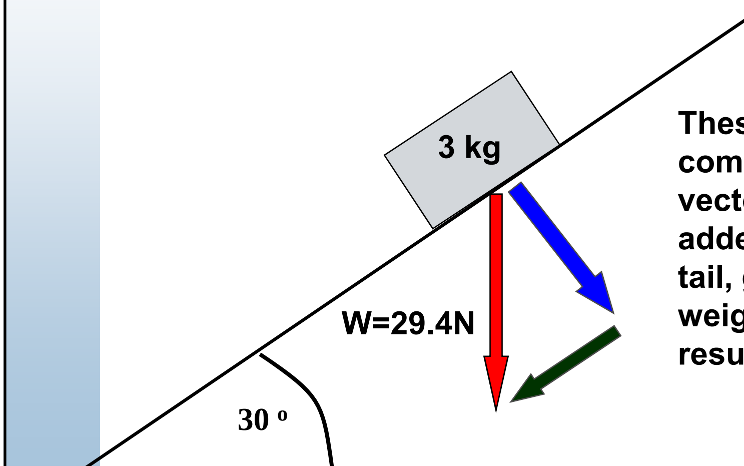
Component Vectors on Inclined Plane

Notice how this weight vector could be broken into two components.



These two component vectors, when added tip to tail, give the weight as a resultant:

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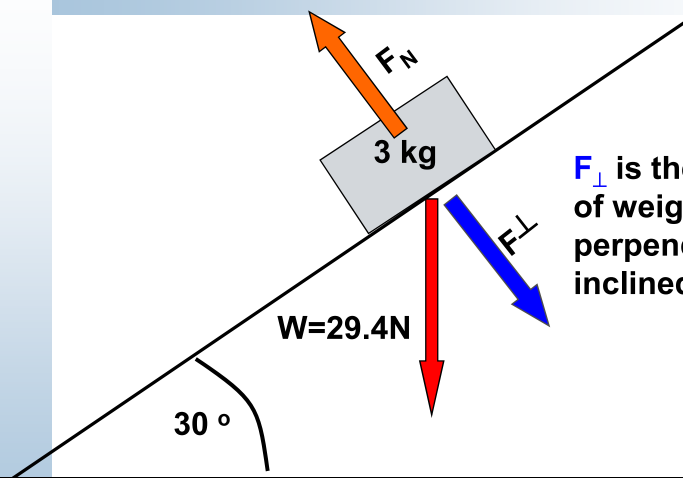
Perpendicular Force Component



$F_\perp$ is the component of weight that is perpendicular to the inclined surface.

This component is responsible for pushing the object into the surface. The reaction force to this one is the normal force, F_N.

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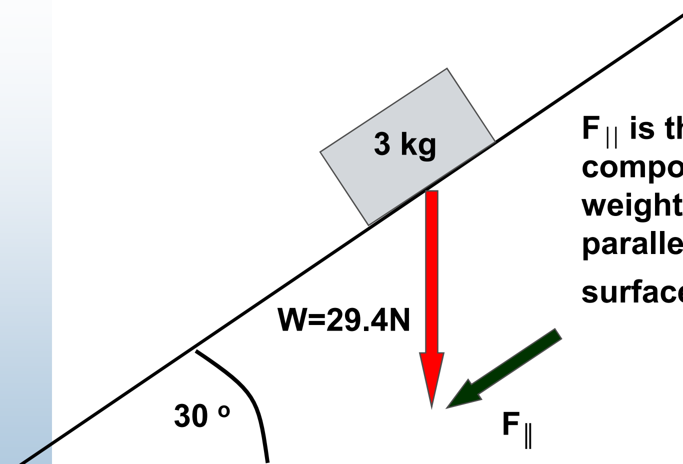
Parallel Force Component



$F_{||}$ is the component of the weight that pushes parallel to the surface.

This component is responsible for pushing the object along the incline.

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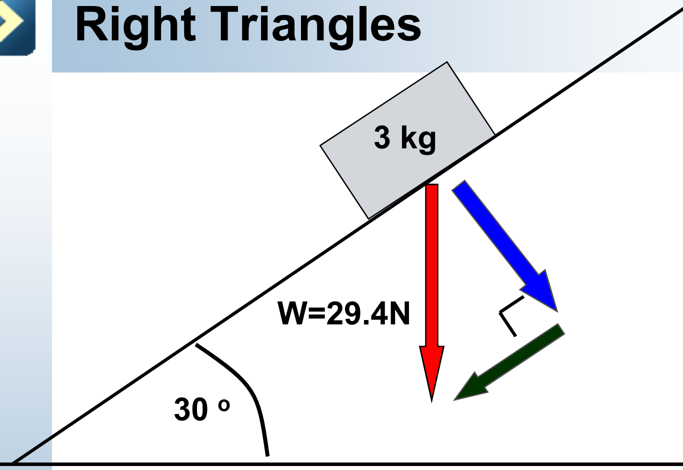
Right Triangles



$F_{||}$, and $F_{\perp}$ can be found relatively easily using simple trigonometry. The triangle they form is a right triangle. The weight is the hypotenuse.

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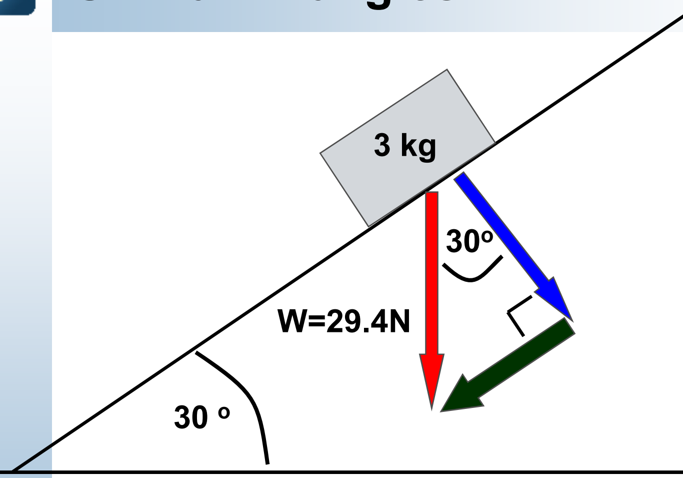
Similar Triangles



The angle at the top of the triangle is the same as the angle of the incline. The two form similar triangles. This concept can be used for any inclined plane.

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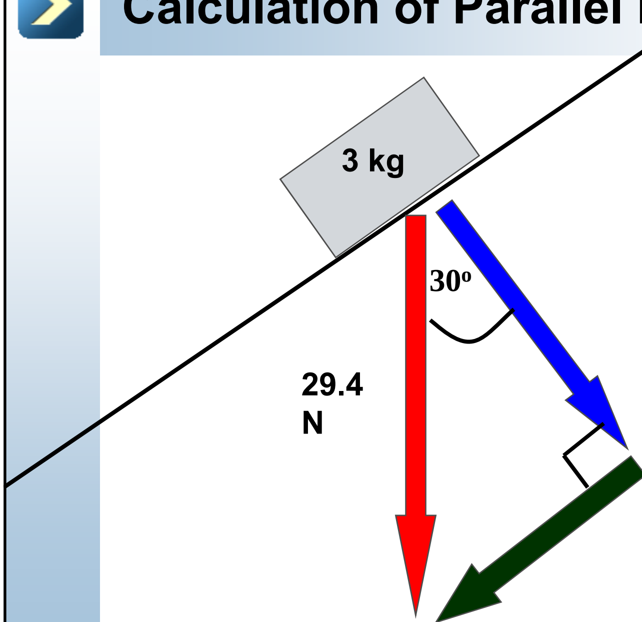
Calculation of Parallel Force



$$\sin\theta = \frac{F_{\parallel}}{W}$$

$$\sin 30^0 = \frac{F_{\parallel}}{29.4N}$$

$$F_{\parallel} = 14.7N$$

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Calculation of Acceleration

Finally, since we now have the force that is pushing the object down the incline, we can use F_{net}=ma.

$F_{\parallel}=F_{net}=ma$

14.7N=3kg(a)

a=14.7N/3kg=4.9m/s^2

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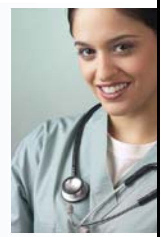
The MCAT Strategies



How are the concepts introduced in this tutorial tested in the MCAT exam?

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MCAT Sample Passage

Passage X (Questions 1-3)
A student completes an experiment involving forces and friction.

A 1 kg block is resting on a horizontal lab table. There is a noticeable amount of friction present.

The student pulls horizontally and gradually with more and more force on the block that is attached to a string of negligible mass.

Force is applied until the block begins to move at a constant rate.

The force applied is charted as a function of time.

The SURE Method:

(1) Skim the passage quickly. In this case try to visualize the experiment that is being conducted.

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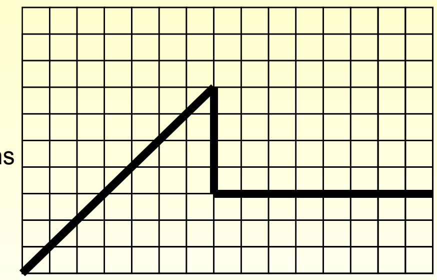
Passage Continued

Experiment results:



Each block on the graph indicates 1 Newton of force, or 1 second of time.

Consider the experiment and graph when answering the following questions.

The SURE Method:

(2) Understand the key points.

Here you must consider the role of static and kinetic friction. Both play a role here.

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1st MCAT Passage Question

1. What is the coefficient of static friction in the experiment?

(A) 1.2

(B) 1

(C) .8

(D) .7

Step 3: Read the question carefully and identify the key concept to be used.

Consider the formula used to calculate the coefficient of static friction. You must also understand what role the normal force plays here.

Step 4: Examine the answer choice and pick the best one.

Correct Answer: (D)

$\mu_s = F_f/F_N$ Coefficient of friction = frictional force/ normal force

In this case, the frictional force is the same as the applied force. The normal force is the same as the weight of the object.

μ_s=7N/10N=.7 This is shown at the peak of the graph

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2^{nd} MCAT Passage Question

2. What is the coefficient of kinetic friction in the experiment?

(A) 1

(B) .5

(C) .3

(D) .1

Step 3: Read the question carefully and identify the key concept to be used.

Consider the graph and identify where the mass is moving.

Step 4: Examine the answer choice and pick the best one.

Correct Answer: (C)

$\mu_k = F_f/F_N$ Coefficient of friction = frictional force/ normal force

In this case, the frictional force is the same as the applied force. The normal force is the same as the weight of the object.

μ_k=3N/10N=.3 This is shown at horizontal portion of the graph.

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3^{rd} MCAT Passage Question

3. During the horizontal section of the graph, what is the acceleration of the mass?

(A) 9.8 m/s^2

(B) .5 m/s^2

(C) 0 m/s^2

(D) There is not enough information to determine.

Correct Answer: (C)

For the horizontal section, the mass has begun moving, and a constant force is still continually applied.

Since there is friction in this situation, the applied force and frictional force balance out to produce a net force of zero.

This gives a zero acceleration too!

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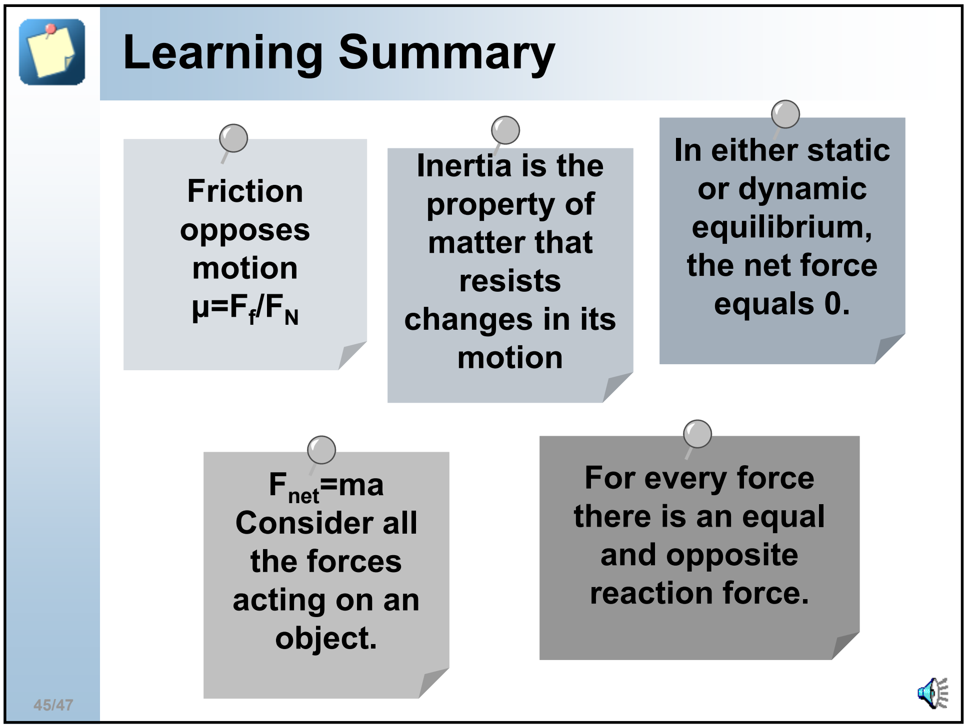
Learning Summary
Friction opposes motion
μ=Ff/FN
Inertia is the property of matter that resists changes in its motion
In either static or dynamic equilibrium, the net force equals 0.
Fnet=ma
Consider all the forces acting on an object.
For every force there is an equal and opposite reaction force.
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Congratulations
You have successfully completed the core tutorial
Force and Motion
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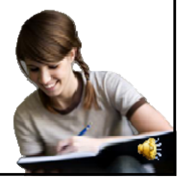
What's Next …

Step 1: Concepts – Core Tutorial (Just Completed)

→ Step 2: Practice – Interactive Problem Drill

Step 3: Recap – Super Review Cheat Sheet

Go for it!



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