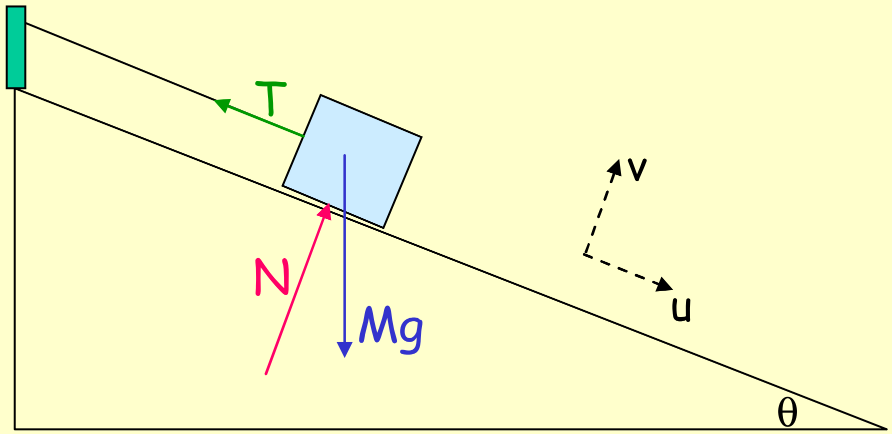
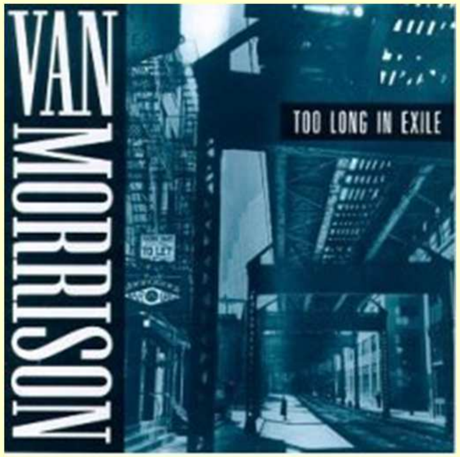
PHYS 100: Lecture 5

NEWTON'S SECOND LAW



$$\vec{F}_{tot} = \sum \vec{F}_i = m\vec{a}$$

Music

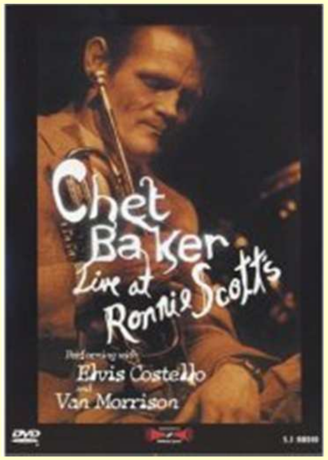


Who is the Artist?

A) Michael McDonald
B) Van Morrison
C) Glenn Frey
D) Robert Palmer
E) David Bowie

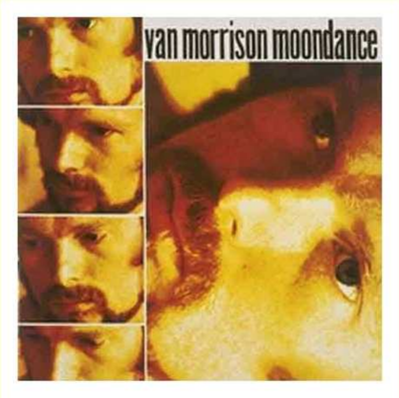
My favorite Van the Man album… Many of my friends agree that this one is on the list of 10 albums you must have on a desert island.. What does that say about my friends??

Did you know he wrote "Gloria".. He did!



Why?..
Remember Chet Baker

Really.. Incredible
"Send in the Clowns"
By Van the Man



A Classic, Of Course !

WHAT DID YOU FIND DIFFICULT?

SORRY.. NO REAL CONSENSUS… every topic was mentioned by several students..

WHAT TO DO??

work through some examples inspired by the preflights that illustrate the use of:

THE BIG IDEA

$$\vec{F}_{tot} = \sum \vec{F}_i = m\vec{a}$$

I will give you plenty of practice applying this equation today !!
Even when I don't have to, I will DO THE CALCULATION !!

THE BIG IDEAS

NOTE: THE BIG IDEAS ARE ALWAYS GIVEN IN THE LAST SLIDE

Summary

DYNAMICS requires TWO NEW CONCEPTS:

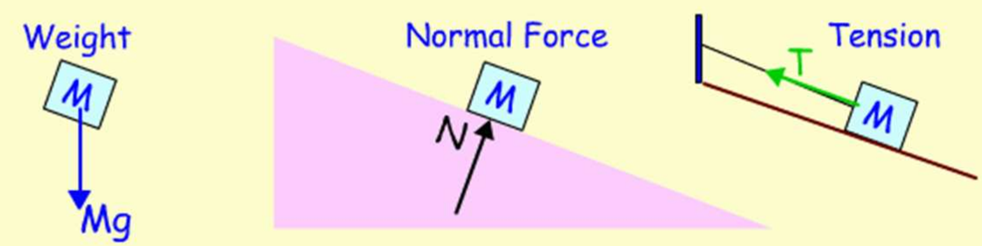
Mass is the property of an object that determines how hard it is to change its velocity

Force is the thing that is responsible for an object's change in velocity

NEWTON'S SECOND LAW CONNECTS THESE TWO NEW CONCEPTS:

$$\vec{F}_{tot} = \sum \vec{F}_i = m\vec{a}$$

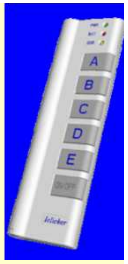
THREE SPECIFIC FORCES:



$$\vec{F} = m\vec{g}$$

1. An object accelerates only when the total force on it is non-zero.
2. The weight of an object is always equal to Mg
3. The Normal Force and Tension forces must be determined from F=ma

Thrown Ball

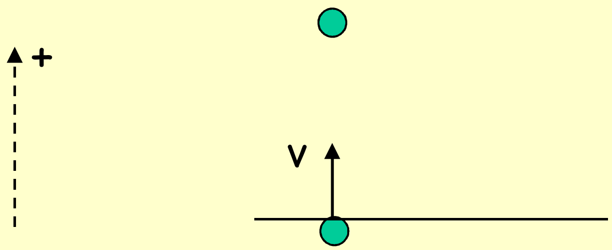


BB

A ball is thrown straight up in the air. Take up to be the positive direction

What are the velocity (v) and acceleration (a) of the ball at its highest point?

(A)	(B)	(C)	(D)	(E)
$v = 0$, $a > 0$	**$v = 0$, $a < 0$**	$v = 0$, $a = 0$	$v \neq 0$, $a = 0$	$v \neq 0$, $a \neq 0$



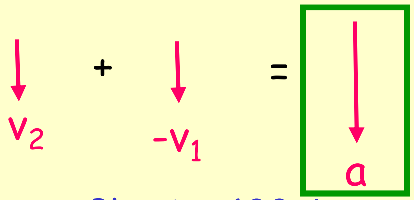
Just before the ball reaches its highest point: what is its velocity? ↑ v_1

Just after the ball reaches its highest point: what is its velocity? ↓ v_2

Just as the ball reaches its highest point: what is its velocity? $v = 0$

Just as the ball reaches its highest point: what is its acceleration?

$$\vec{a} \equiv \frac{d\vec{v}}{dt} \Rightarrow \vec{a} \propto \Delta\vec{v} = \vec{v}_2 - \vec{v}_1$$



Preflight 1

BB

A ball is thrown straight up in the air.

How many forces are acting on the ball at its highest point?

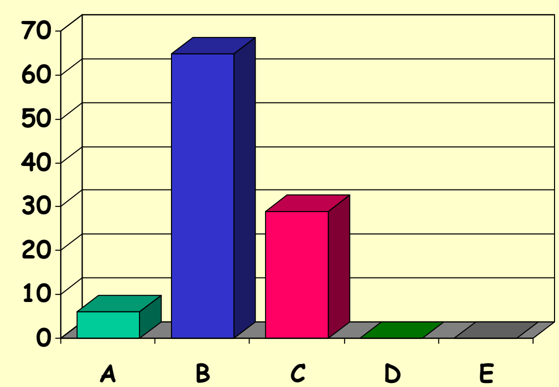
(A) 0 **(B) 1** (C) 2 (D) 3 (E) Greater than 3

You said:

- At its highest point, the ball is not moving. At this point, the two forces exerted on it previously are now cancelling each other out.
- The force of gravity is the only force acting upon the ball.
- Gravity (down) and force given to the ball (up).

We know $a = g$ throughout the flight of the ball ! The net force at all times then must be given by:

$F = ma = mg$ (the weight !!)



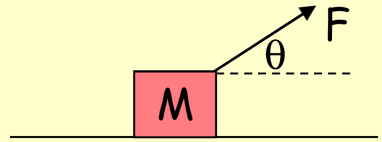
Pulling a block

BB

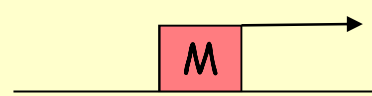
In both cases shown, forces of equal magnitude, F, are exerted on identical blocks supported by a frictionless floor. In Case I, the force is applied at an angle θ wrt horizontal while in Case II, the force is applied horizontally.

Compare a_I to a_{II}:

- (A) $a_I < a_{II}$
- (B) $a_I = a_{II}$
- (C) $a_I > a_{II}$



Case I

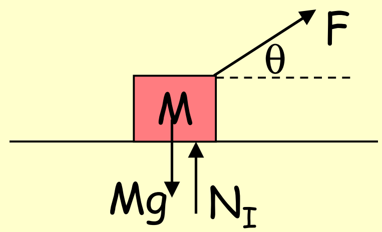


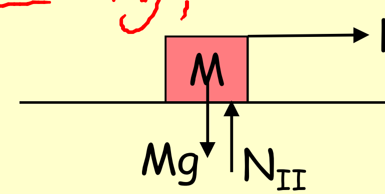
Case II

WHAT DO YOU KNOW?? $\vec{F}_{tot} = \sum \vec{F}_i = m\vec{a}$ $\Rightarrow$ $\sum F_{x_i} = m a_x$, $\sum F_{y_i} = m a_y$

WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!



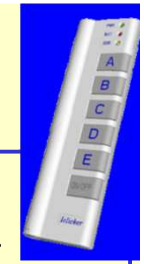


APPLY NEWTON'S SECOND LAW IN HORIZONTAL DIRECTION

$$F\cos\theta = Ma_I \qquad F = Ma_{II}$$

$$a_I = \frac{F}{M}\cos\theta \Rightarrow \boxed{a_I = a_{II}\cos\theta} \Leftarrow a_{II} = \frac{F}{M}$$

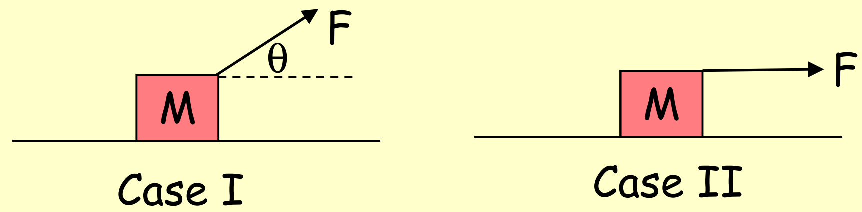
Pulling a block



In both cases shown, forces of equal magnitude, F, are exerted on identical blocks supported by a frictionless floor. In Case I, the force is applied at an angle θ wrt horizontal while in Case II, the force is applied horizontally.

Compare N_I to N_{II}:

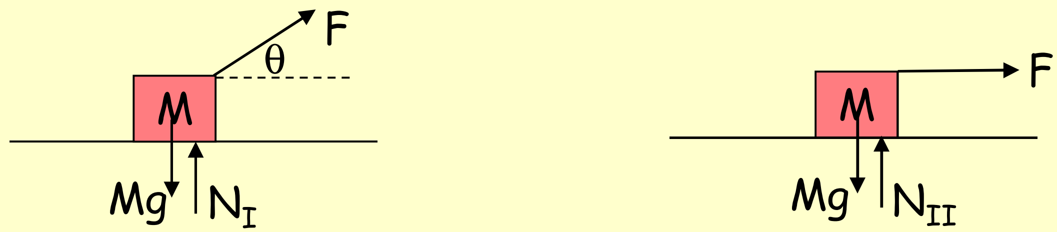
- (A) $N_I < N_{II}$
- (B) $N_I = N_{II}$
- (C) $N_I > N_{II}$



WHAT DO YOU KNOW?? $\vec{F}_{tot} = \sum \vec{F}_i = m\vec{a}$

WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!



APPLY NEWTON'S SECOND LAW IN VERTICAL DIRECTION

$$F\sin\theta + N_I = Mg \qquad N_{II} = Mg$$

$$N_I = Mg - F\sin\theta \;\Rightarrow\; \boxed{N_I = N_{II} - F\sin\theta}$$

Preflight 3

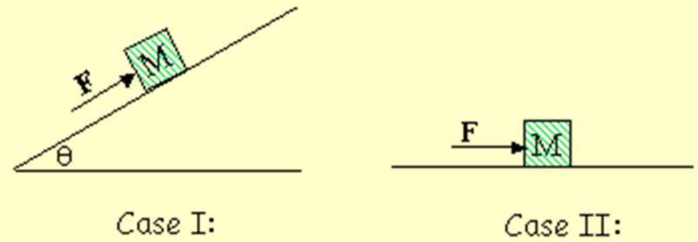
In both cases shown, forces of equal magnitude, F, are exerted on identical blocks. The forces are directed parallel to the frictionless surfaces

Compare a_I to a_{II}:

(A) $a_I < a_{II}$

(B) $a_I = a_{II}$

(C) $a_I > a_{II}$



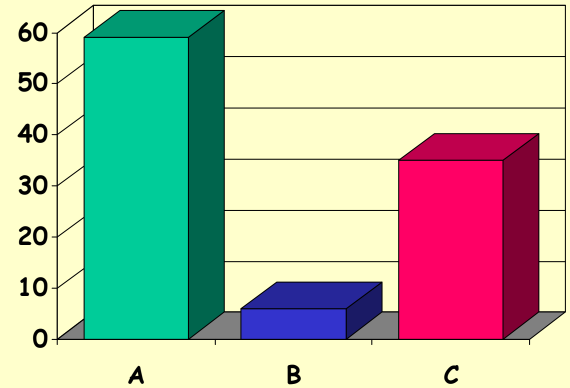
BB

You said:

- Gravity is working against the foce in case 1 so the force would need to be greater for the accelerations to be equal

- Since F=ma, the blocks have the same Force and Mass, therefore they must have the same acceleration

- According to the formula, a=gsin(degree), the larger the angle, the larger the acceleration. In case II, the degree equals 0.



Preflight 3

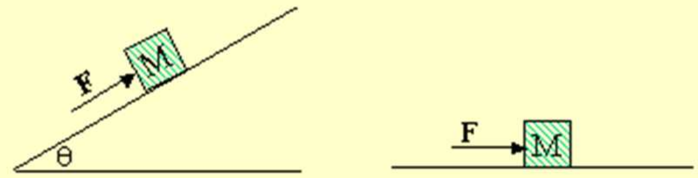
In both cases shown, forces of equal magnitude, F, are exerted on identical blocks. The forces are directed parallel to the frictionless surfaces

Compare a_I to a_{II}:

(A) $a_I < a_{II}$

(B) $a_I = a_{II}$

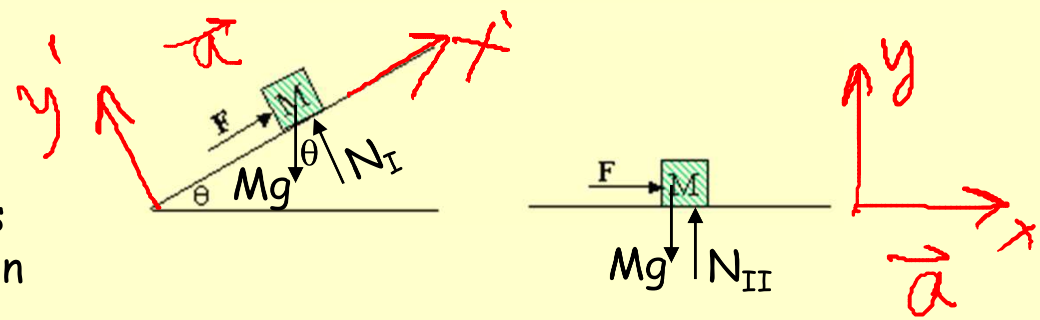
(C) $a_I > a_{II}$



Case I: Case II:

WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!



Same kind of forces, but differences in orientation will cause differences in magnitude !

APPLY NEWTON'S SECOND LAW IN DIRECTION OF ACCELERATION

$$F - Mg\sin\theta = Ma_I \qquad F = Ma_{II}$$

$$a_I = \frac{F}{M} - g\sin\theta \qquad a_{II} = \frac{F}{M}$$

$$a_I = a_{II} - g\sin\theta$$

Follow-Up

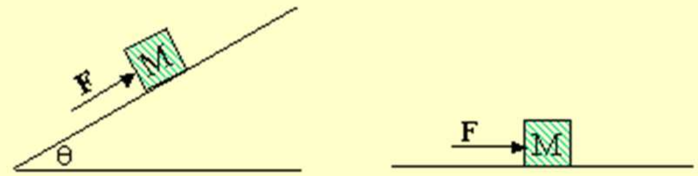
In both cases shown, forces of equal magnitude, F, are exerted on identical blocks. The forces are directed parallel to the frictionless surfaces

Compare N_I to N_{II}:

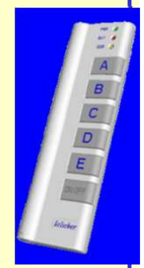
(A) $N_I < N_{II}$

(B) $N_I = N_{II}$

(C) $N_I > N_{II}$



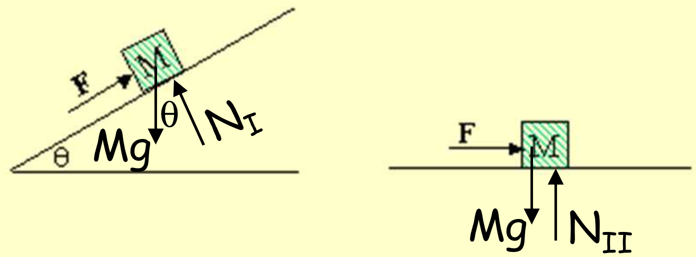
Case I: Case II:



BB

WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!



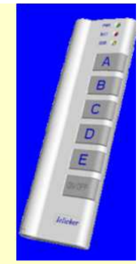
APPLY NEWTON'S SECOND LAW PERPENDICULAR TO THE PLANE

$$N_I - Mg\cos\theta = 0 \quad\Rightarrow\quad N_I = Mg\cos\theta$$

$$N_{II} - Mg = 0 \quad\Rightarrow\quad N_{II} = Mg$$

$$\boxed{N_I = N_{II}\cos\theta}$$

Elevators

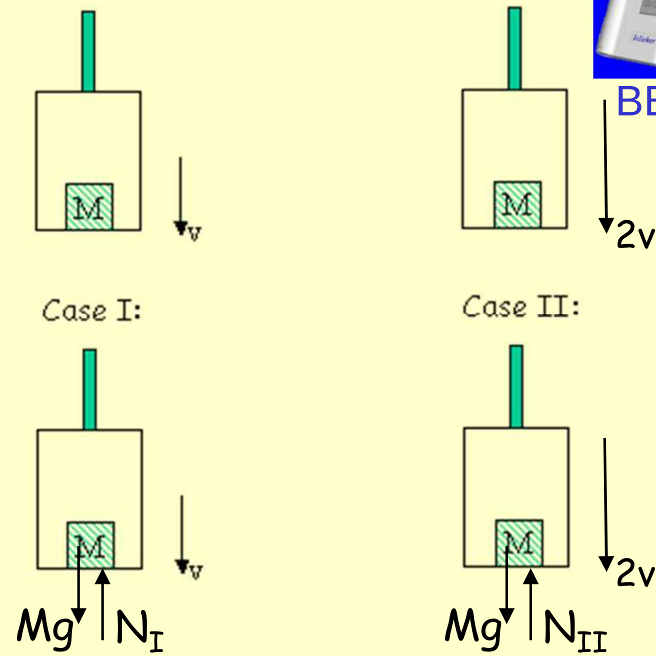


Both elevators shown carry identical crates and are moving down. In Case I, the elevator is moving at constant velocity v, while in Case II the elevator is moving at constant velocity 2v.

Compare N_I to N_{II}:

(A) $N_I < N_{II}$ **(B) $N_I = N_{II}$** (C) $N_I > N_{II}$

BB



WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!

APPLY NEWTON'S SECOND LAW IN VERTICAL DIRECTION

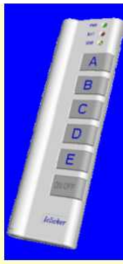
(**a** = 0 !!)

$$N_I - Mg = 0 \qquad N_{II} - Mg = 0$$

$$N_I = Mg \qquad N_{II} = Mg$$

$$\boxed{N_I = N_{II}}$$

Preflight 5

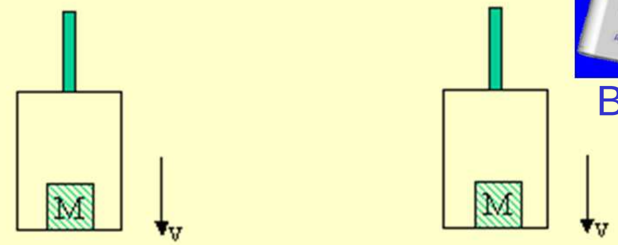


BB

Both elevators shown carry identical crates and are moving down. In Case I, the elevator is slowing down, while in Case II the elevator is speeding up.

Compare N_I to N_{II}:

(A) $N_I < N_{II}$ (B) $N_I = N_{II}$ (C) $N_I > N_{II}$



Case I: Elevator slowing down

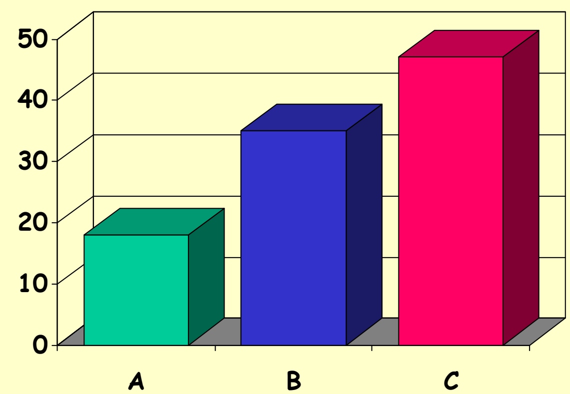
Case II: Elevator speeding up

You said:

- case II has more acceleration because it is speeding up therefore a larger normal force f=ma

- normal force is only mass times gravity which remain constant in both situatiuons

- The force exerted by elevator 1 is greater than the force of gravity and is slowing the crate down. The force exerted by elevator 2 is less than the force of gravity, and thus is speeding up. Therefore, N1 has to be greater than N2.



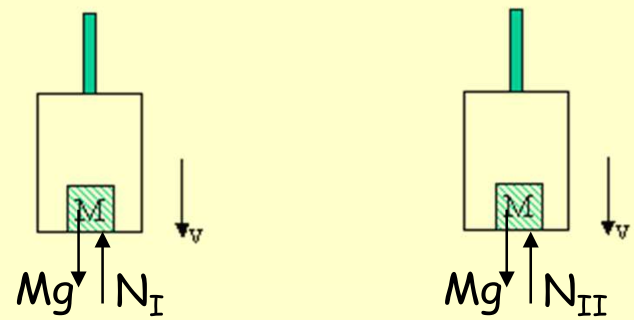
Preflight 5

Both elevators shown carry identical crates and are moving down. In Case I, the elevator is slowing down, while in Case II the elevator is speeding up.
Compare N_I to N_{II}:

(A) $N_I < N_{II}$ (B) $N_I = N_{II}$ **(C) $N_I > N_{II}$**

Case I: Elevator slowing down

Case II: Elevator speeding up



WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!

WHAT IS ACCELERATION ??

↑ a_I ↓ a_{II}

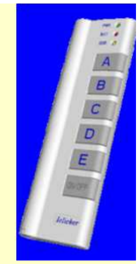
APPLY NEWTON'S SECOND LAW IN VERTICAL DIRECTION
(take direction of **a** to be positive)

$$N_I - Mg = Ma_I \qquad Mg - N_{II} = Ma_{II}$$

$$N_I = M(g + a_I) \qquad N_{II} = M(g - a_{II})$$

$$\boxed{N_I > N_{II}}$$

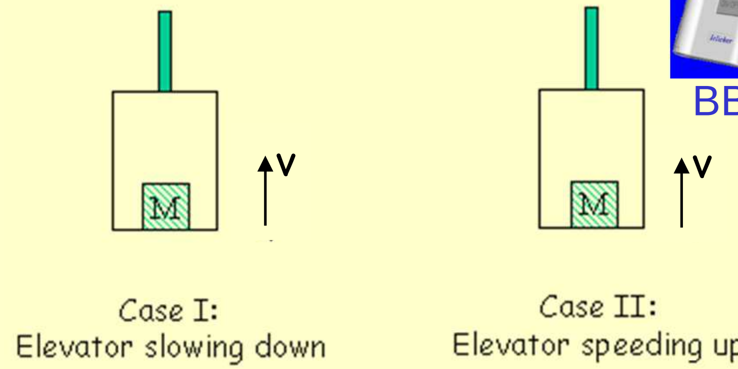
Follow Up


BB

Both elevators shown carry identical crates and are moving up. In Case I, the elevator is slowing down, while in Case II the elevator is speeding up.

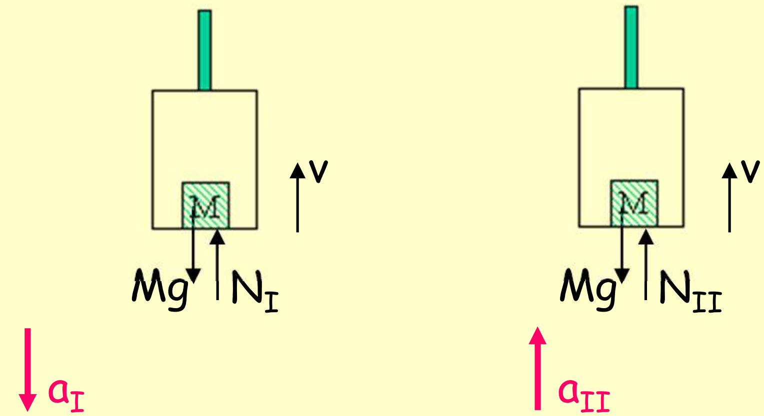
Compare N_I to N_{II}:

(A) $N_I < N_{II}$ (B) $N_I = N_{II}$ (C) $N_I > N_{II}$



WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!



WHAT IS ACCELERATION ??

APPLY NEWTON'S SECOND LAW IN VERTICAL DIRECTION

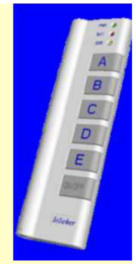
(take direction of **a** to be positive)

$$Mg - N = Ma_I \qquad N_{II} - Mg = Ma_{II}$$

$$N_I = M(g - a_I) \qquad N_{II} = M(g + a_{II})$$

$$\boxed{N_I < N_{II}}$$

Preflight 7

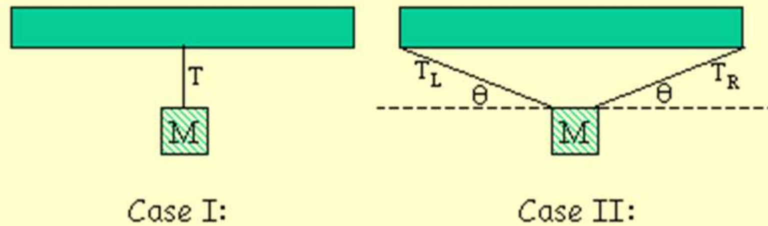


BB

In both cases shown identical signs are suspended from the ceiling. One string is used in Case I, while two strings, each making an angle of θ = 20° with the horizontal, are used in Case II.

Compare T to T_L:

(A) $T < T_L$ (B) $T = T_L$ (C) $T > T_L$



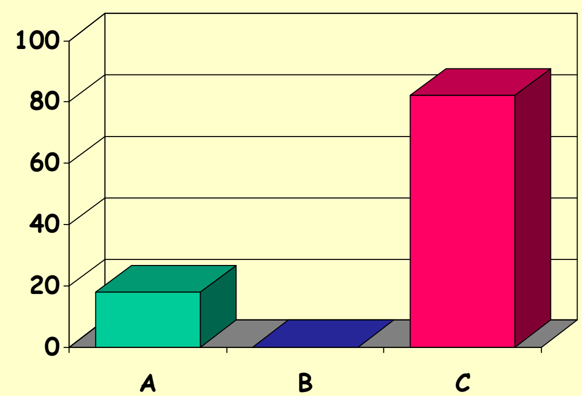
You said:

- TL must deal with both a horizontal and vertical component and with the vertical component being equal to half of the force of gravity and the angle being as small as it is, then the tension in TL would be considerably greater.

- Since both blocks have the same weight and are not accelerating the, magnitude of the tension must be the same.

- Because there are two strings in case 2, each string only has to support half of the weight, requiring less tension

LET'S DO THE EXPERIMENT !!

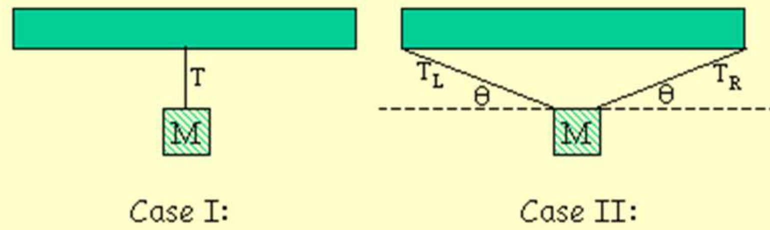


Preflight 7

In both cases shown identical signs are suspended from the ceiling. One string is used in Case I, while two strings, each making an angle of θ = 20^{o} with the horizontal, are used in Case II.

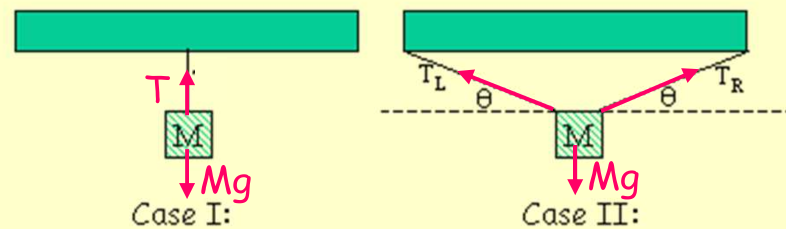
Compare T to T_L:

(A) $T < T_L$ (B) $T = T_L$ (C) $T > T_L$



WHAT DO YOU DO FIRST?

Draw Free Body Diagram !!



APPLY NEWTON'S SECOND LAW IN VERTICAL DIRECTION

(Symmetry of Case II insures a_x = 0)

(i.e., $T_L = T_R$)

$$T = Mg \qquad 2T_L \sin\theta = Mg$$

$$T_L = \frac{T}{2\sin\theta} \quad \Leftarrow \quad T_L = \frac{Mg}{2\sin\theta}$$

$T_L > T$ if $\sin\theta < 1/2$ i.e., $\theta < 30^{o}$