S-15

Name all the forces that you think are acting on the creature below

Dynamics: Newton’s Laws of Motion

AP Physics

Chapter 4

Dynamics: Newton's Laws of Motion

4.1 Force

Standard

IB1a

Students should be able to analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

4.1 Force

Analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

Dynamics – connection between force and motion

Force

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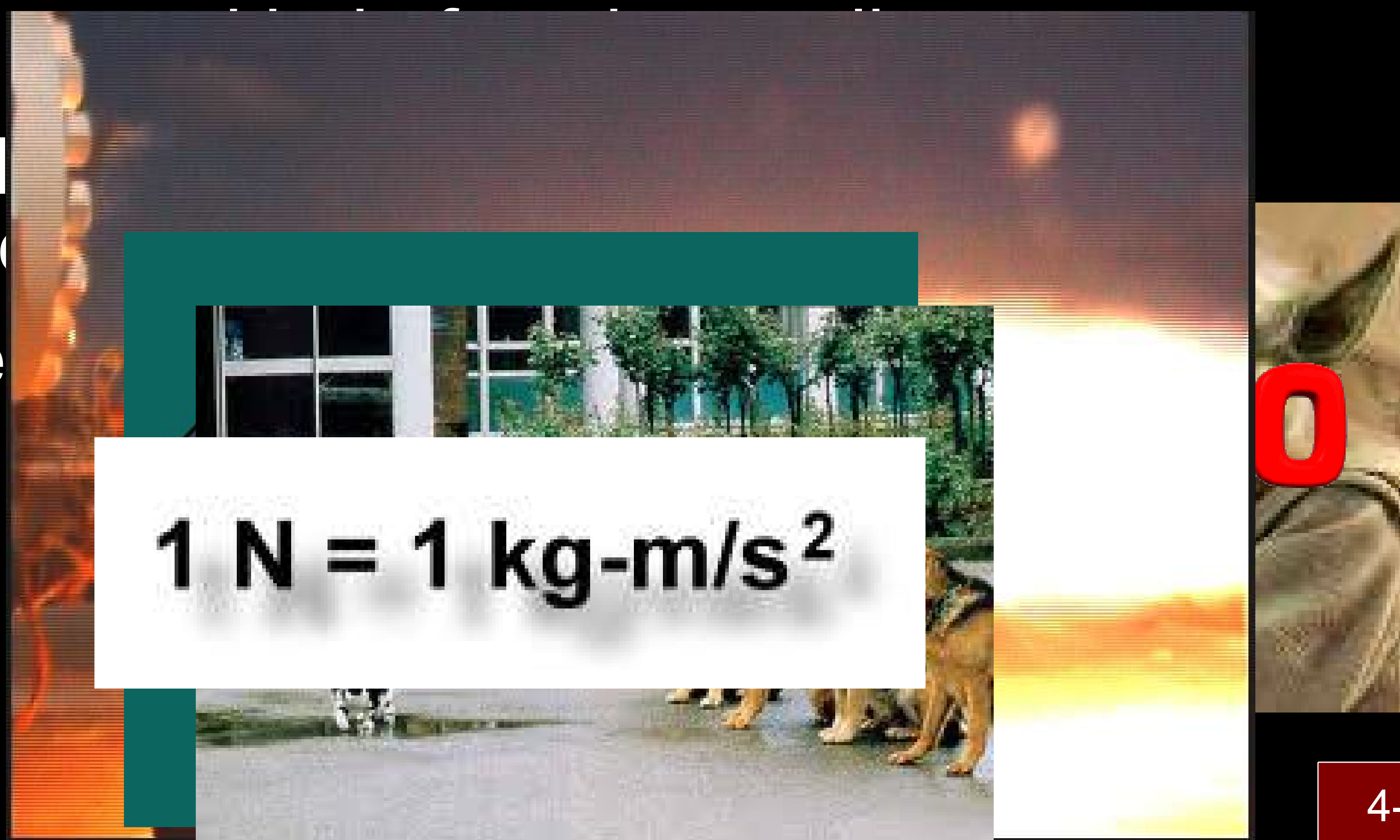


Dynamics: Newton’s Laws of Motion

4.2 Newton’s First Law of Motion

First Law – Every object continues in its state of rest, or of uniform velocity in a straight line, as long as no net force acts on it.

First Law … est
remains … on,
remains … by an
outside

4.2 Newton's First Law of Motion

Analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

Newton's Laws are only valid in an Inertial Frame of Reference

For example, if your frame of reference is an accelerating car – a cup in that car will slide with no apparent force being applied

4.2 Newton's First Law of Motion

Analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

An inertial frame of reference is one where if the first law is valid

Inertia – resistance to change in motion

Inertia Demonstration

If the bus travels at a constant speed down a straight path, then it is an enertial frame of reference.

Dynamics: Newton's Laws of Motion

4.3 Mass

4.3 Mass

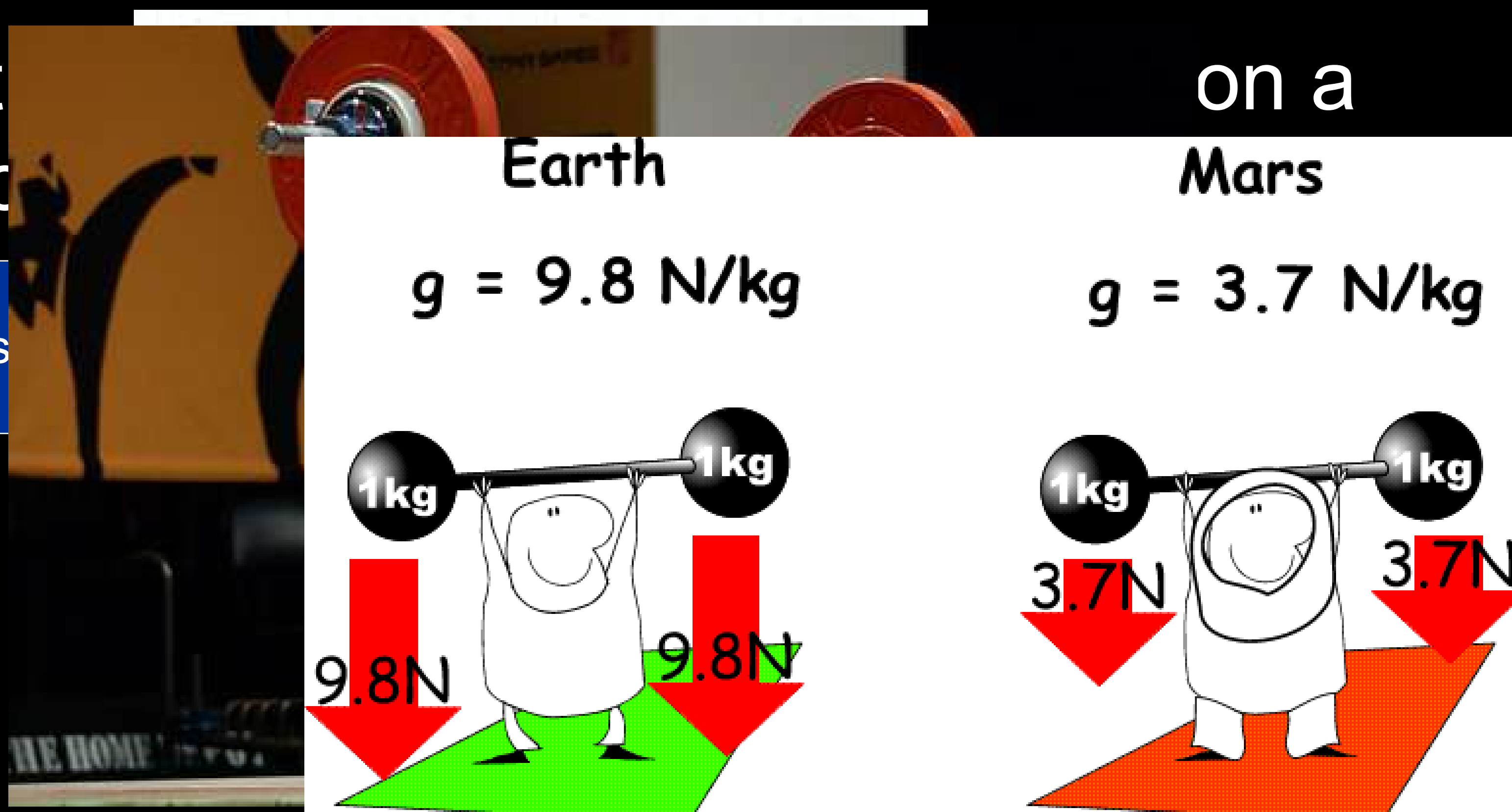
Analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

Mass – a measurement of inertia

A larger mass requires more force to accelerate it

Weight … on a specific…

Mas…



Dynamics: Newton's Laws of Motion

4.4 Newton's Second Law

Standard

IB2a

Students should understand the relation between the force that acts on a body and the resulting change in the body's velocity.

4.4 Newton's Second Law

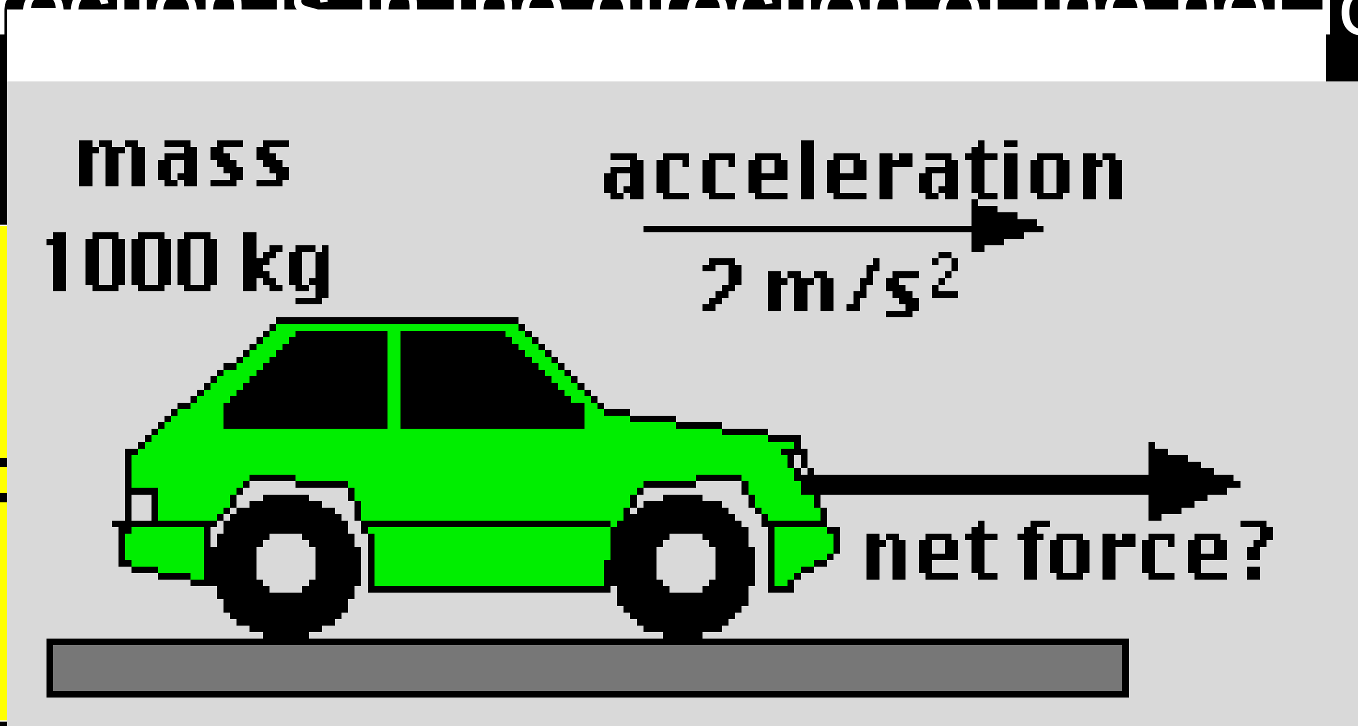
Understand the relation between the force that acts on a body and the resulting change in the body's velocity.

Second Law – acceleration is directly proportional to the net force acting on it, and inversely proportional to its mass.

-the direction is in the direction of the net force

Easier

$a =$

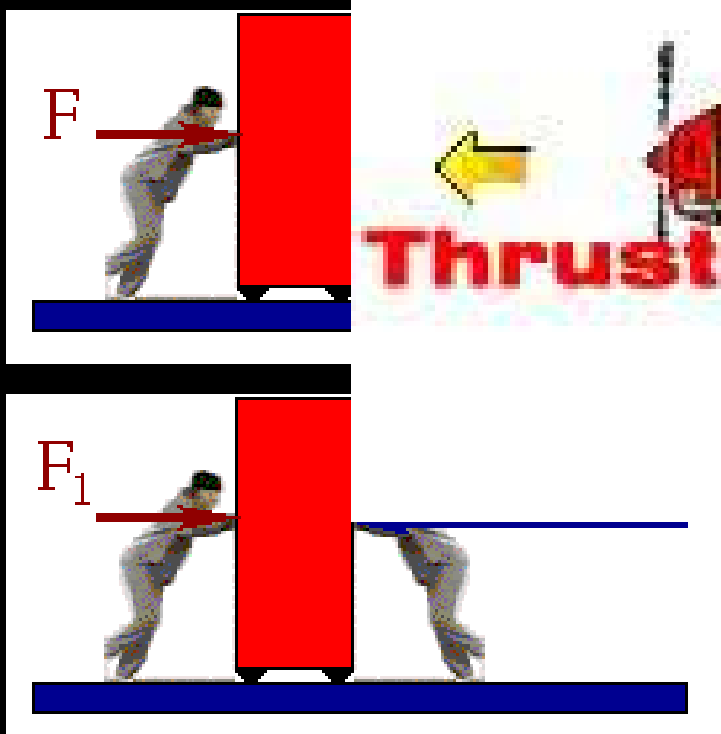


4.4 Newton's Second Law

Understand the relation between the force that acts on a body and the resulting change in the body's velocity.

ΣF – the vector sum of the forces

In one dimension this is simply adding or subtractin

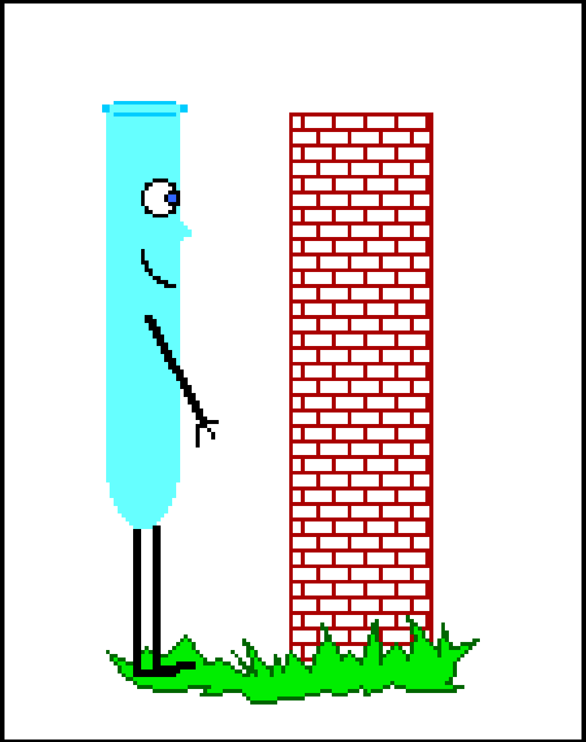


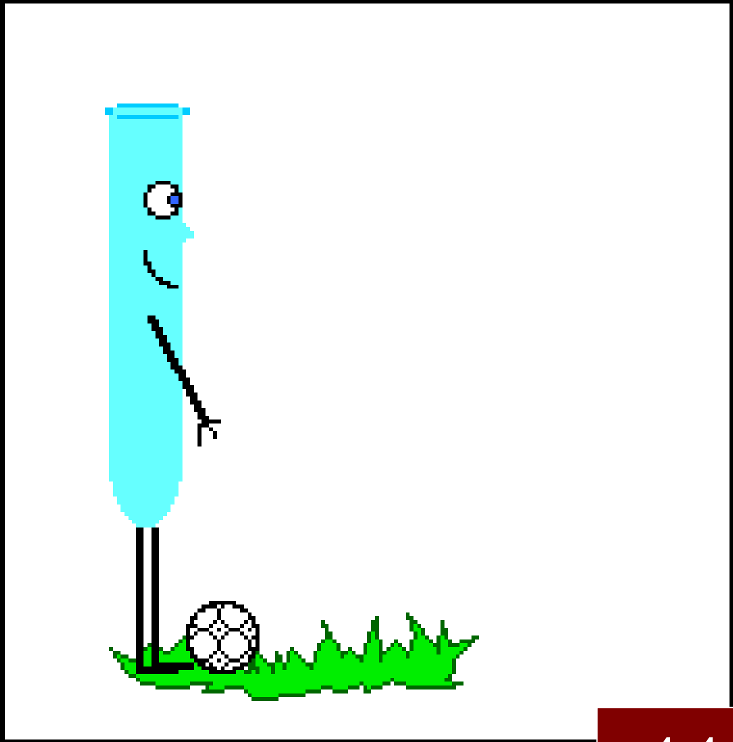
4.4 Newton's Second Law

Understand the relation between the force that acts on a body and the resulting change in the body's velocity.

We know that it takes a larger force to accelerate a large object

And it is easier to accelerate a small object





Practice Second Law Problems

Understand the relation between the force that acts on a body and the resulting change in the body's velocity.

S-17

A 115 kg football player is hit by three other guys at the same time. “Crusher” Smith hits him with a force of 500 N east. “Pulverizer” Jones hits with a force of 800 N west. And “Bone Breaker” Zibowski hits with a force of 1200 N @ 37^{o}. What

acceleration of our

Dynamics: Newton's Laws of Motion

4.5 Newton's Third Law of Motion

Standard

IB3a

Students should understand Newton’s Third Law so that, for a given force, they can identify the body on which the reaction force acts and state the magnitude and direction of this reaction.

4.5 Newton’s Third Law

Understand Newton’s Third Law so that, for a given force, they can identify the body on which the reaction force acts and state the magnitude and direction of this reaction.

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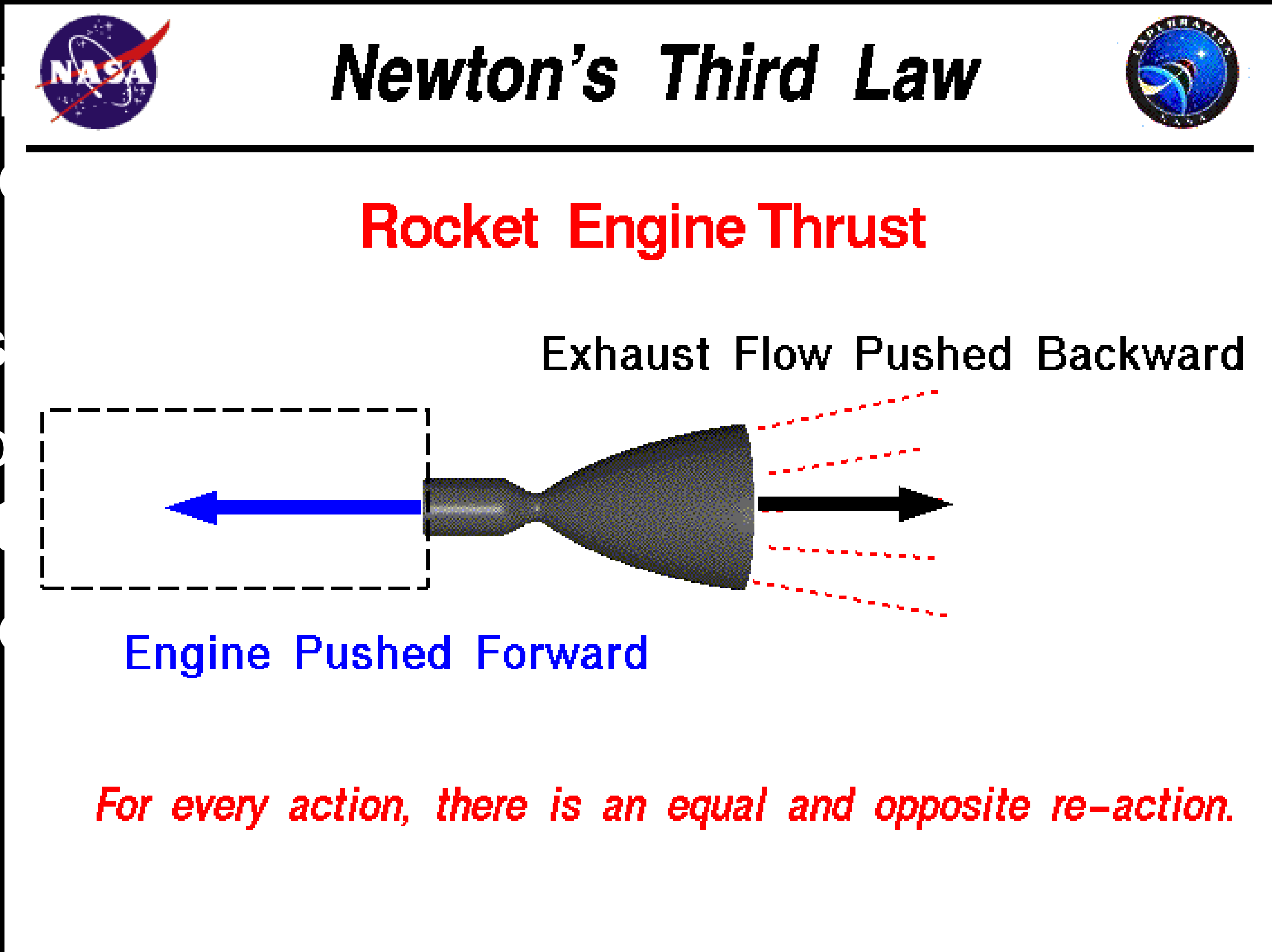


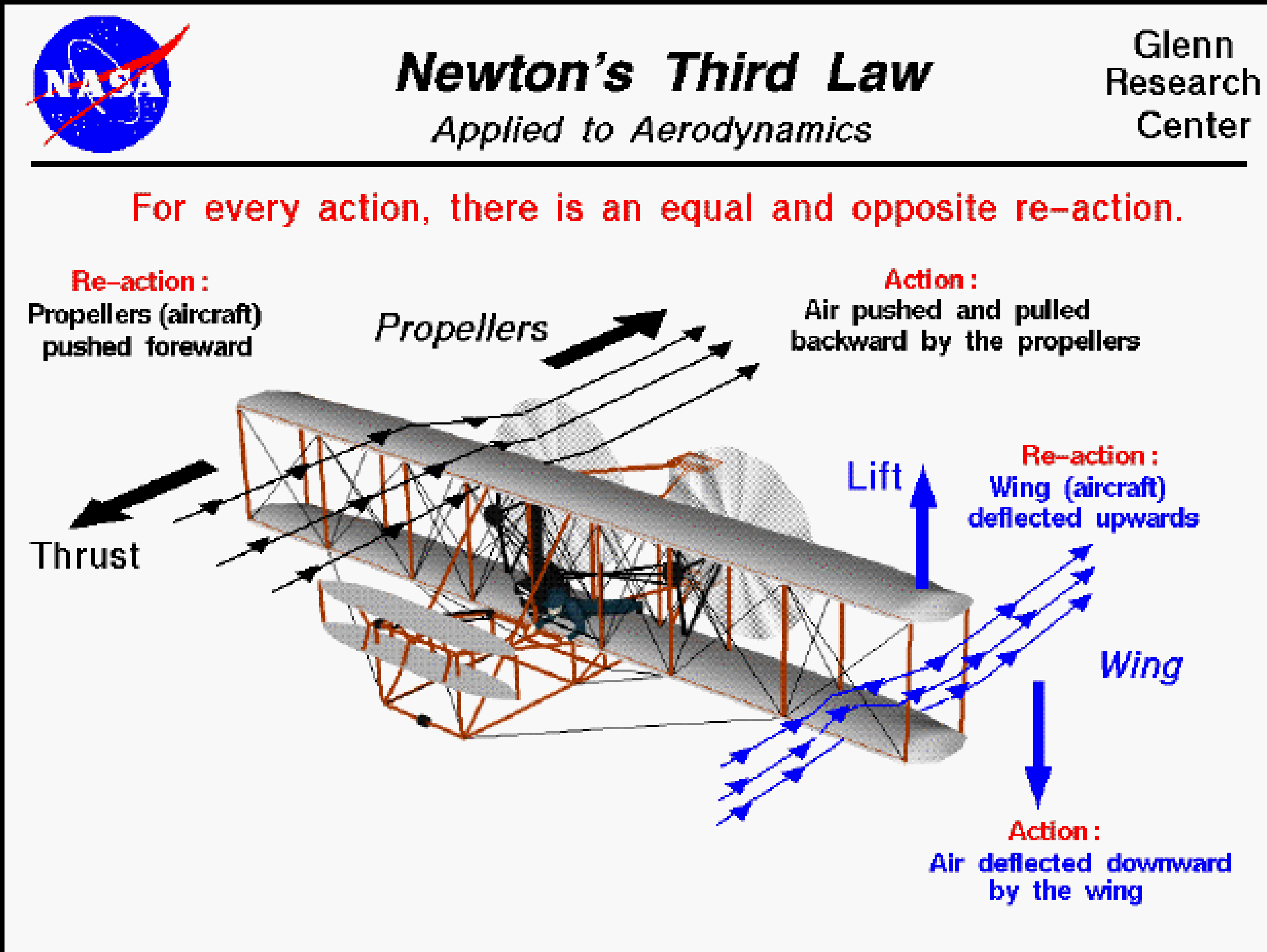
4.5 Newton's Third Law

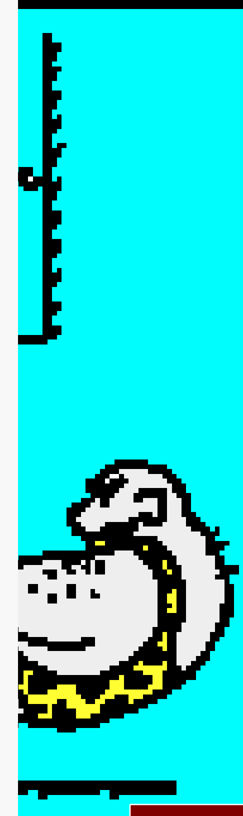
Understand Newton's Third Law so that, for a given force, they can identify the body on which the reaction force acts and state the magnitude and direction of this reaction.

When object applies a force, the reaction force is on a different object

4.5 Newton's Third Law

Understand Newton's Third Law so that, for a given force, they can identify the body on which the reaction force acts and state the magnitude and direction of this reaction.





4.5 Newton’s Third Law

Understand Newton’s Third Law so that, for a given force, they can identify the body on which the reaction force acts and state the magnitude and direction of this reaction.

How does someone walk then

Action force is pushing back on the ground

Reaction force, the ground pushes back and makes the pers[illegible]ward

Dynamics: Newton's Laws of Motion

4.6 Weight – the Force of Gravity and the Normal Force

Standard

IB2b

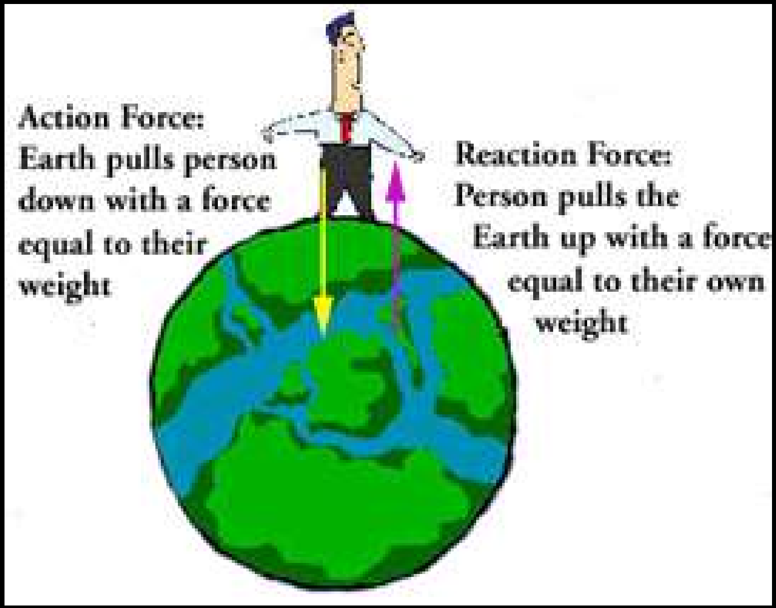
Students should understand how Newton's Second Law, F=ma, applies to a body subject to forces such as gravity, the pull of strings, or

4.6 Weight – the Force of Gravity

Understand how Newton's Second Law, F=ma, applies to a body subject to forces such as gravity, the pull of strings, or contact forces.

Force of gravity (F_g, F_w, W) the pull of the earth (in most of our problems) on an object

$$W = mg$$



Common errors

not mass

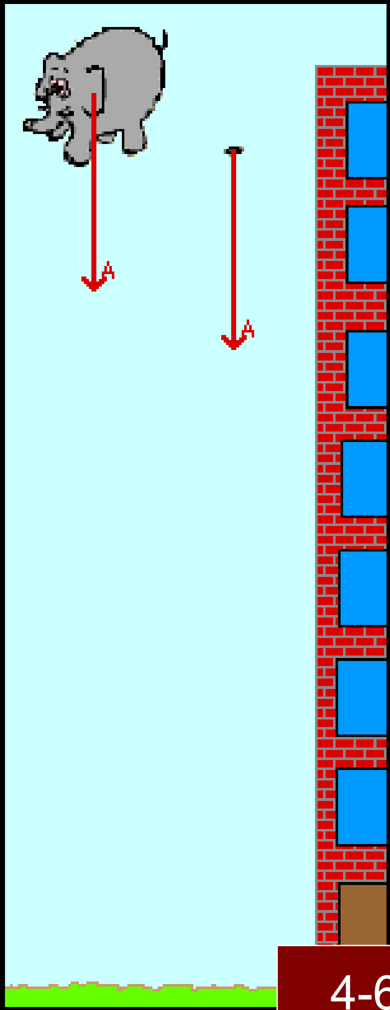
not gravity

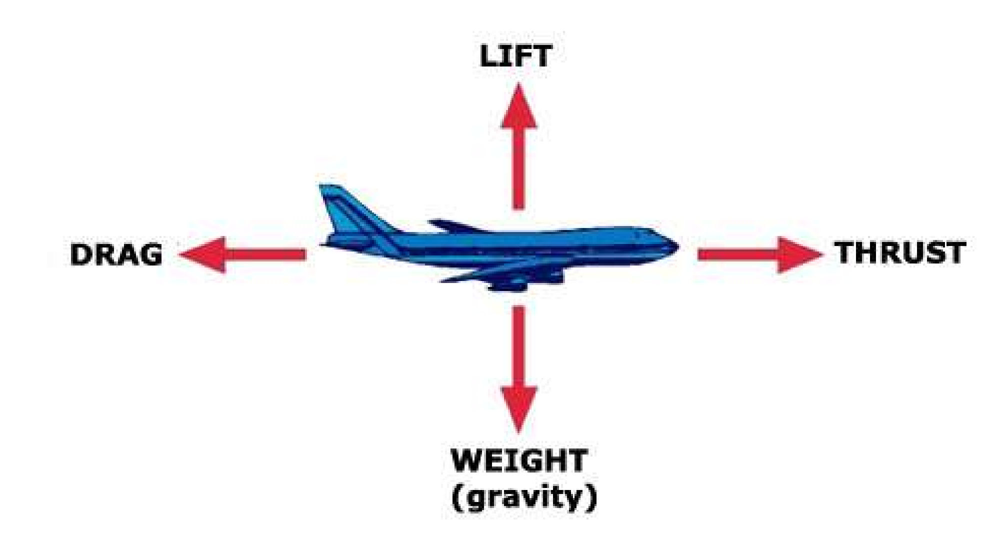
Reaction force – the object pulls with the same force on the earth

4.6 Weight – the Force of Gravity

Understand how Newton's Second Law, F=ma, applies to a body subject to forces such as gravity, the pull of strings, or contact forces.

- Weight is a field force, no contact needed
- Every object near a planet will have a force of gravity on it
  - We always have to include weight as one of the force on an object





4.6 Weight – the Force of Gravity

Understand how Newton's Second Law, F=ma, applies to a body subject to forces such as gravity, the pull of strings, or contact forces.

Concepts

Contact force – most forces require that the objects be in contact

Normal F

pushing c

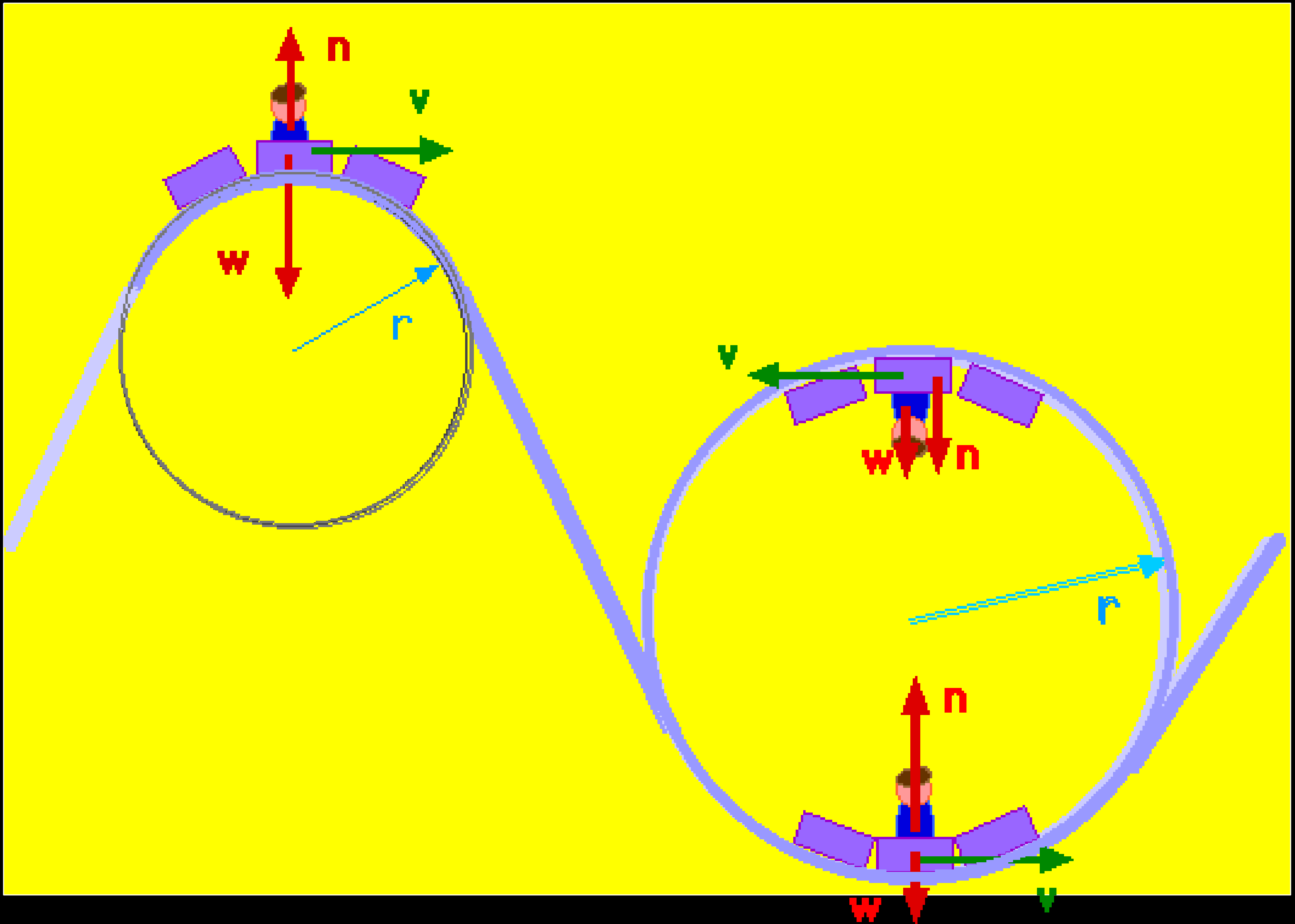
Always p

Normal m

surface

4.6 Weight – the Force of Gravity

Understand how Newton's Second Law, F=ma, applies to a body subject to forces such as gravity, the pull of strings, or contact forces.



Practice Weight and Normal Force

Understand how Newton's Second Law, F=ma, applies to a body subject to forces such as gravity, the pull of strings, or contact forces.

Dynamics: Newton’s Laws of Motion

4.7 Solving Problems with Newton’s Laws

Free – Body Diagrams

Standard

IB3d

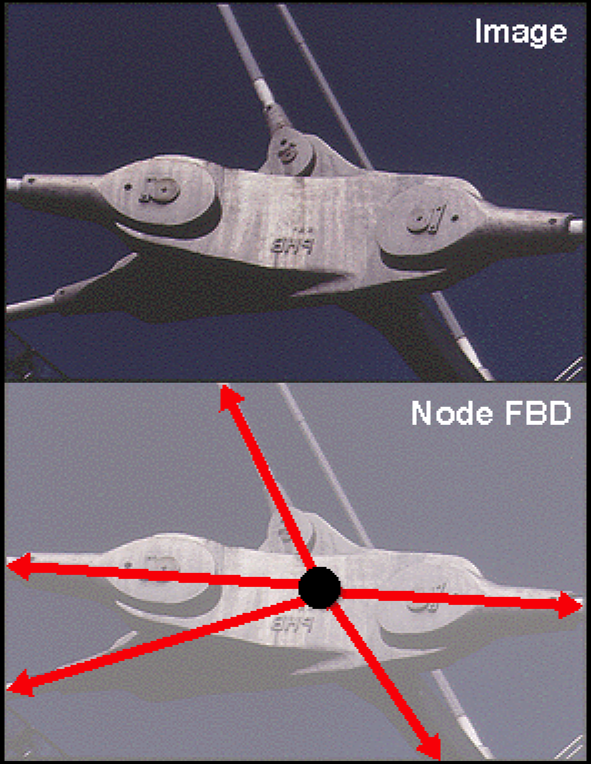
Students should be able to solve problems in which application of Newton’s Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

A free body diagram shows all the forces on an object

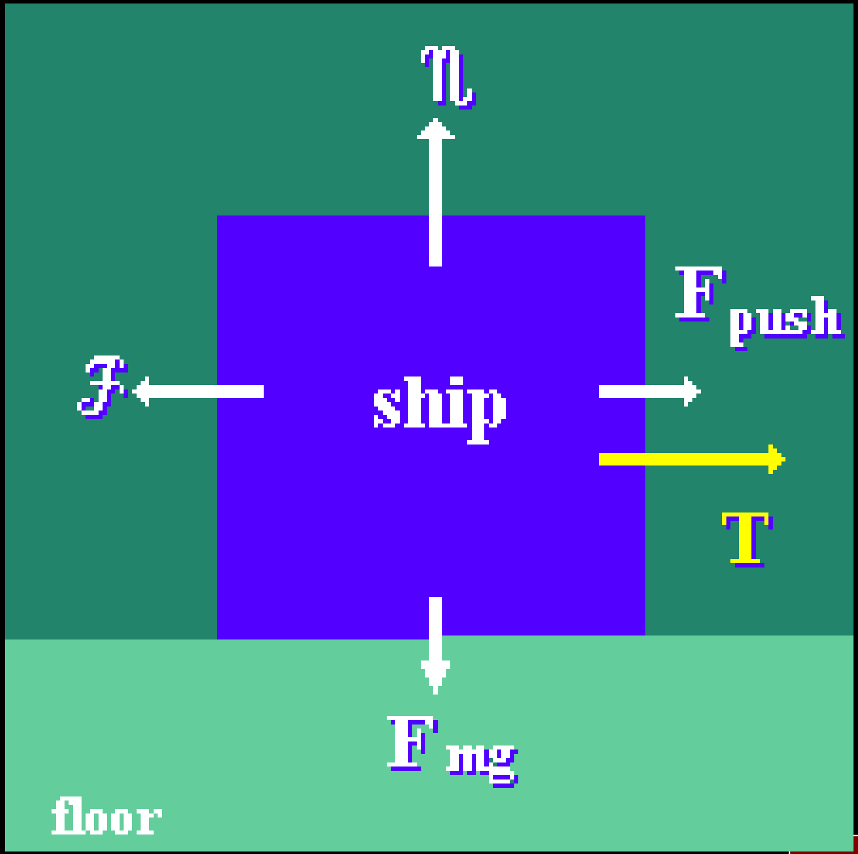
The object is represented as a dot (point mass)



4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

For example: a ship has its engines on and is being pulled by a tug boat

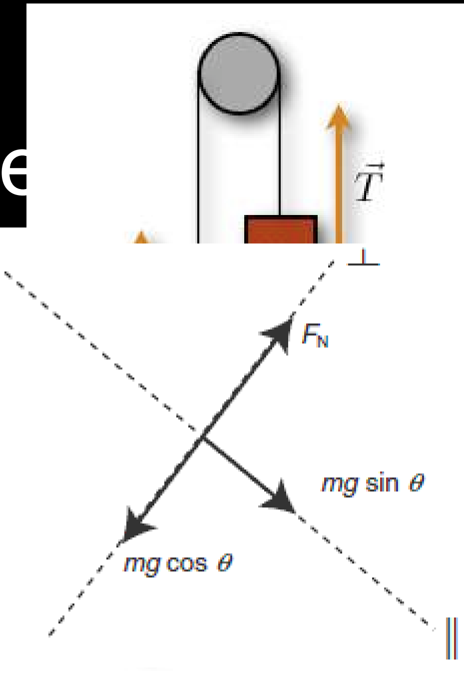


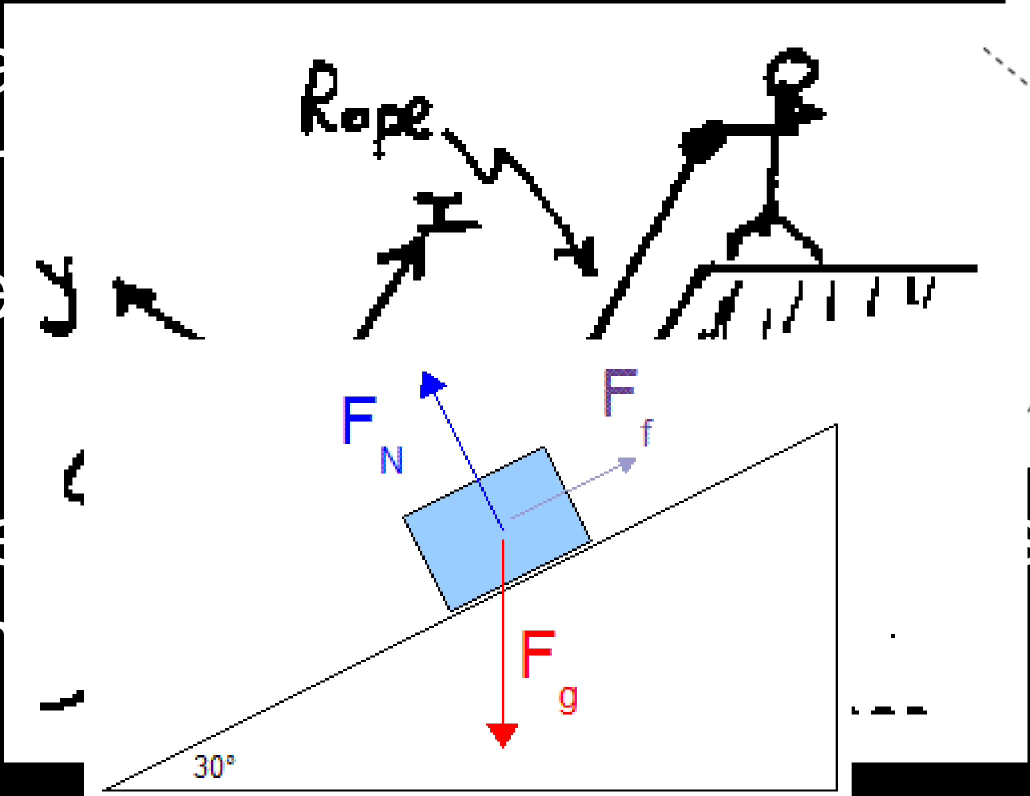
4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Steps

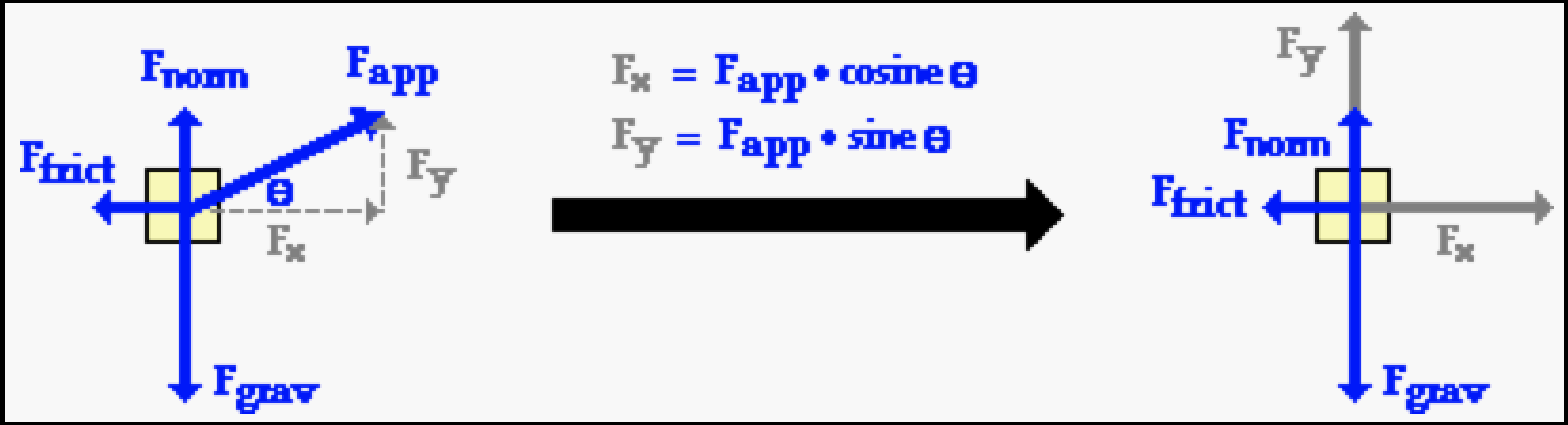
1. Draw a sketch
2. Consider only one object at a time
3. Show a
   includin
4. Label e
5. Draw d
6. Choose s the
   problem





Steps

6. Resolve vectors into components
7. Apply newton's second law (F=ma) to each object $\Sigma F_x = ma_x$
8. Solve the equations for the unknowns

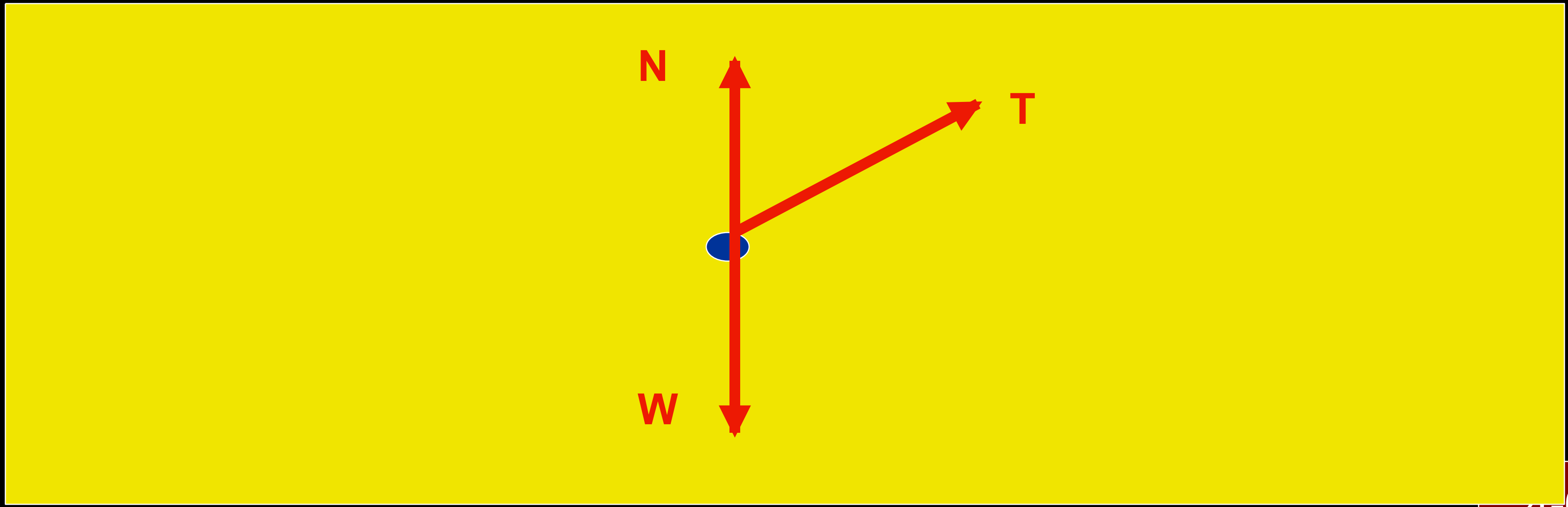


4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 1

A 25 kg box is being pulled by a rope along a level frictionless surface with a force of 30 N at an angle of 40°. What is the acceleration of the box?

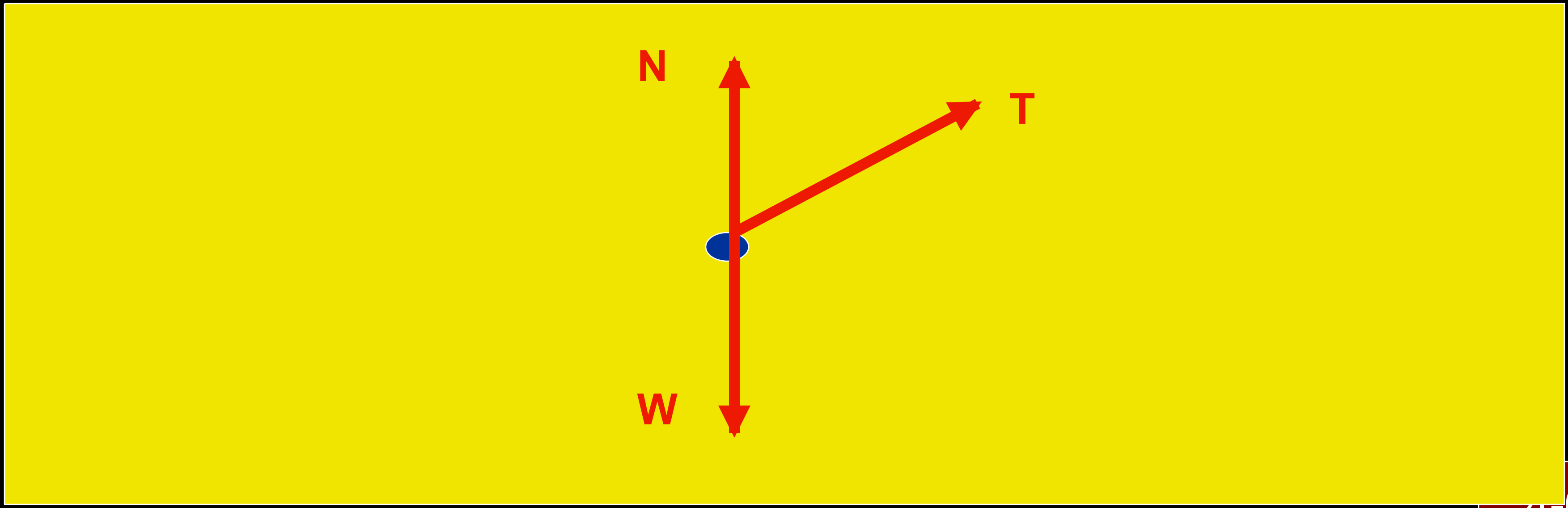


4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 1

Must be broken into x and y components.



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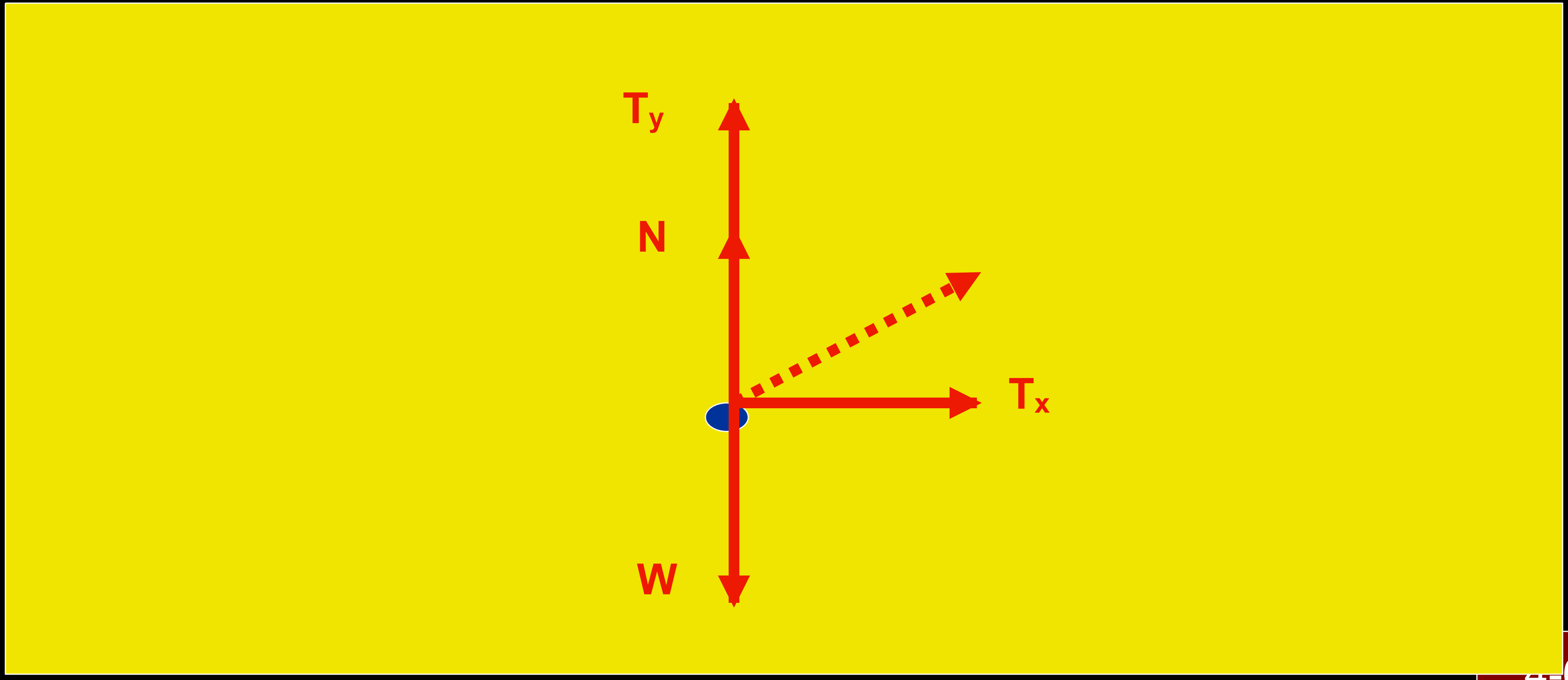


4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 1

Equations are written for x and y

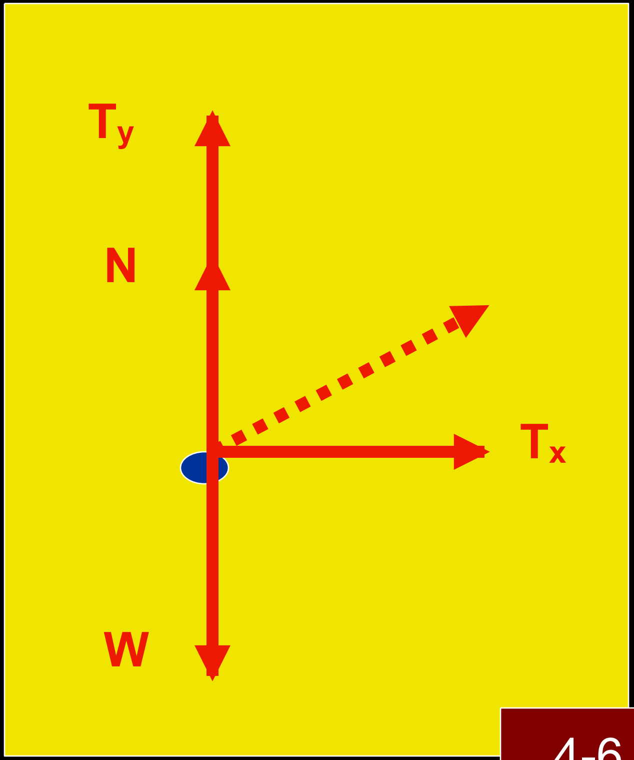
$\Sigma F_x = ma_x$

$Tx = ma_x$

$\Sigma F_y = ma$

$N + T_y - W = ma_y$

$(a_y = 0)$



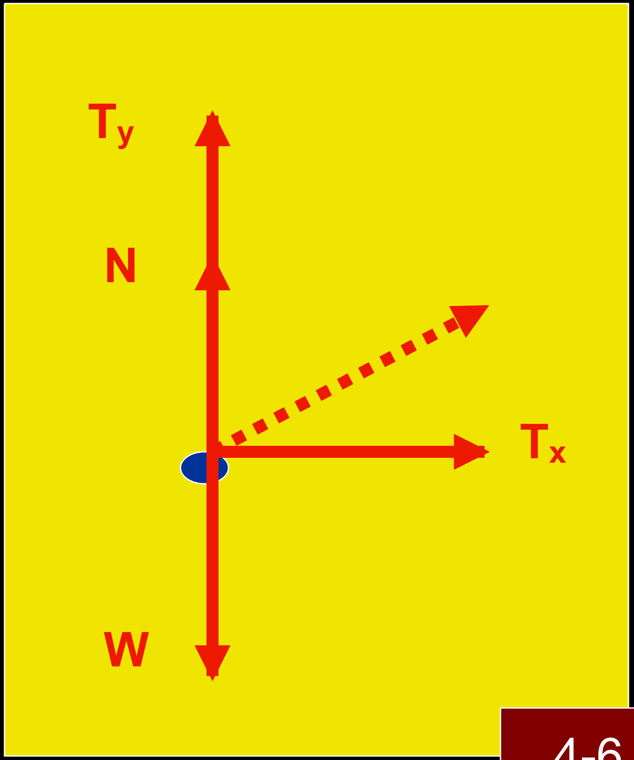
Sample 1

We only care about acceleration in the x, so

$T\cos\theta = ma$

$(30)\cos(40) = 25a$

$a = 0.92 m/s^2$



S-18

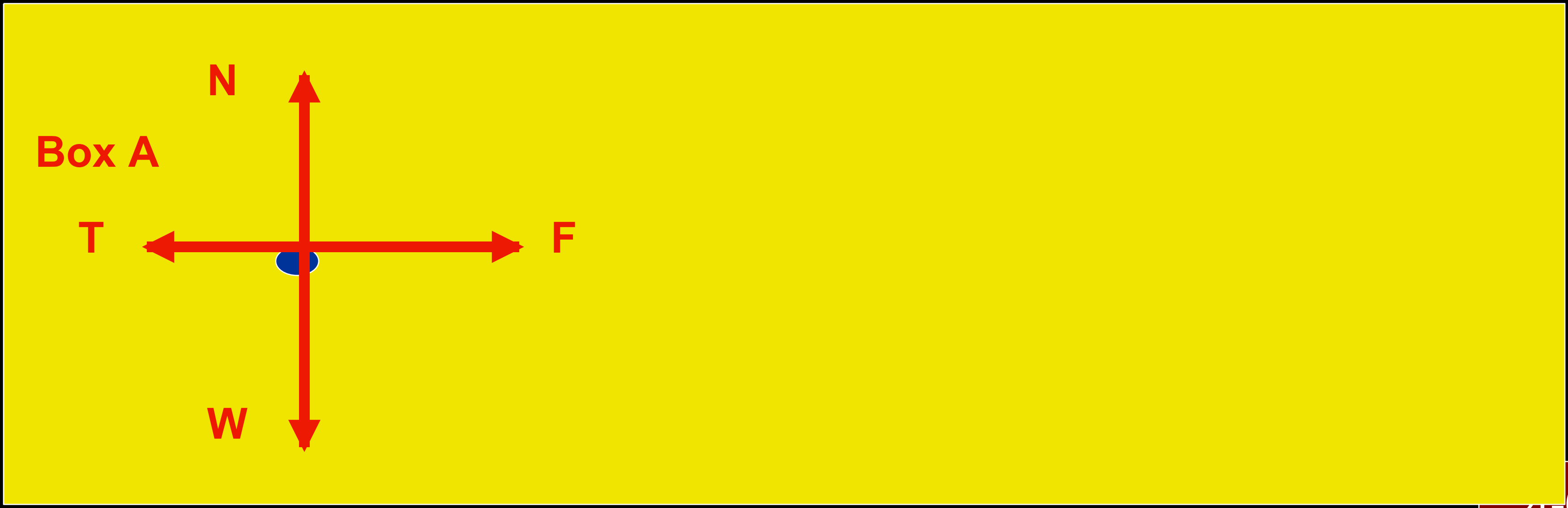
Pablo performs a difficult face-trap during a soccer match. The ball has a mass of 1.0 kg and Pablo's face has a mass of 3.0 kg. If the ball strikes Pablo traveling at 20 m/s to the right and leaves traveling at 10 m/s to the left, what is the force on the ball if the collision lasts 0.15s? What is the force on Pablo's face?

4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 2

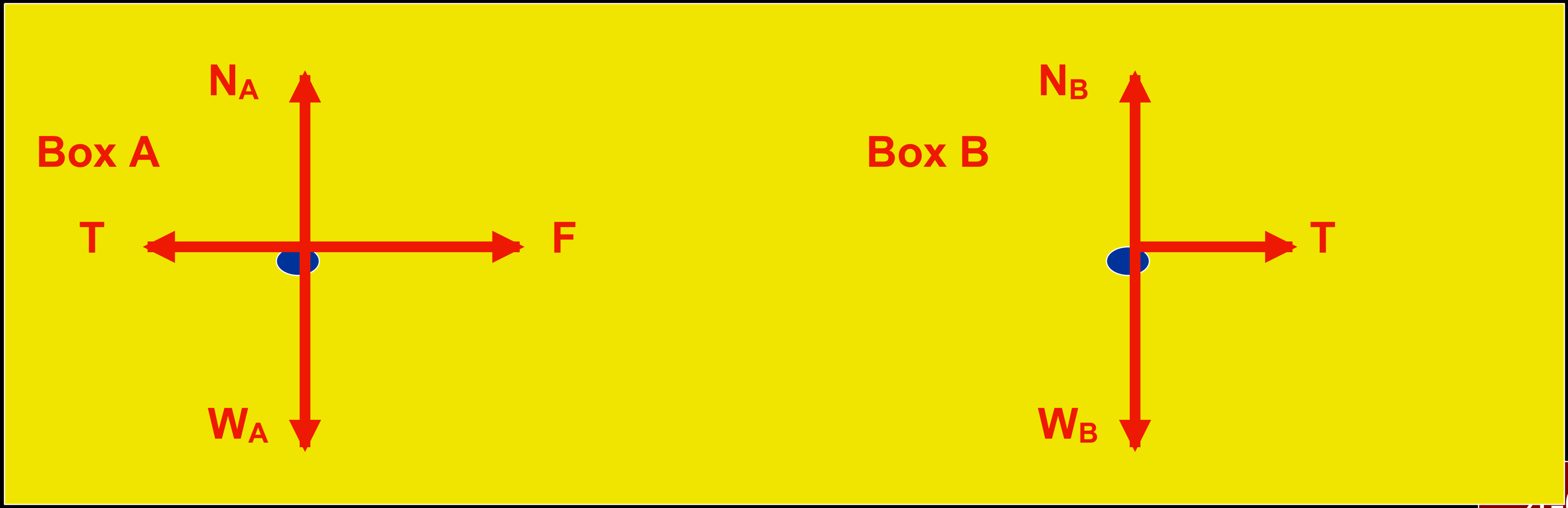
Box A, mass 25kg, and box B, mass 30kg, are tied together with a massless rope. Box A is pulled horizontally with a force of 50N across a frictionless surface. What is the tension on the rope?



Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 2

Box A, mass 25kg, and box B, mass 30kg, are tied together with a massless rope. Box A is pulled horizontally with a force of 50N. What is the tension on the rope?



4.7 Solving Problems with Newton's Laws

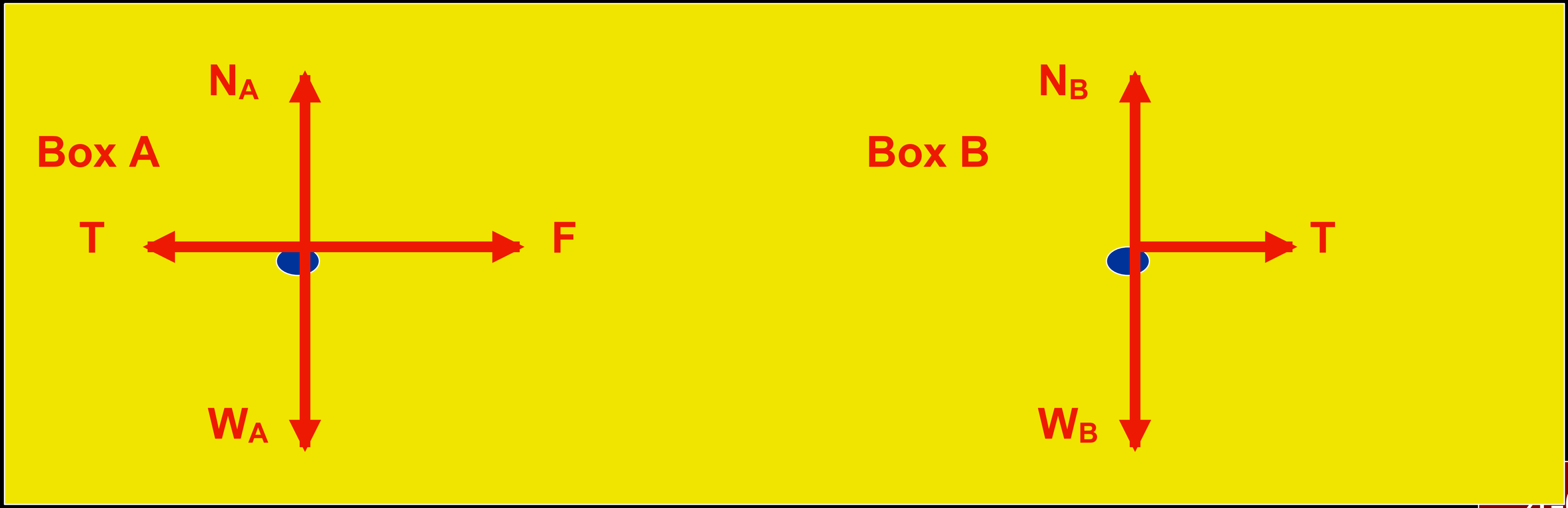
Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 2

Equations for A

$F - T = ma$

$N_A - W_A = 0$



4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 2

Equations for A

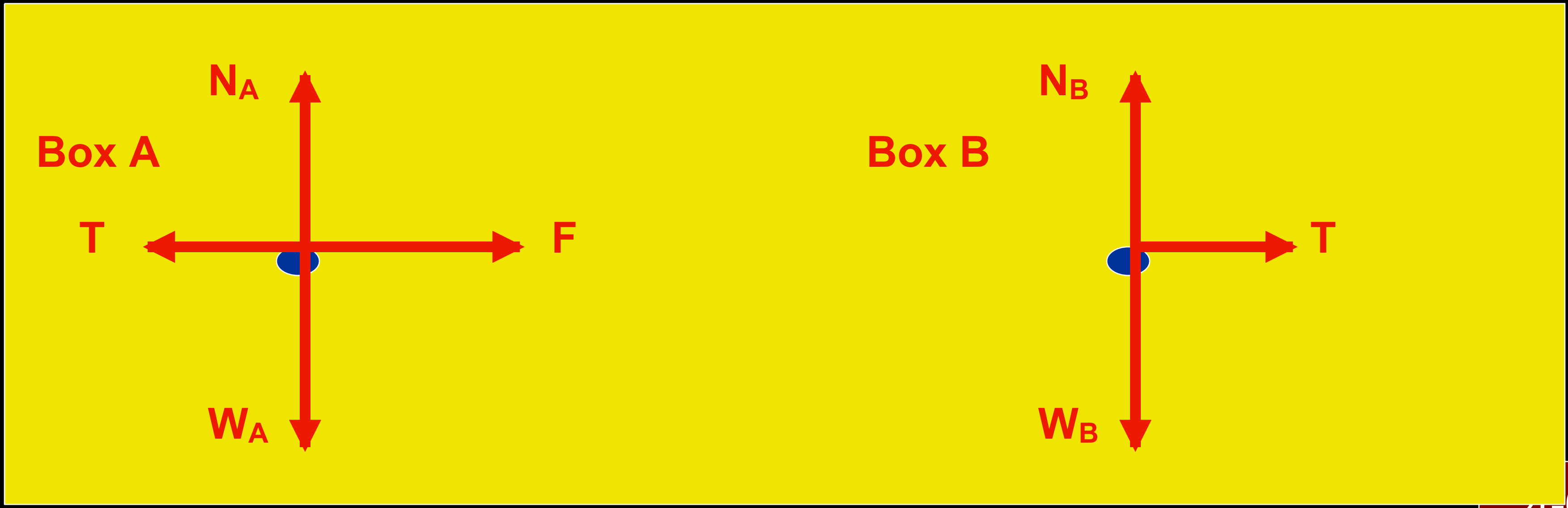
$F - T = ma$

$N_A - W_A = 0$

Equations for B

$T = ma$

$N_B - W_B = 0$



4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 2

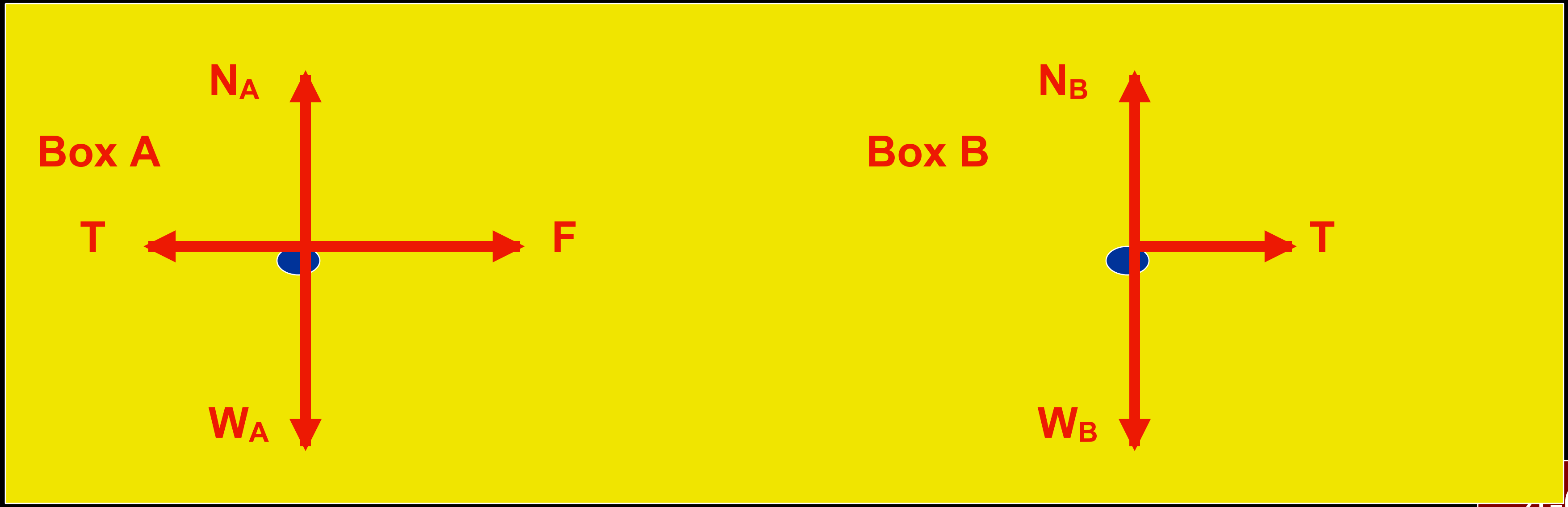
We'll only worry about x

50-T=25a

T=30a

Combine

50-30a=25a



4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

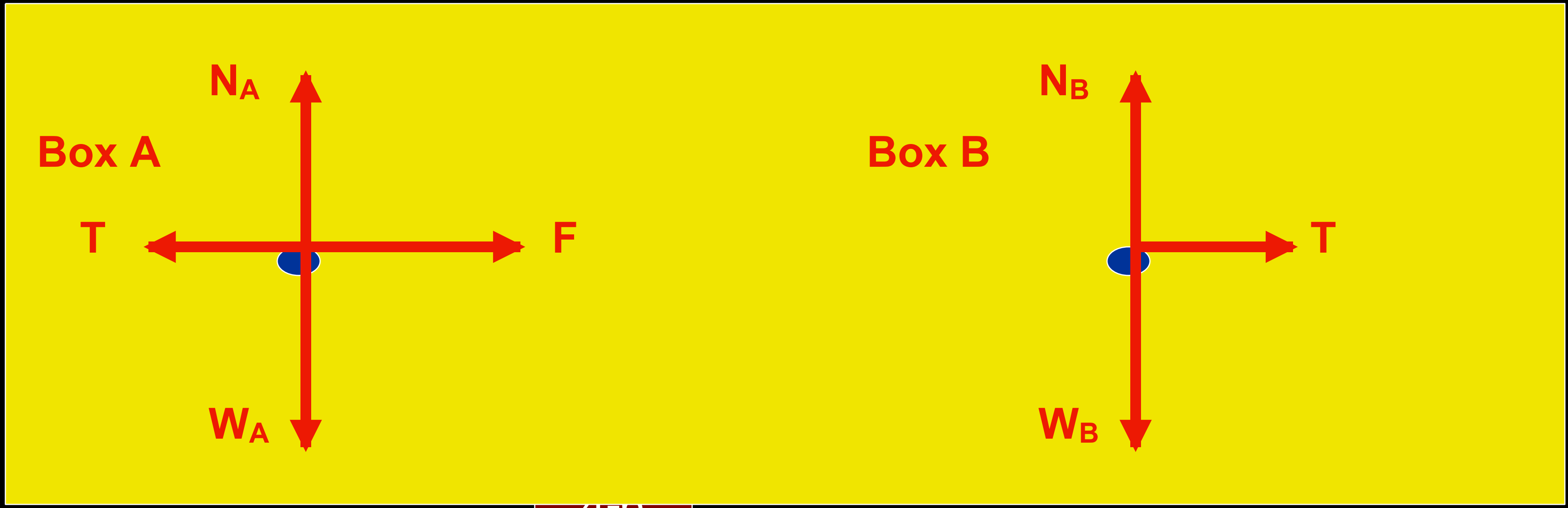
Solve

$50=55a$

$a=0.91 m/s^2$

Combine

$50-30a=25a$



4.7 Solving Problems with Newton's Laws

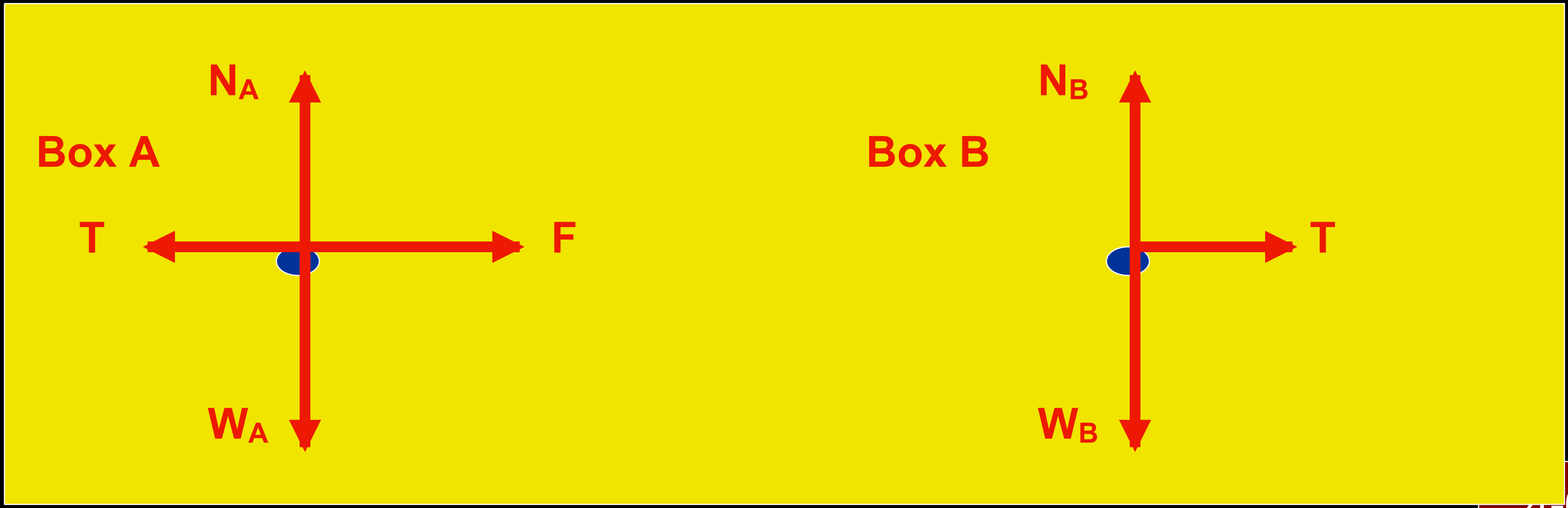
Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 2

Substitute value to solve for T

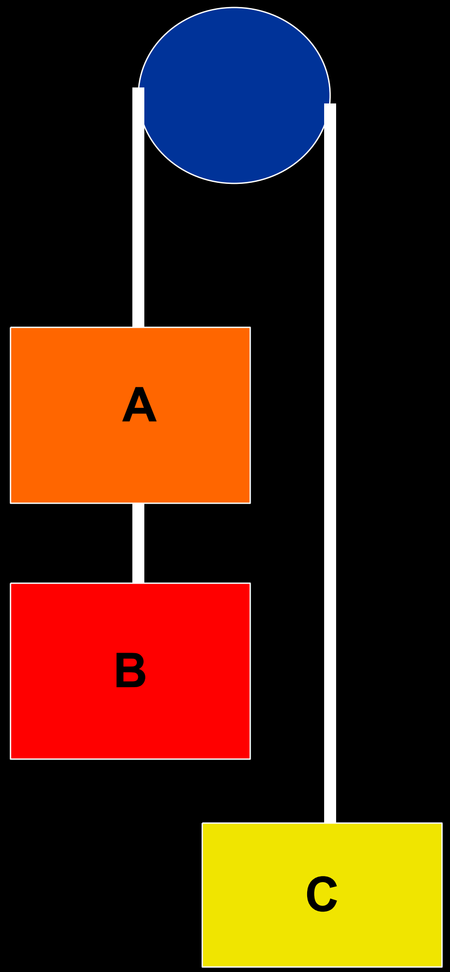
T=30a

T=30(.91)=27N



Sample 3

Three boxes are hung from a pulley system as shown in the following diagram. If box A has a mass of 25 kg, box B has a mass of 40 kg, and box C has a mass of 35 kg, what is the acceleration of the boxes?

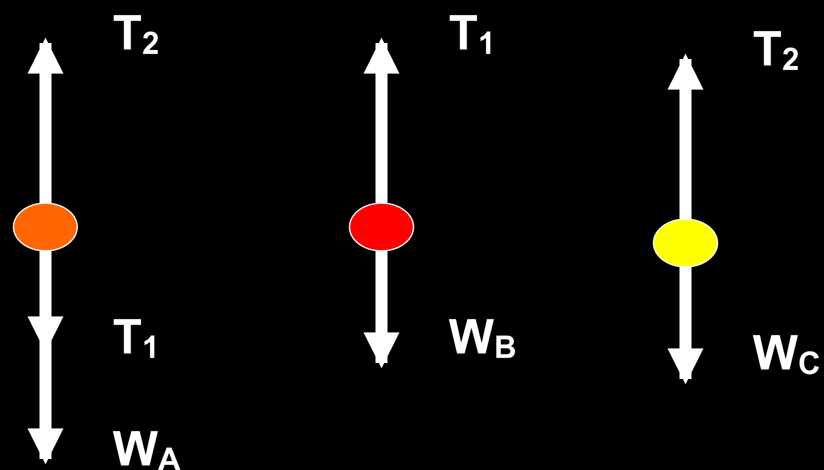


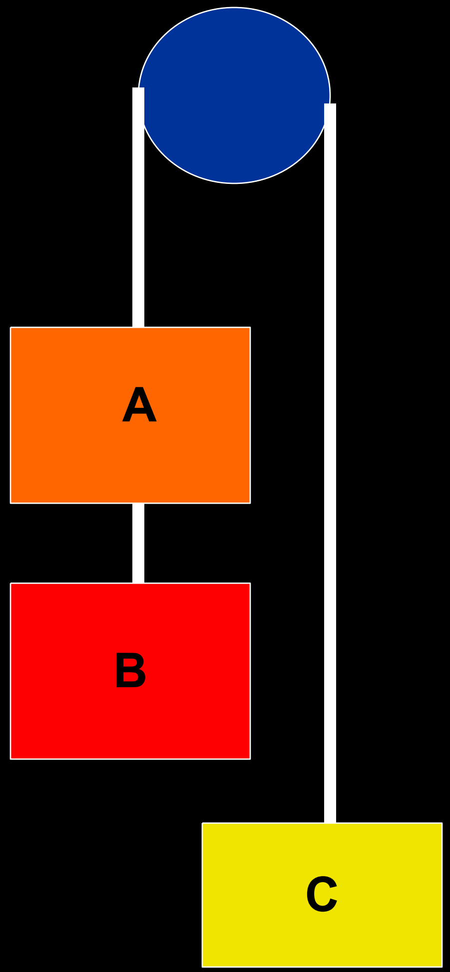
4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

Sample 3

(a) Draw the free body diagram for the three boxes





4.7 Solving Problems with Newton's Laws

Apply Newton's Third Law in analyzing the force of contact between two bodies that accelerate together along a horizontal or vertical line, or between two surfaces that slide across one another.

Sample 3

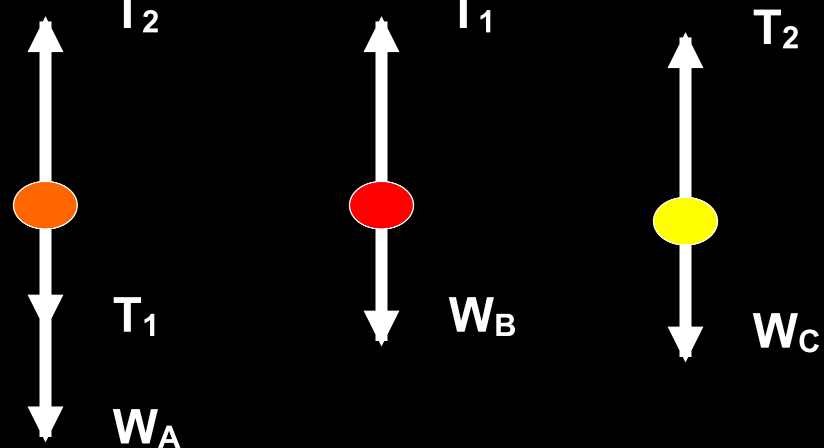
(b) Write equations (first choose a direction for positive rotation

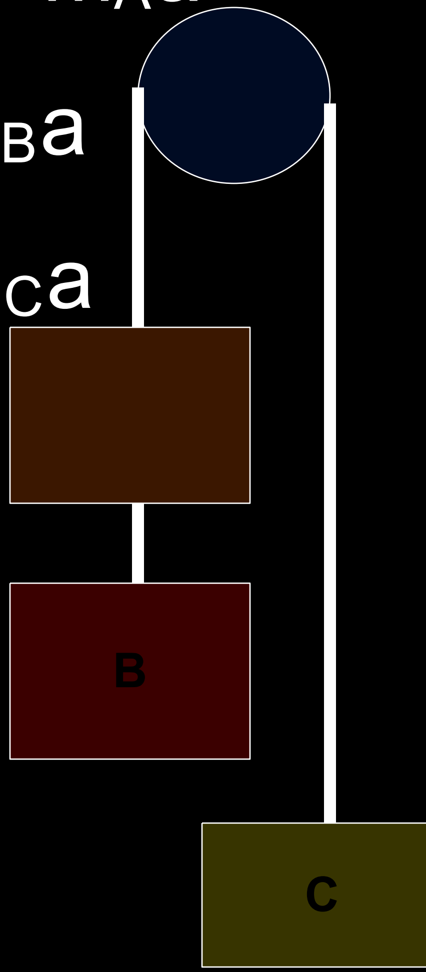
clockwise

$T_2 - T_1 - W_A = m_A a$

$T_1 - W_B = m_B a$

$W_C - T_2 = m_C a$





4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

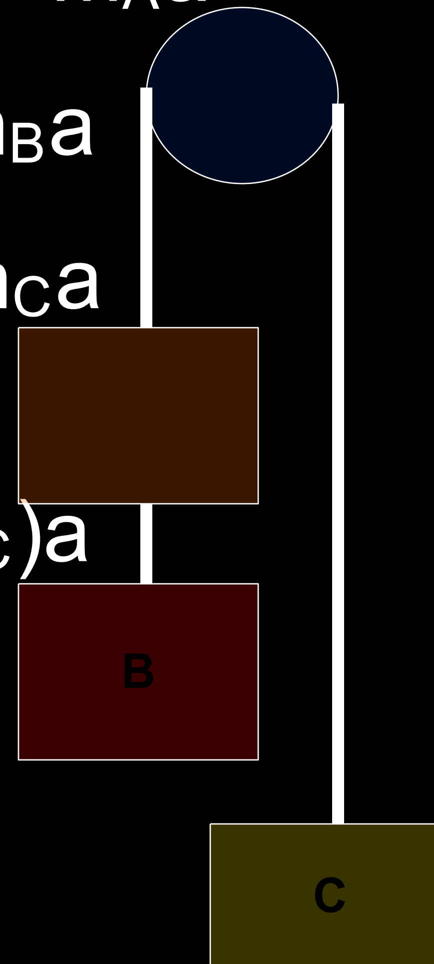
Sample 3

(c) Add equations, this should eliminate all internal forces

$$T_2 - T_1 - W_A = m_A a$$

$$T_1 - W_B = m_B a$$

$$W_C - T_2 = m_C a$$



$$T_2 - T_1 - W_A + T_1 - W_B + W_C - T_2 = (m_A + m_B + m_C)a$$

$$W_C - W_A - W_B = (m_A + m_B + m_C)a$$

4.7 Solving Problems with Newton's Laws

Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown force or accelerations.

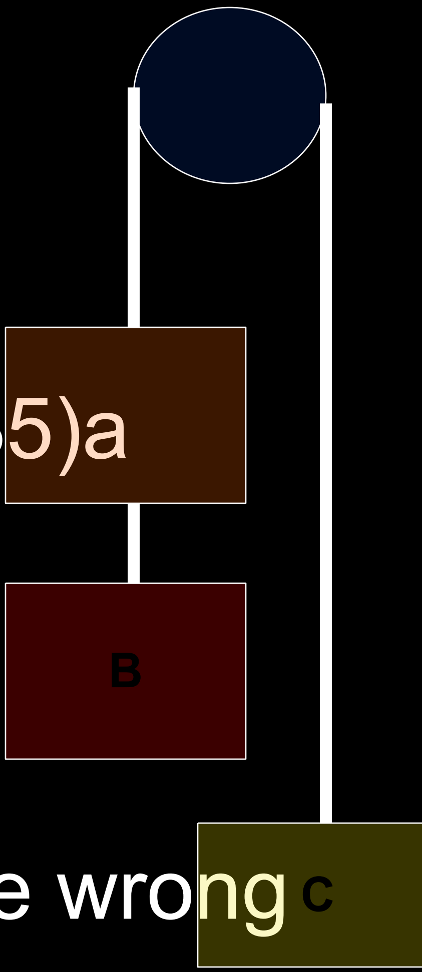
Sample 3

(c) Enter known quantities and solve

$W_C - W_A - W_B = (m_A + m_B + m_C)a$

$(35)(9.8) - (25)(9.8) - (40)(9.8) = (25+40+35)a$

$a = -2.94 m/s^2$



Negative sign just means we chose the wrong direction

Dynamics: Newton's Laws of Motion

4.8 Problems Involving Friction, Inclines

Standard

IB2d

Students should understand the significance of the coefficient of friction.

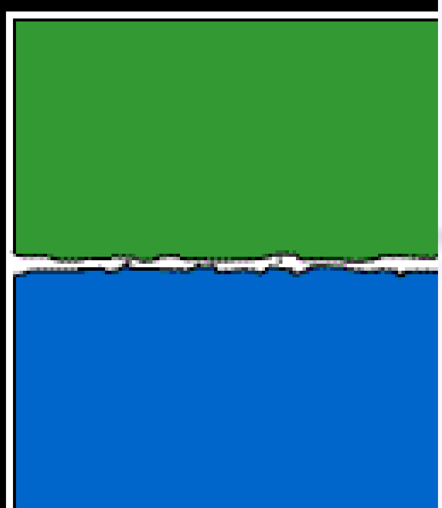
4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Friction – force between two surfaces that resists change in position

Always acts  event the motion o

Caused by r



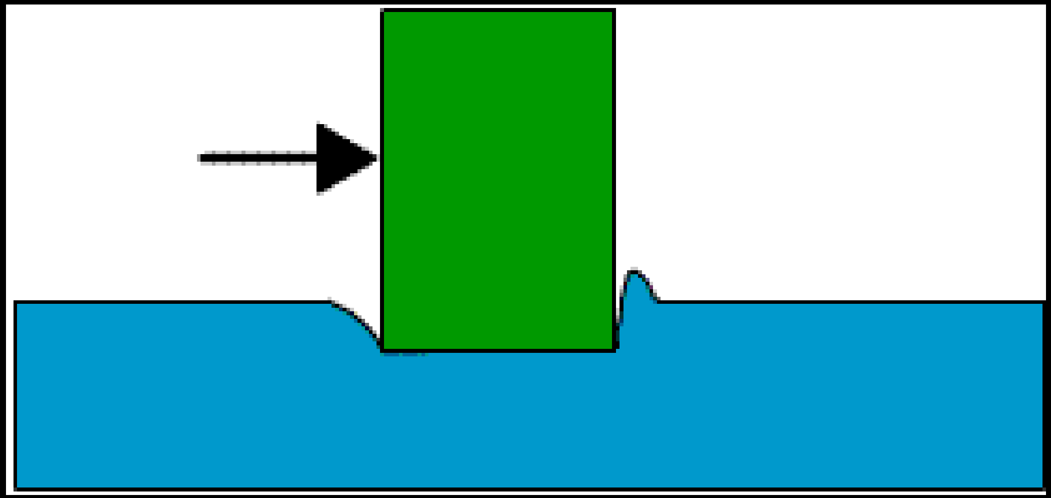
4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Friction – force between two surfaces that resists change in position

Always acts to slow down, stop, or prevent the motion of an object

Or by build up of material



4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Friction – force between two surfaces that resists change in position

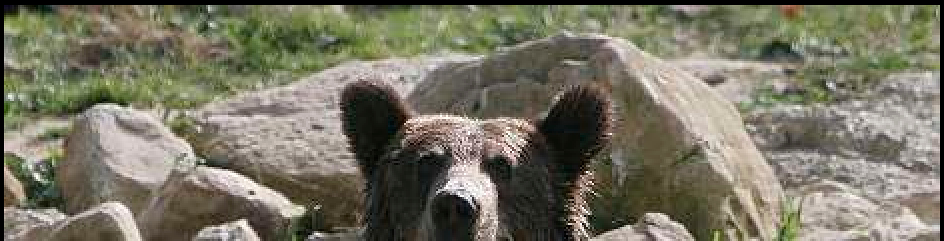
Always acts to slow down, stop, or prevent the motion of an object

Or Sticky Surfaces (The glue that Mollusks use is one of the stickiest substances)

S-19

In an attempt to keep the bears from playing with his ATV, Jimbo hoists it up a tree with a rope.

If the 150 kg ATV accelerates at 1.2 m/s upward, what is the tension on the rope?



4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Three types

1. Static Friction – parts are locked together, strongest
2. Kinetic
3. Rolling g friction

4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

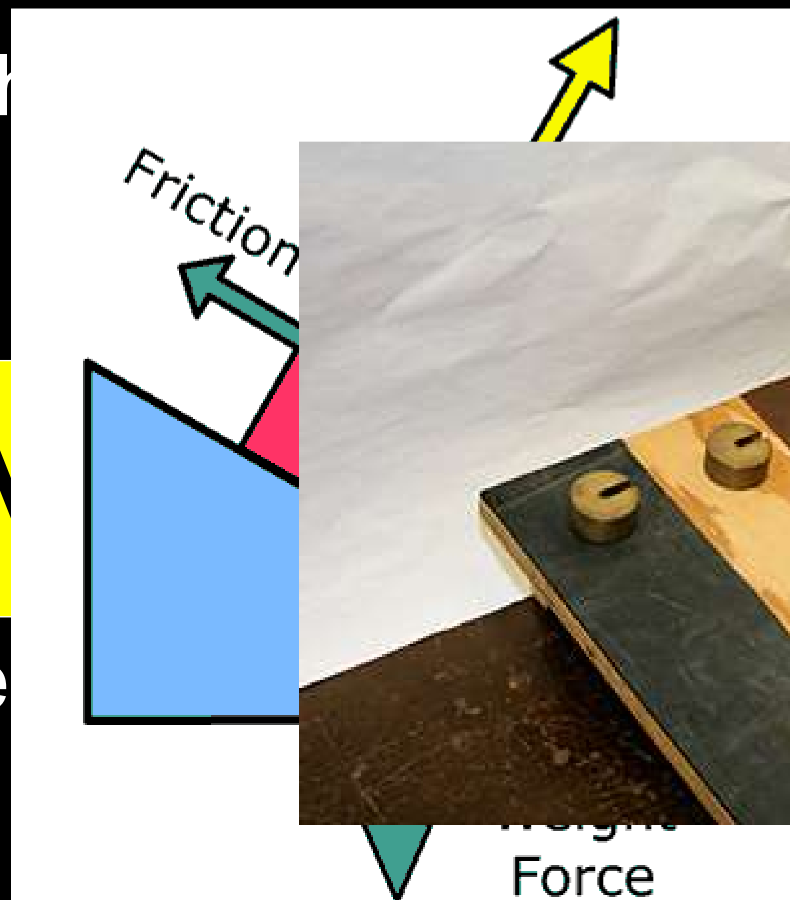
Friction is proportional to the normal force (not weight)

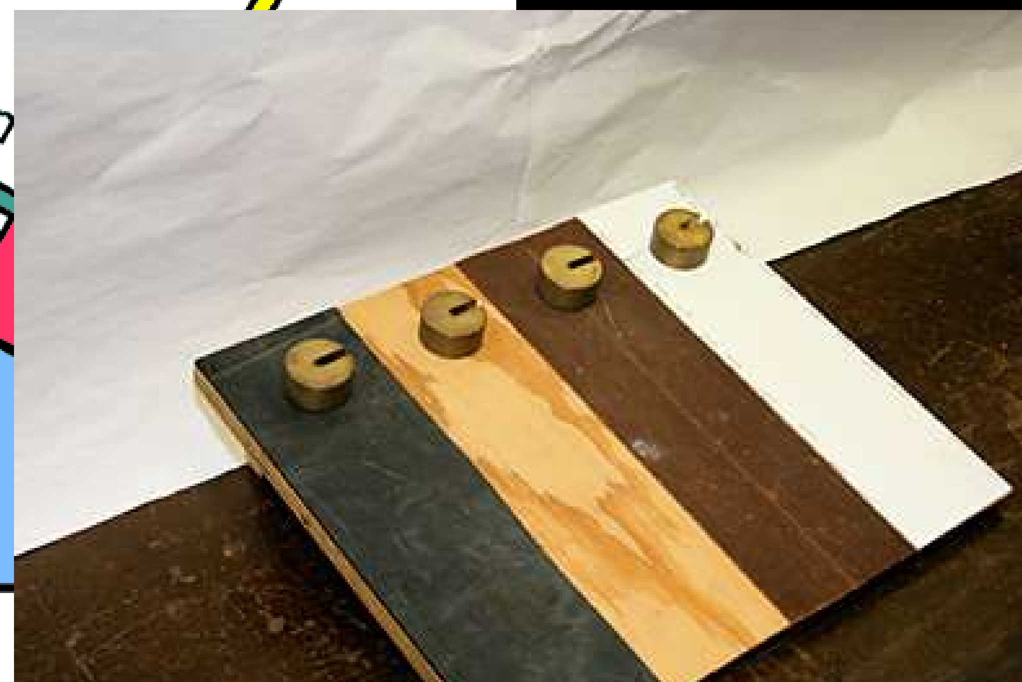
Depends on th aterials that are in

So

$$f = \mu N$$

μ is called the unit





Some common coefficients of friction

Materials in Contact	*Coefficient of Static Friction** $_S$	*Coefficient of Kinetic Friction ** $_K$
Wood on wood	0.5	0.3
Waxed ski on snow	0.1	0.05
Ice on ice	0.1	0.03
Rubber on concrete (dry)	1	0.8
Rubber on concrete (wet)	0.7	0.5
Glass on glass	0.94	0.4
Steel on aluminum	0.61	0.47
Steel on steel (dry)	0.7	0.6
Steel on steel (lubricated)	0.12	0.07
Teflon on steel	0.04	0.04
Teflon on Teflon	0.04	0.04
Synovial joints (in humans)	0.01	0.01

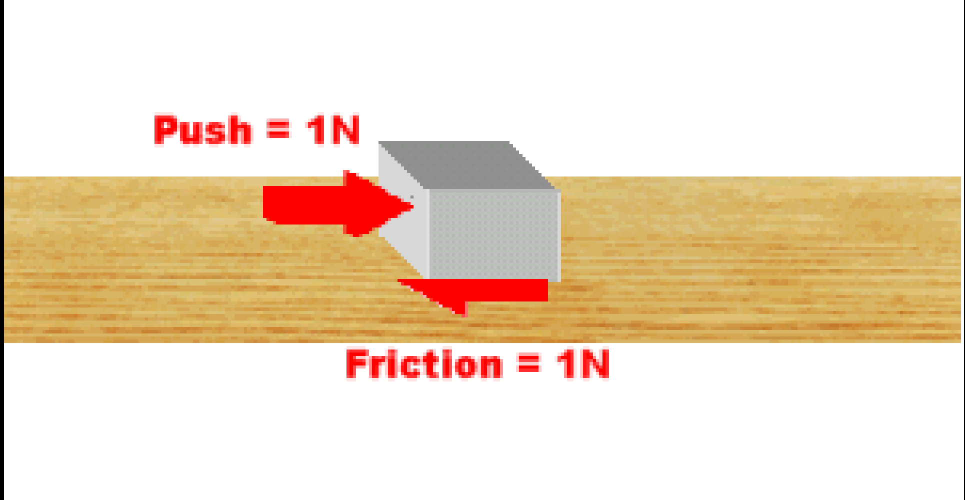
* These values are approximate and intended only for comparison.

4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Values calculated are maximum values

It is a responsive force



4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Sample 1 – A wooden sled is being pulled by horizontally by a rope. If the sled has a mass of 30 kg, and is moving at a constant 2 m/s, what is the tension on the rope. The coefficient of friction between the surfaces is $\mu_k = 0.15$.

Free body dia

T

4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Equations

$T - f = ma$

$N - W = ma$

Constant v

$T - f = 0$

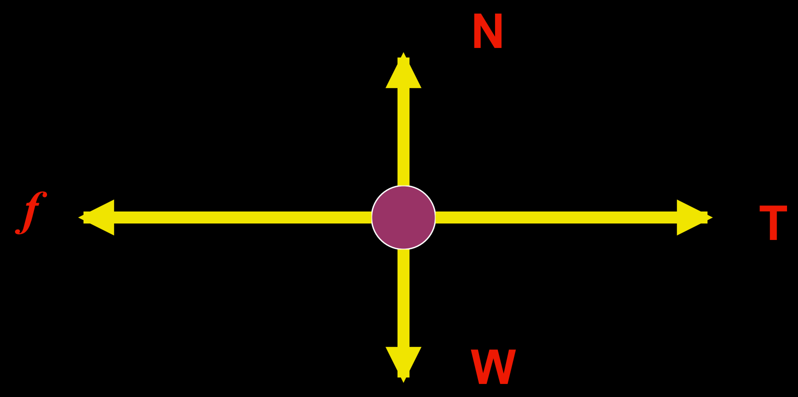
$T = f$

$N - W = 0$

$N = W = mg = (30)(9.80) = 294\ N$

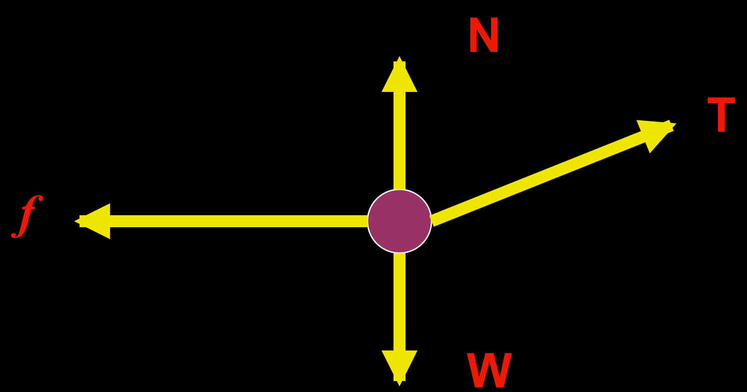
$f = \mu N = (0.15)(294) = 44.1N$

$T = f = 44.1N$



Sample 2 – If the same tension is applied to the rope, but at 25º above the horizontal, what will be the acceleration of the block?

Free body diagram

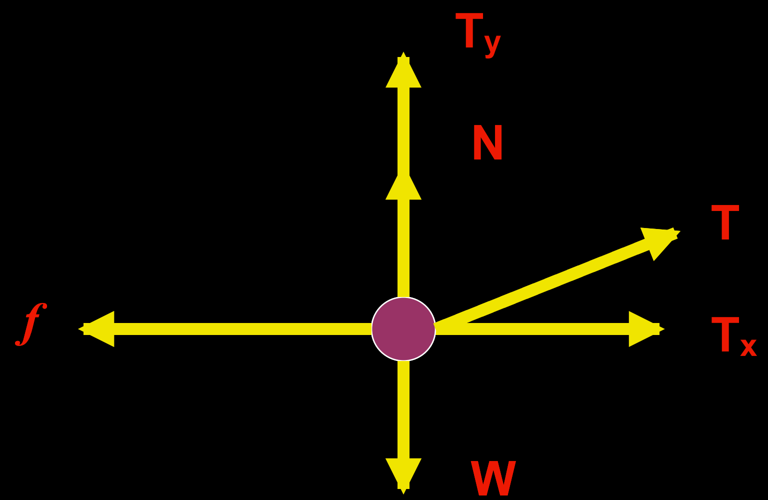


4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Sample 2 – If the same tension is applied to the rope, but at 25^o above the horizontal, what will be the acceleration of the block?

Redraw with components



4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Equations

$T_y + N - W = 0$

$T_x - f = ma$

$N = W - Ty$

$N = mg - T\sin\theta$

$N = (30)(9.8) - (44.1)\sin(25)$

$N = 275$ N

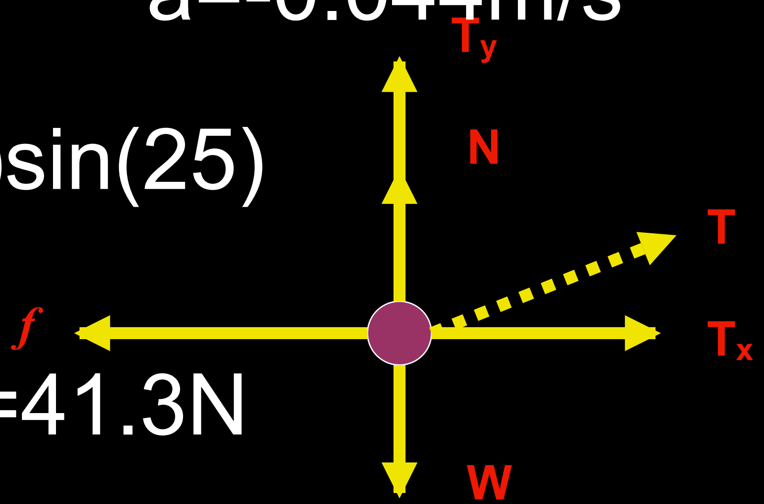
$f = \mu N = (0.15)(275) = 41.3$N

$T_x - f = ma$

$T\cos\theta - f = ma$

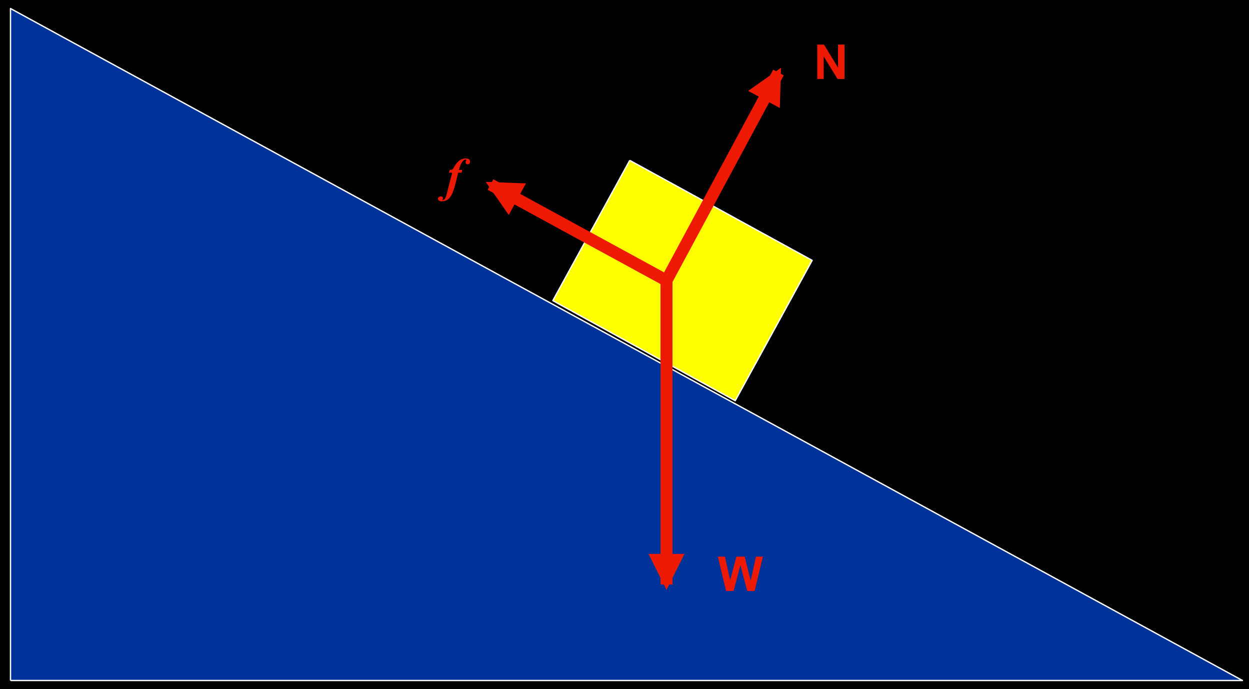
$(44.1)\cos 25 - 41.3 = 30a$

$a = -0.044 \text{ m/s}^2$



Inclines

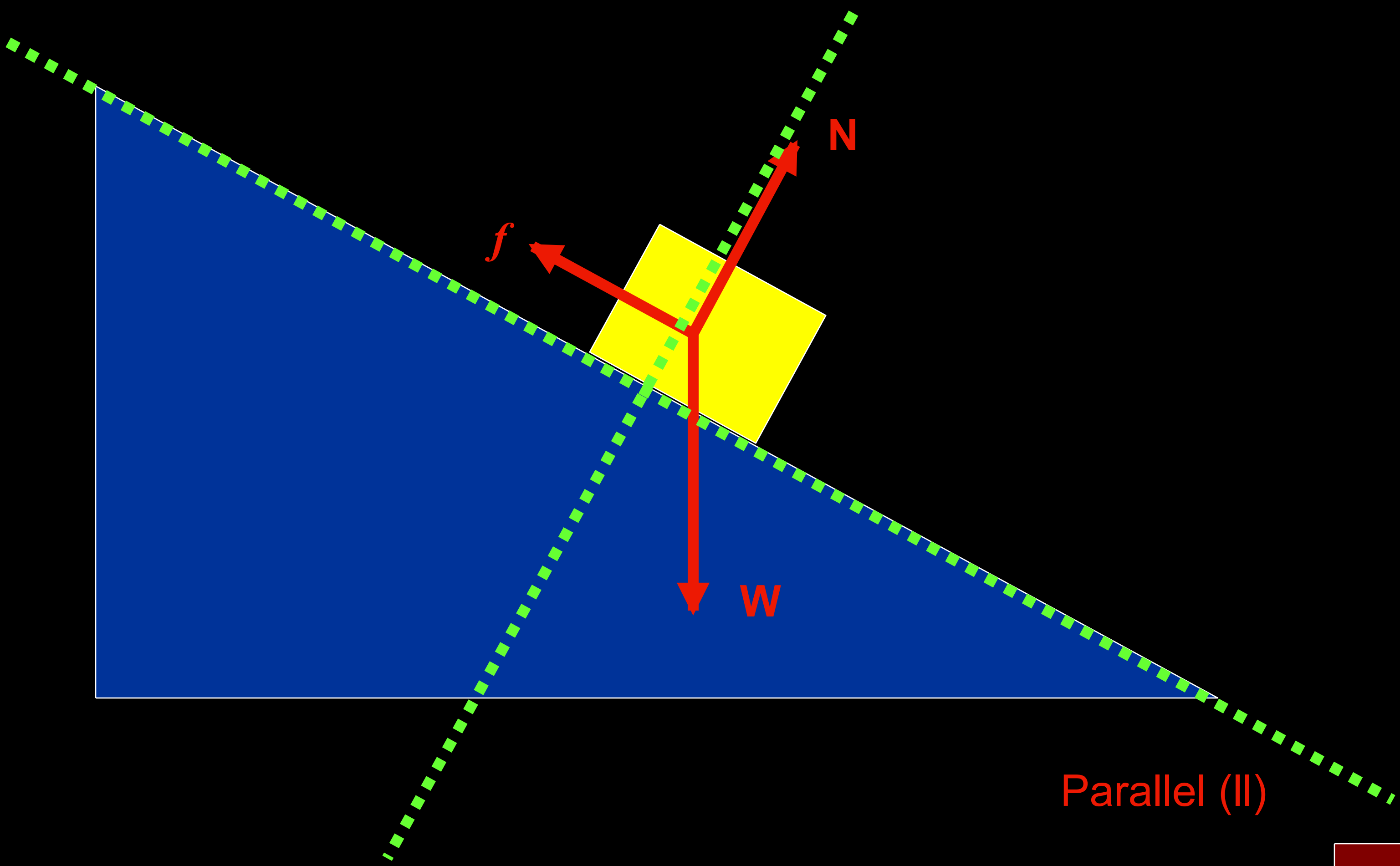
What is the free body diagram?



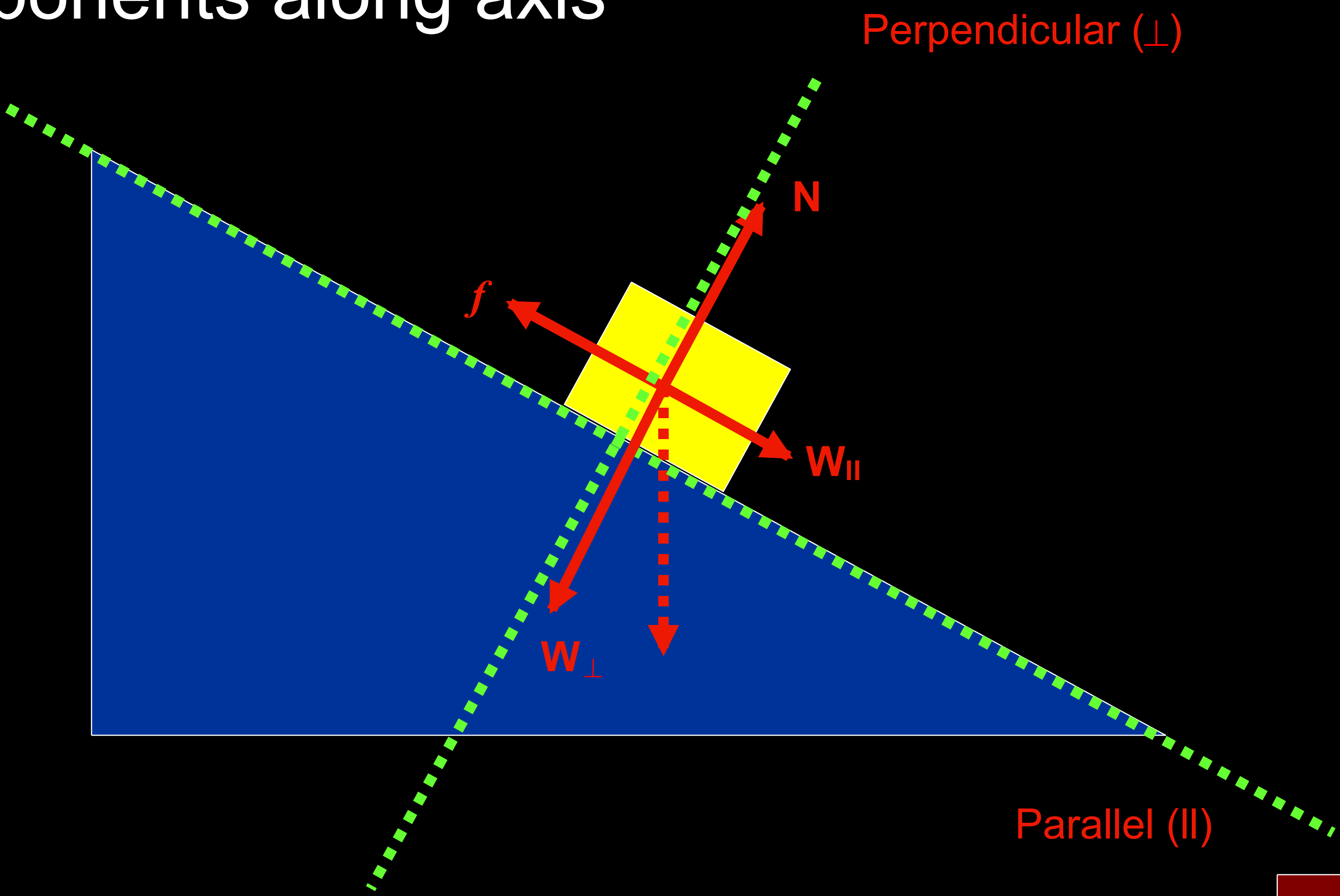
4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

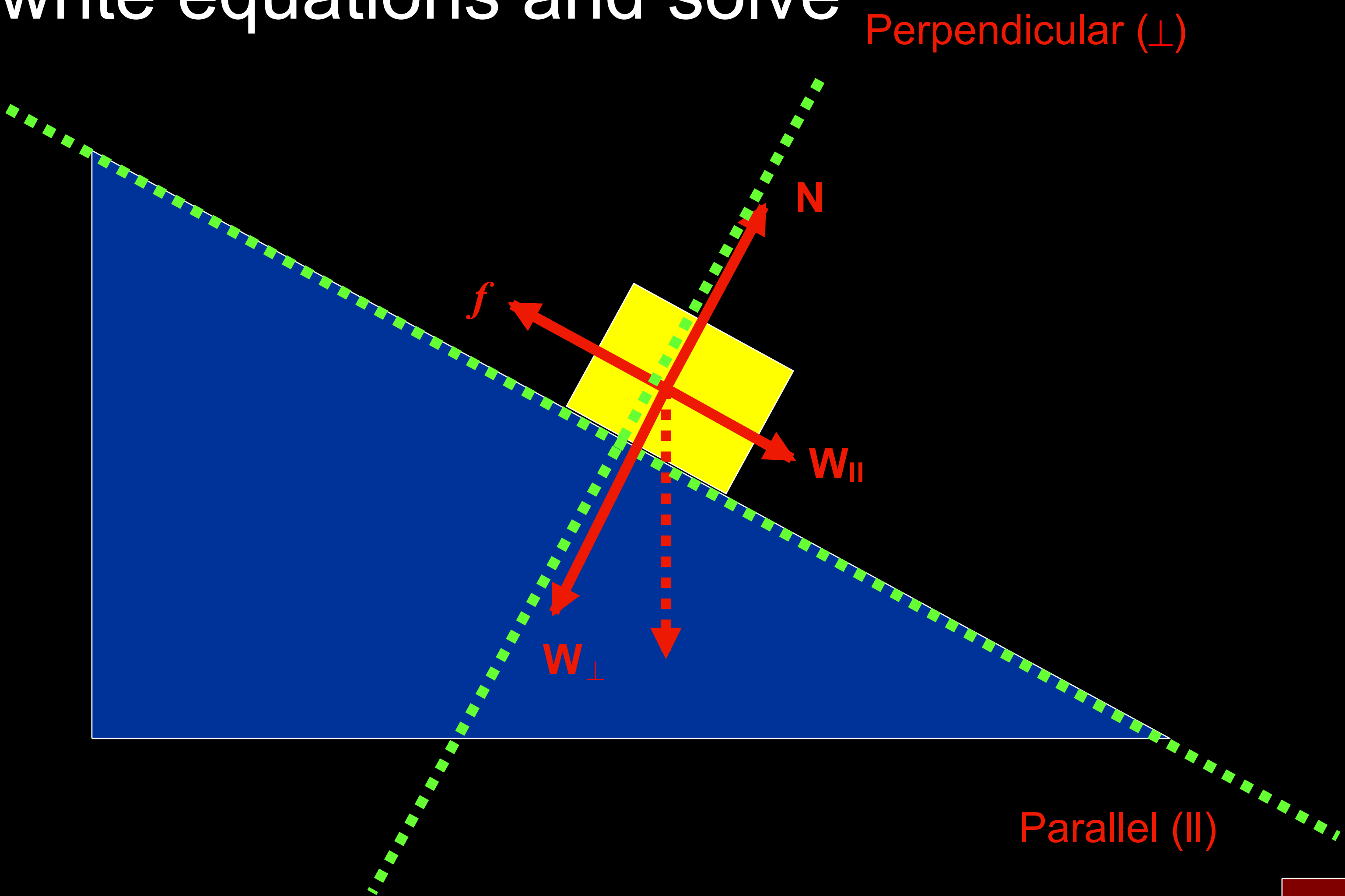
What axis?



Components along axis



Now write equations and solve

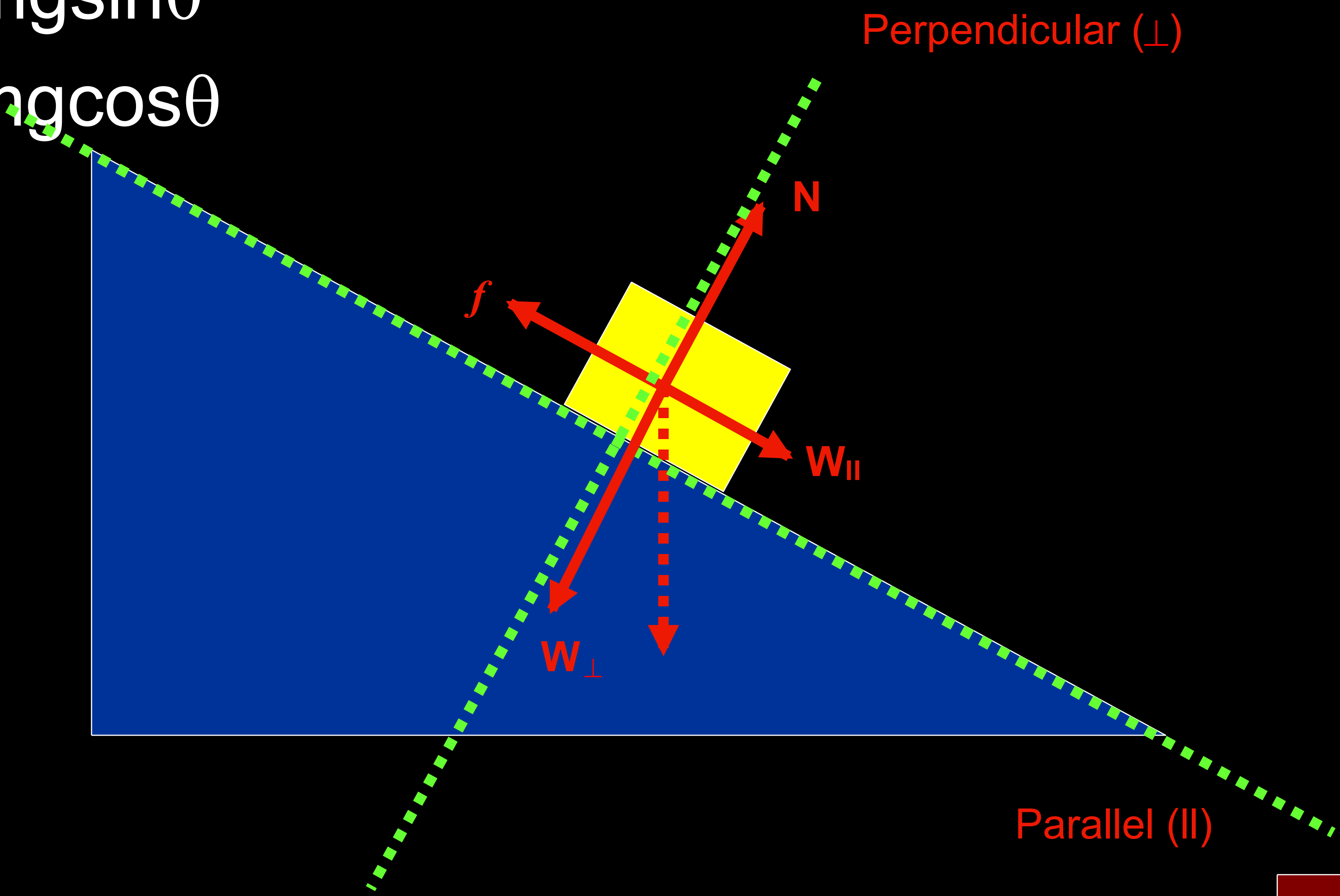


4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

$W_{II} = mg\sin\theta$

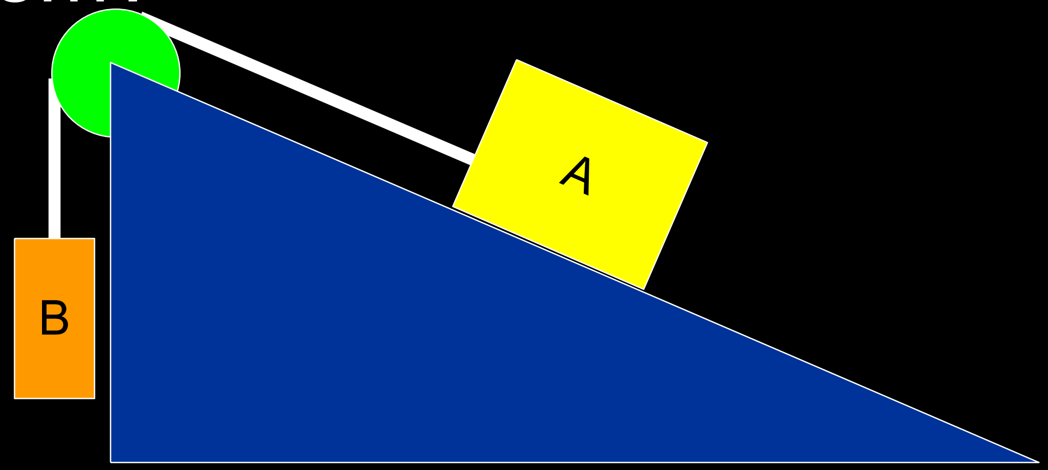
$W_{\perp} = mg\cos\theta$



4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Sample – Box A has a mass of 100 kg, and sits on an incline of 65°. Box B is attached by a rope and hanging off a pulley. It has a mass of 25 kg. What is the acceleration of the system?

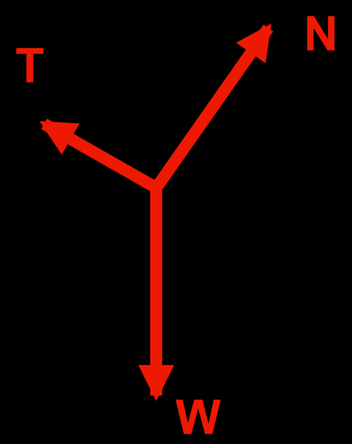


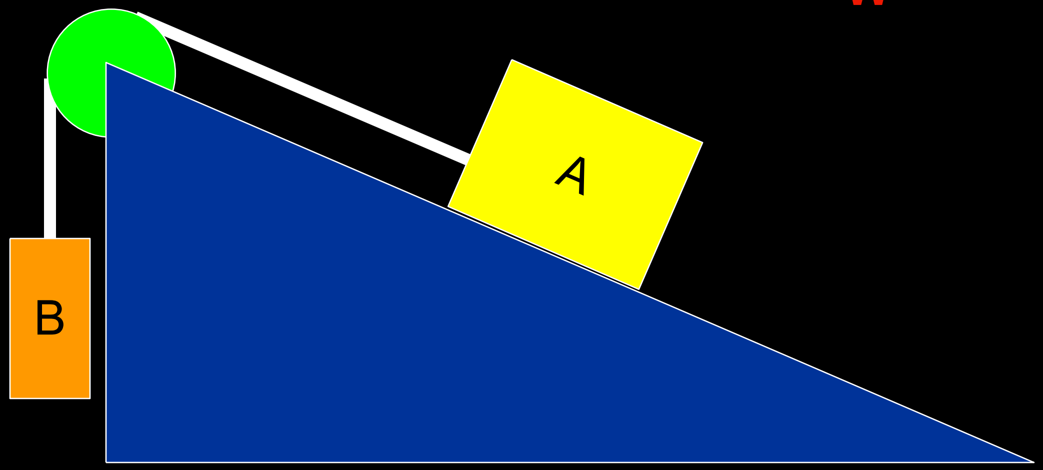
4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Free body diagram of A?

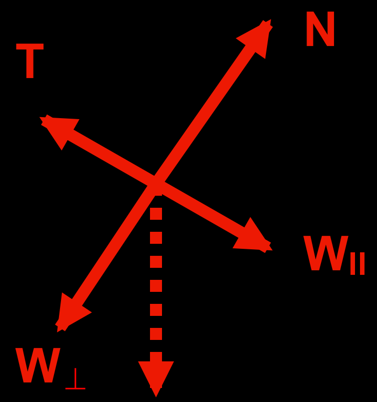
Components?

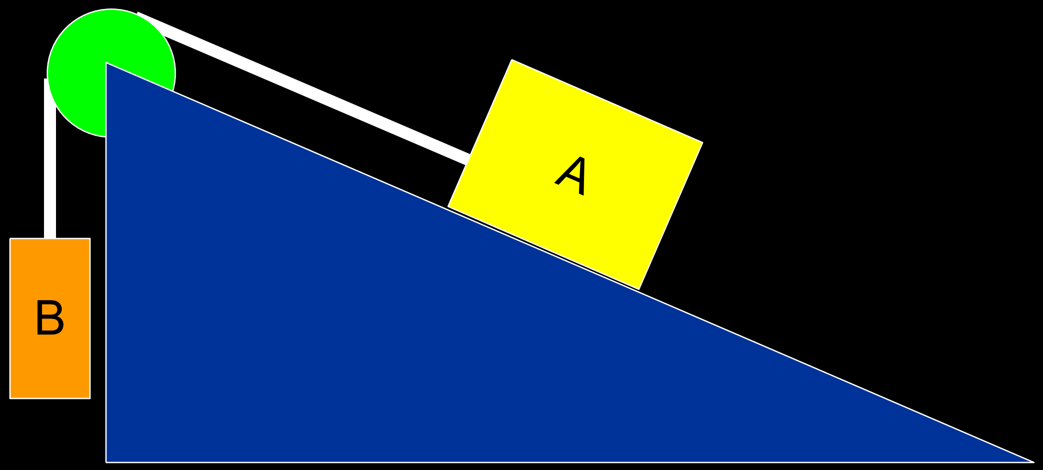




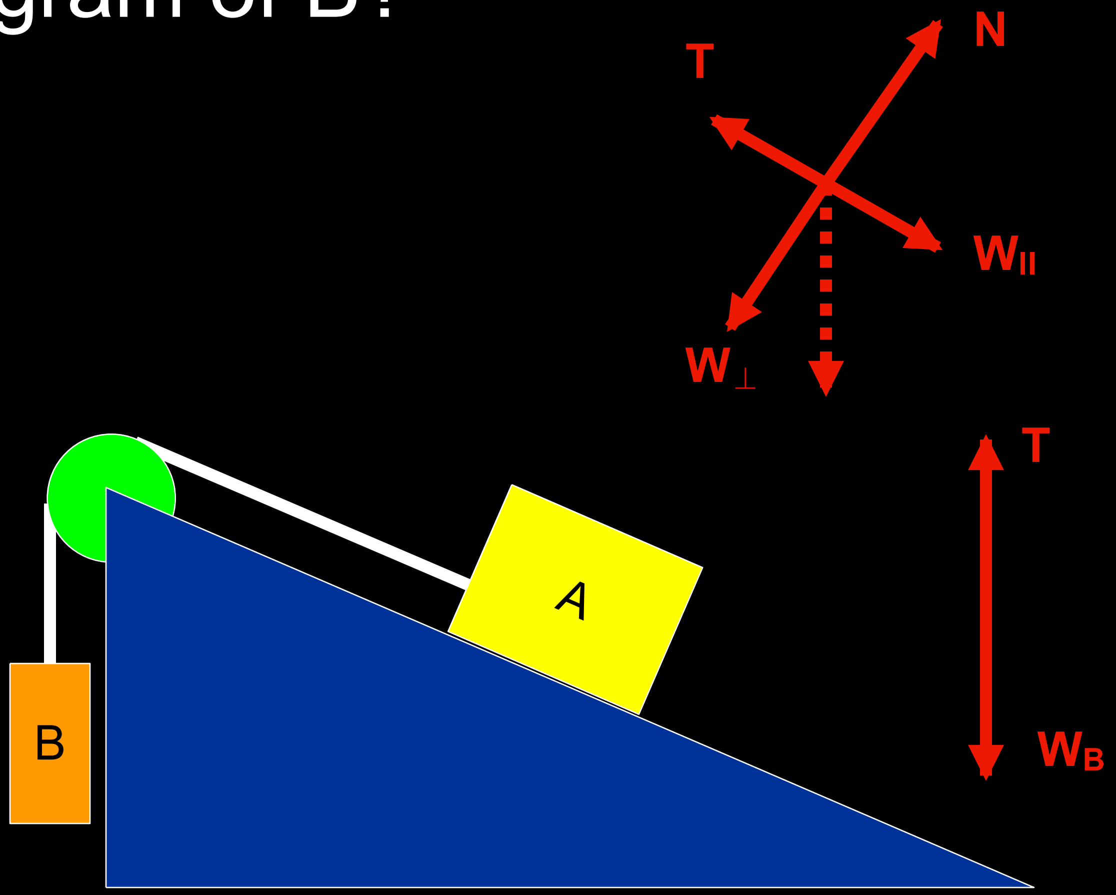
Free body diagram of A?

Components?





Free body diagram of B?



Equations? Choose downhill as positive

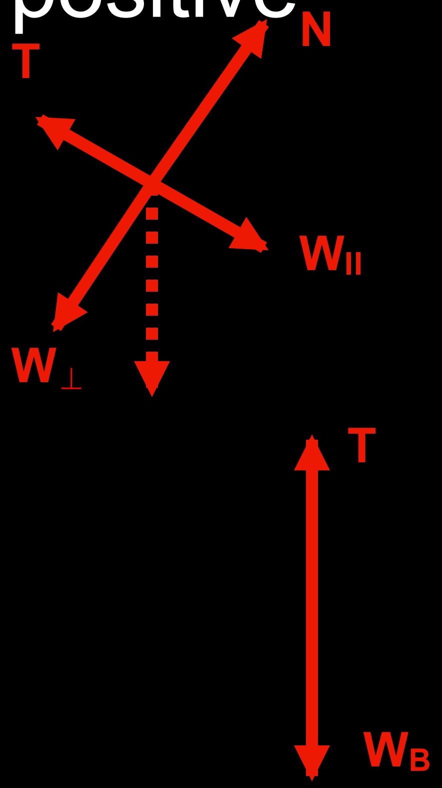
For A

$N - W_{\perp} = 0$

$W_{II} - T = m_A a$

For B

$T - W_B = m_B a$



Expand Equations

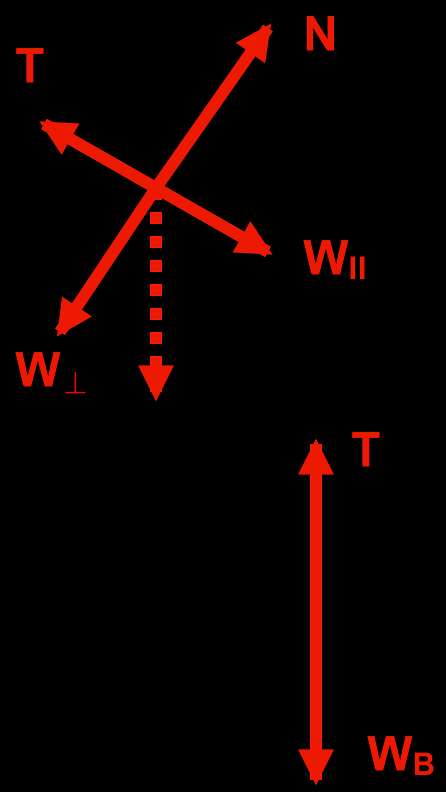
For A

$N - W_{\perp} = 0$

$W_{II} - T = m_A a$

For B

$T - W_B = m_B a$



4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Expand Equations

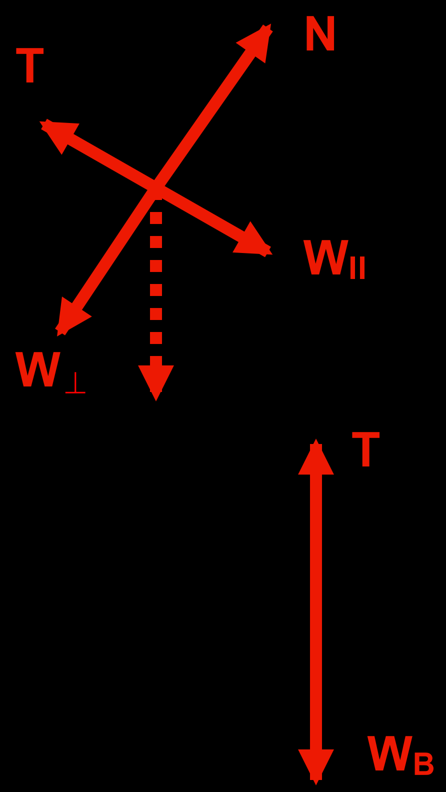
For A

$N - mg\cos\theta = 0$

$W_{II} - T = m_A a$

For B

$T - W_B = m_B a$



Expand Equations

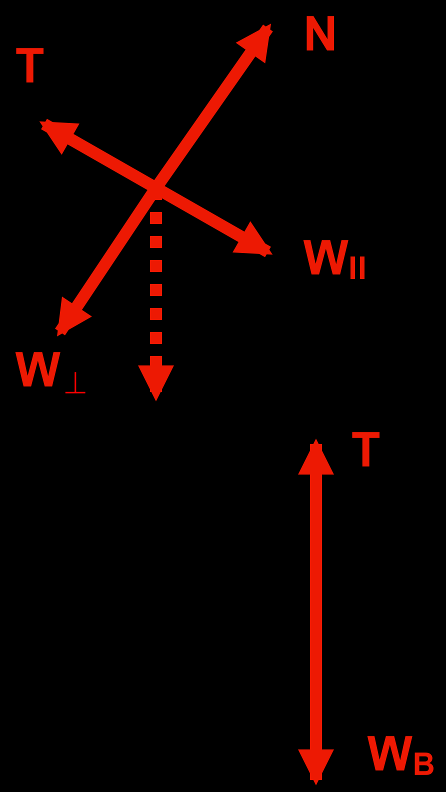
For A

$N - mg\cos\theta = 0$

$mg\sin\theta - T = m_A a$

For B

$T - W_B = m_B a$



4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

Expand Equations

For A

$N - mg\cos\theta = 0$

$mg\sin\theta - T = m_A a$

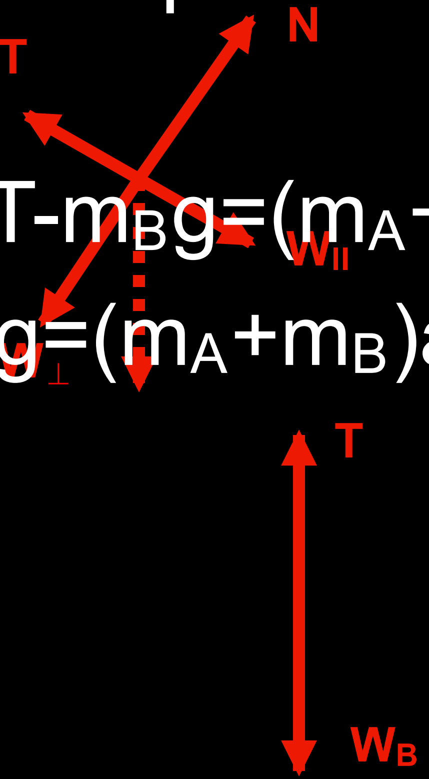
For B

$T - m_B g = m_B a$

Add relevant equations

$mg\sin\theta - T + T - m_B g = (m_A + m_B)a$

$mg\sin\theta - m_B g = (m_A + m_B)a$



Substitute

$(100)(9.8)\sin(65) - (25)(9.8) = (100+25)a$

$a = 5.15 m/s^2$

4.8 Friction and Inclines

Understand the significance of the coefficient of friction.

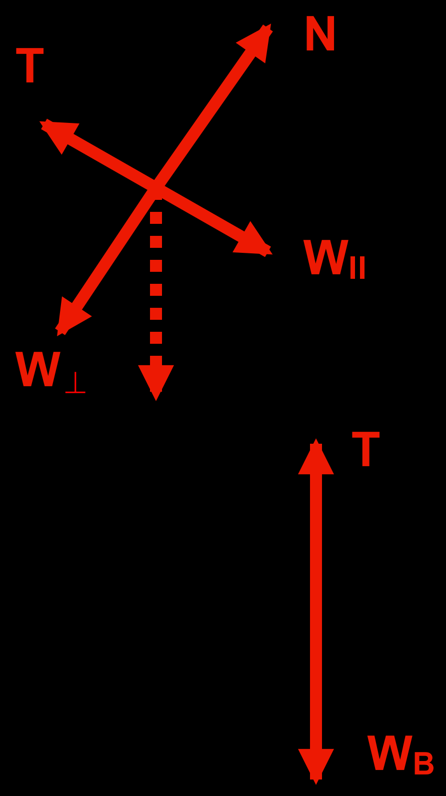
To solve for Tension

$mg\sin\theta - T = m_A a$

$a = 5.15 m/s^2$

$(100)(9.8)\sin(65) - T = (100)(5.15)$

$T = 373$ N



S-20

A penguin starts from rest on a 200 m long slope. If the slope has an angle of 50° (black diamond), how fast is the skiing penguin going at the bottom of the slope. Assume that the coefficient of friction between the snow and the skis is 0.10.

S-21

Bob the Zebra (named by missionaries) gets on his motorcycle to get away from the angry lion he has just poked with a stick. The combined mass of the bike and Bob is 200 kg. If the bike accelerates at 6.9 m/s2, and the coefficient of friction between bike and ground is 0.30, what is the force produced by the motorcycle engine?

S-22

Zeke the Koala is sleeping in a tree. He is known affectionately to his friends as “Large Bottom.”

What is the coefficient of friction between the tree and Zeke if he can sleep and not fall when the angle of the tree is 40.0°?