Using Newton’s Laws

Physics 1425 Lecture 7

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Today's Topics

- Weight: the force of gravity
- The Normal Force: a surface pushes back
- Free Body Diagrams: finding the *total* force on a body

Weight: the Force of Gravity

- Newton introduced the idea of a gravitational force to explain Galileo's "natural downward acceleration".

- Previously, force was only used to describe direct physical contact forces, the idea of a gravitational force seemed weird—kind of irrational and magical.

Weight and Inertial Mass

- All falling objects have the same acceleration (when air resistance is eliminated), so applying

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

  the gravitational force on an object—its weight—must be directly proportional to its inertial mass. (It isn't obvious why this should be true!)

- If an object is taken to the Moon, its inertial mass *doesn't change*—it takes the same energy to accelerate a car. But its weight *does* change.

The Normal Force

- Right now, the force of gravity is pulling us all downwards—but we're not moving!

- What about $\vec{F} = m\vec{g}$?

- Remember $\vec{F}$ is the total force on a body.

- If the floor disappears, I will accelerate downwards!

The Normal Force

- Conclusion: the floor is providing the force balancing that of gravity: it’s called the normal force.
- Question: how can something as inert and immoveable as the floor provide a force?
- Clue: how does a spring balance provide a force to measure weight?

Normal Force and Springiness

- When the tomatoes are put on the scale, it moves down, compressing a spring until the spring's force balances gravity.

- The floor is elastic too! Where you stand, it sags a little, and pushes back like a very stiff spring.

Clicker Question

I stand on roller skates facing a wall. I reach out and push against the wall, I accelerate backwards. What force caused my acceleration?

A. My arm and back muscles
B. My pushing against the wall
C. The normal force from the wall
D. Friction between the skates and the floor

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D. Friction between the skates and the floor

- A body can only be accelerated by an *outside* force—and friction only helps if I actively push against the floor, as in skating.

Clicker Question

What is the normal force from the elevator floor on a person weighing mg, if the elevator is accelerating upwards at $0.1g$?

A. $1.1mg$

B. mg

C. $0.9mg$

D. None of the above

Clicker Question

What is the normal force from the elevator floor on a person weighing *mg*, if the elevator is accelerating upwards at 0.1*g*?

A. 1.1*mg*

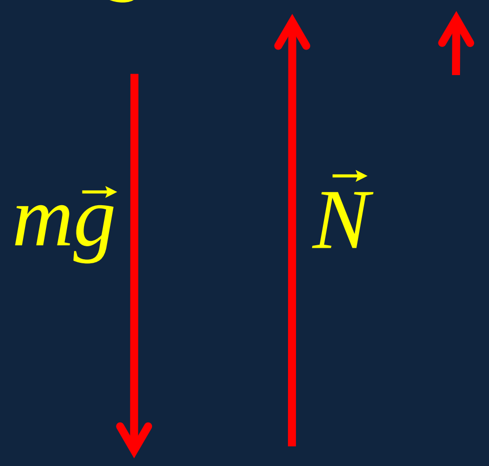
B. mg

C. 0.9*mg*

D. None of the above

[Link to movie!]

$$\vec{F} = m\vec{g} + \vec{N} = m\vec{a}$$



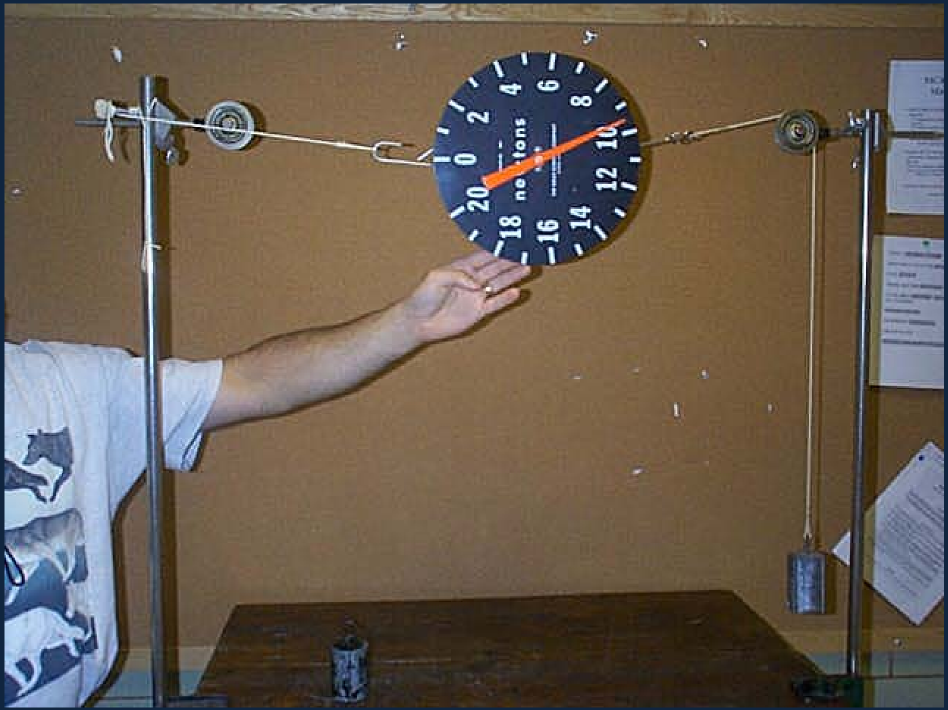
Tension!

- In Newton’s original statement of his Third Law, he features a horse pulling a rope attached to a stone.
- The tension in the string means that if the stone is subject to a certain force from the horse’s efforts, the horse feels an equal and opposite force from the tug of the string.

- The string is pulling **inwards** at both ends.

Tension Puzzle…

- A one kg mass hangs from the string, the other end is looped over a hook.



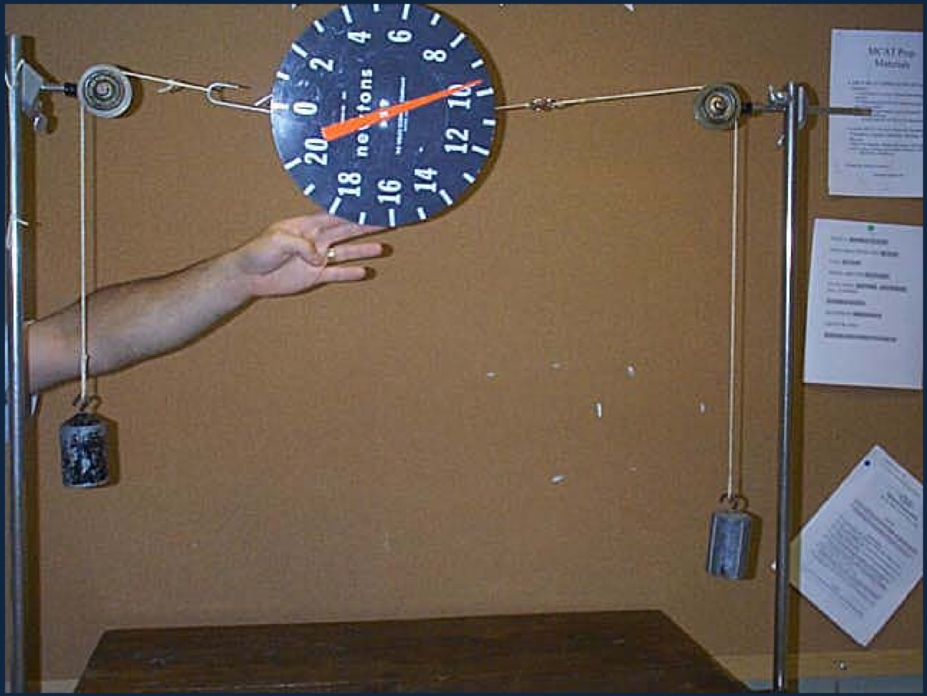
- Suppose the looped end of the string is taken from the hook, put over the pulley, and a one kg mass is hung from that end too. What will the spring scale read now?

A. About the same

B. About double

Tension Puzzle Answered

- We did the experiment, this is what we saw:



- The tension in the string is the weight of one kg, 9.8N. In the first case, the string was pulling the hook with 9.8N force, and the hook was pulling right back!

Free Body Diagrams

- To apply Newton's Laws to find how a body moves, we must focus on that body alone and add all the (vector) forces acting on it.

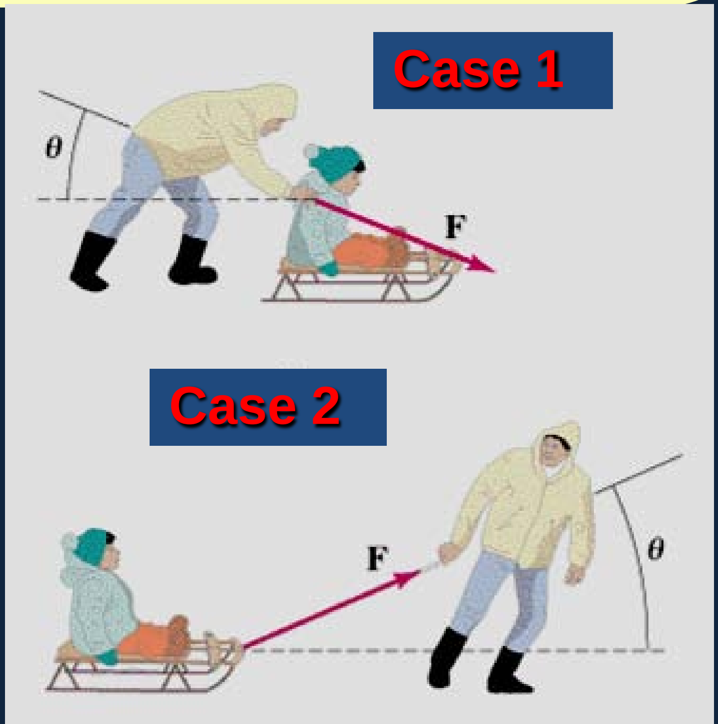
- The diagram showing all the forces on one body (or even part of a body) is called a "free body diagram"—we've "freed" the body from the rest of the system, representing everything else just by the forces on this body.

- The net (total) force then goes into $\Sigma\vec{F} = m\vec{a}$.

ConcepTest 4.10 Normal Force

Below you see two cases: a physics student **pulling** or **pushing** a sled with a force *F* that is applied at an angle θ. In which case is the normal force greater?

1) case 1
2) case 2
3) it's the same for both
4) depends on the magnitude of the force *F*
5) depends on the ice surface



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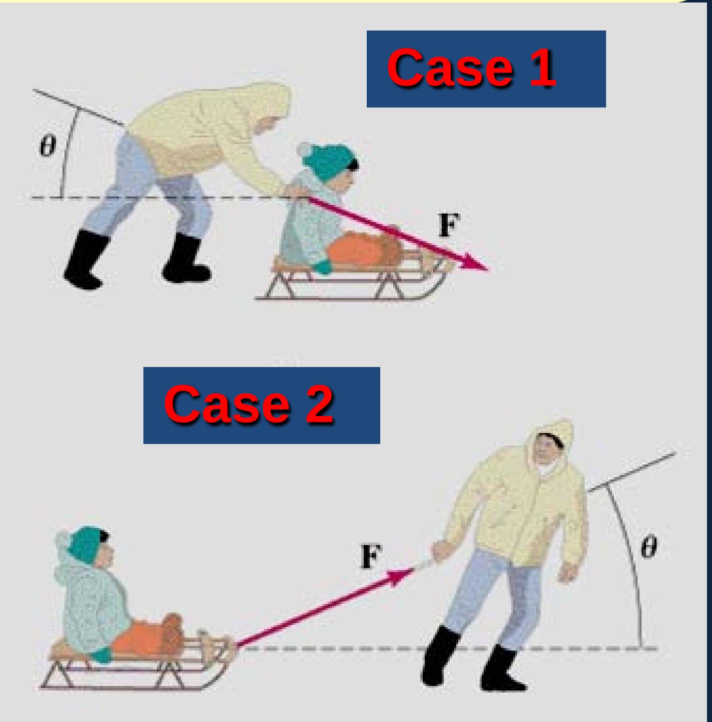
In case 1, the force *F* is pushing down (in addition to *mg*), so the normal force needs to be larger. In case 2, the force *F* is pulling up, against gravity, so the normal force is lessened.



ConcepTest 4.15b Contact Force II

Two blocks of masses 2*m* and *m* are in contact on a horizontal **frictionless** surface. If a force *F* is applied to mass 2*m*, what is the force on mass *m* ?

1) $2F$
2) F
3) $\frac{1}{2}F$
4) $\frac{1}{3}F$
5) $\frac{1}{4}F$

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The force *F* leads to a specific acceleration of the entire system. In order for **mass *m* to accelerate at the same rate, the force on it must be smaller!** How small?? Let's see...

Follow-up: What is the acceleration of each mass?

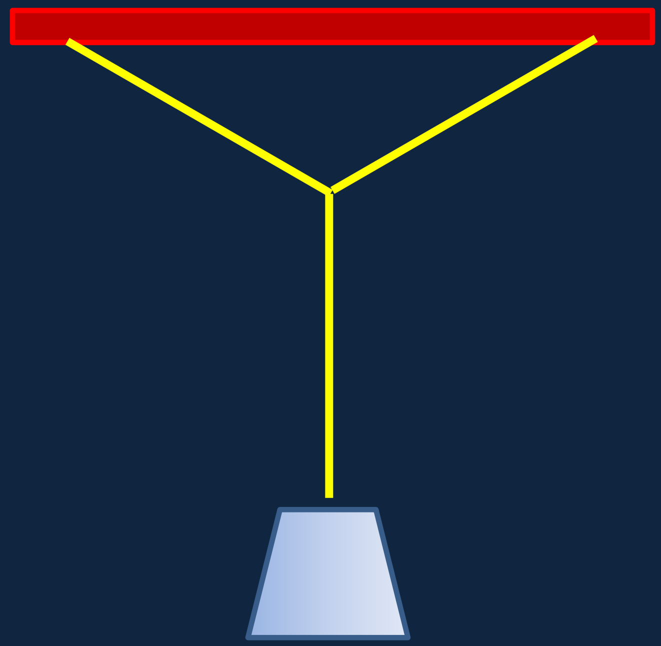
Clicker Question

- The strings shown are all at 120° to each other. For the vertical string, $T = Mg$. What is T in one of the sloping strings?

A. $Mg/2$

B. Mg

C. $Mg/\sqrt{3}$



Clicker Question Answer

- The strings shown are all at 120° to each other. For the vertical string, $T = Mg$. What is T in one of the sloping strings?

A. $Mg/2$

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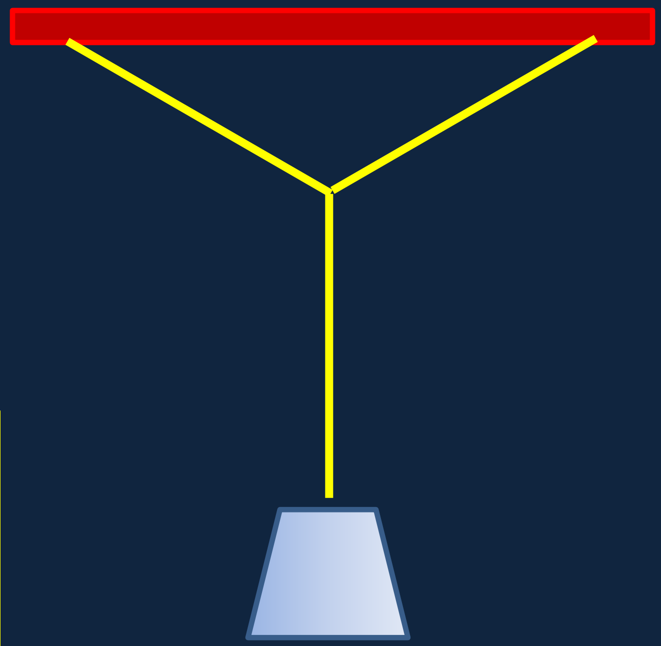
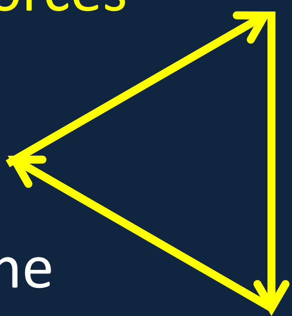


The knot where the strings meet isn't moving—so the three forces acting there add to zero.

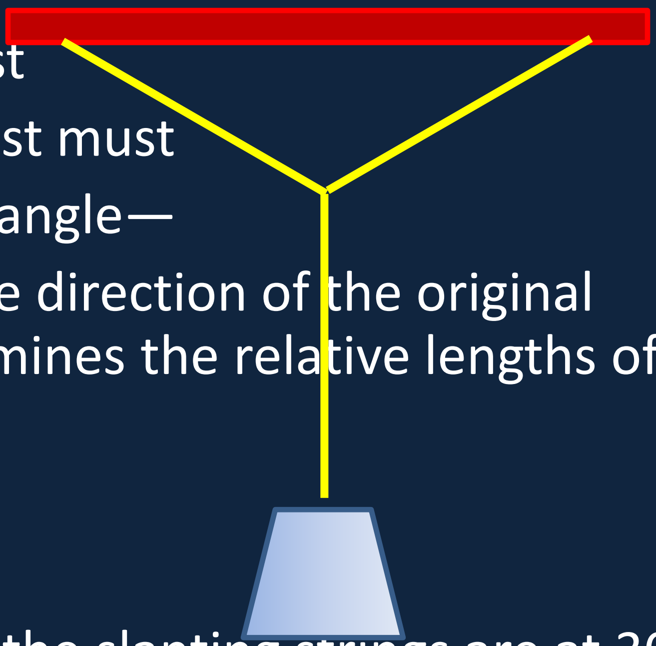


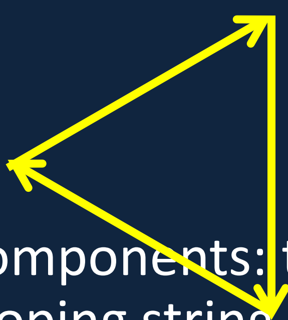
They form an equilateral triangle, so all forces have the same magnitude (you can also balance vertical components.)

Further Explanation…

The knot where the strings meet isn't moving—so the three forces acting there add to zero. If you add together three vectors, the sum is the vector going from the tail of the first vector to the head of the last one. If they add to zero, the head of the last must be at the tail of the first! So they form a triangle—

And the sides of this triangle must be in the direction of the original forces: drawing the angles right determines the relative lengths of the sides.

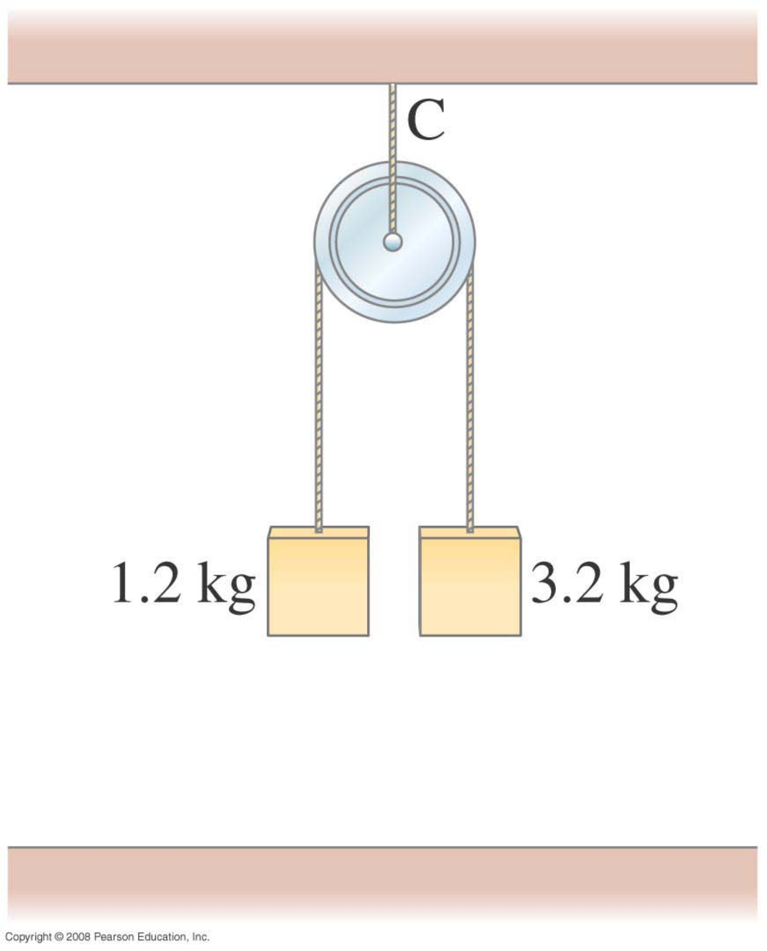




You can also balance vertical components: the slanting strings are at 30° to the horizontal, so the sloping string tension force has a vertical component equal to Tsin30 = T/2.

Problem from Book

- **54.** Suppose the pulley in Fig. 4–46 is suspended by a cord C. Determine the tension in this cord after the masses are released and before one hits the ground. Ignore the mass of the pulley and cords.



Problem from Book

- The tension in the top cord = 2T, where T is the tension in the lower cord, since the pulley isn't accelerating up or down.
- If the acceleration of the mass m = 1.2 is a upwards, the acceleration of M = 3.2 is a *downwards*, which we'll write as –a upwards.
- F = ma for the little mass is T – mg = ma,
- And for the big mass T – Mg = -Ma (this is the same equation I wrote in class, but I switched the sign of both sides to make it easier to use).
- Subtracting the two equations as written gives: (M – m)g = (M + m)a. This gives a, then T = mg + ma gives T, etc.