CTN-1.
Two forces labeled $\vec{F}_1$ and $\vec{F}_2$ act on the same object. $\vec{F}_1$ and $\vec{F}_2$ have the same magnitude $F$, but are at right angles to each other. What is the magnitude of the net force (total force) acting on the object?

A) $F$  
B) $2F$  
C) between $F$ and $2F$  
D) more than $2F$

Answer: between $F$ and $2F$. The vector sum has magnitude $= \sqrt{2} F \approx 1.41 F$.

CTN-2.
A glider is gliding along an air track at constant speed. There is no friction (assume that the air resistance is small enough to ignore).
What can you say about the net force (total force) on the glider?
A) The net force is zero.
B) The net force is non-zero and is in the direction of motion.
C) The net force is non-zero and is in the direction opposite the motion.
D) The net force is non-zero and is perpendicular to the motion.

$v = \text{constant}$

Answer: The net force is zero. Apply either Newton’s first or second law: since the velocity is constant, the acceleration is zero, and the net force is zero.
CTN-3.
An astronaut in intergalactic space is twirling a rock on a string. Suddenly the string breaks when the rock is at the point shown.

Which path (A, B, C, or D) does the rock follow after the string breaks?

Answer: Path C. After the string breaks, there are no forces acting on the rock, so the net force is zero. By Newton’s first law, if the net force is zero, the velocity must be constant.
CTN-4. An object is being lowered on a cord at a constant speed. Assume no air resistance. How does the magnitude of the tension $T$ in the cord compare to the magnitude of the weight $mg$ of the object?

A) $T = mg$
B) $T > mg$
C) $T < mg$

Answer: $T = mg$. By Newton’s first law, if the velocity is constant, the net force is zero, and if the net force is zero, the forces must exactly cancel.
An object is being lowered on a cord at a speed which is decreasing. There are only two forces on the object, the weight, magnitude mg, and the tension, magnitude T, in the cord. What is the direction of the acceleration?

A) up↑ B) down↓ C) a=0

Which equation is true:
A) \( T = mg \) B) \( T > mg \) C) \( T < mg \)

Free-body diagram

Answers: The direction of the acceleration is up. To see why, draw a \( v_1-\Delta v-V2 \) diagram. Since the acceleration is upward, the direction of the net is upward, and so we must have \( T > mg \).
CTN-6. A sailboat is being blown across the sea at a constant velocity. What is the direction of the net force on the boat?

A) Left ← B) Right → C) Net force is zero
D) Down ↓ E) Up ↑

Answer: The net force is zero. Since \( v = \text{constant} \), acceleration = 0, and so \( F_{\text{net}} = 0 \).
CTN-7.
A glider is on a tilted air track and is sliding downhill (NO FRICTION).

What is the direction of the net force on the glider?
D) None of these. Some other direction.

Answer: B  The direction of the net force is the same as the direction of the acceleration (by NII). The direction of the acceleration is down the hill, parallel to the track. To see this, draw a $v_1$-$v_2$-$\Delta V$ diagram.

Would the answer be different if the glider was moving uphill because it had recently been pushed uphill?
A) Yes, the net force would now be in a different direction than before.
B) No, the net force would be the same as before.

Answer: No. The net force is the same, regardless of the direction of the velocity.

CTN-8. What is the correct equation for this situation?

A) $T + mg = ma$
B) $T - mg = ma$
C) $T + mg = -ma$
D) $T - mg = -ma$
E) None of these

Answer: $T - mg = ma$. Remember: the symbol $g$ means the magnitude of the acceleration of gravity. $g$ is never negative: $g = +9.8 \text{ m/s}^2$
CTN-9. A glider is on a tilted air track (NO FRICTION) and it is moving uphill because it was given a brief shove in the recent past. What is the direction of the acceleration?

Answer: C, down the hill, parallel to the track.

TN-10. In a tilted xy coordinate system, the acceleration vector is along the x-axis. The coordinates are tilted at an angle $\theta$ as shown. What are $a_x$ and $a_y$, the x- and y-components of the vector $a$?

A) $a_x = -a$, \hspace{0.5cm} a_y = 0

B) $a_x = 0$, \hspace{0.5cm} a_y = +a

C) $a_x = +a$, \hspace{0.5cm} a_y = 0

D) $a_x = +a \sin \theta$, \hspace{0.5cm} a_y = -a \cos \theta

E) $a_x = +a \cos \theta$, \hspace{0.5cm} a_y = -a \sin \theta

Answer: $a_x = +a$, \hspace{0.5cm} a_y = 0
CTN-11. In a tilted $xy$ coordinate system, the weight vector $mg$ is straight down. The coordinates are tilted at an angle $\theta$ as shown. What is $W_y$, the $y$-component of the weight $mg$?
A) $+mg \sin\theta$

Answer: $-mg \cos\theta$
Consider the following 1D motion problems:

Situation I) A constant force is exerted for a short time interval on a frictionless cart that is initially at rest. The cart acquires a final velocity $v_f$. (1D Motion)

Situation II) The same constant force is exerted for the same short time interval on a frictionless cart that is initially moving at velocity $v_1$. The cart has a final velocity of $v_2$. The change in the speed of the cart $\Delta v = v_2 - v_1$, compared to the final speed in situation I, is...

A) the same, $\Delta v = v_f$.
B) greater, $\Delta v > v_f$.
C) less, $\Delta v < v_f$.
D) answer depends on the sign of $v_1$ and $v_2$.

Answer: the same, $\Delta v = v_f$. In both cases, $\Delta v = a \Delta t = (F/m) \Delta t$
Consider a person standing in an elevator that is moving upward at constant speed. The magnitude of the upward normal force, \( N \), exerted by the elevator floor on the person's feet is (larger than/same as/ smaller than) the magnitude of the downward weight, \( W \), of the person.

A) \( N > W \)  
B) \( N = W \)  
C) \( N < W \)

Now suppose the elevator is accelerating upward. How does the normal force compare to the weight of the person then?

A) \( N > W \)  
B) \( N = W \)  
C) \( N < W \)

Answer: \( N > W \)  
Since \( a = 0 \), we must have \( \text{Fnet} = 0 \).

Answer: \( N = W \)
A glider on a level air track is coasting along at constant velocity. Which of the following free-body diagrams correctly indicates all the forces on the glider? Assume that there is no air resistance or friction.

Answer: A  Notice that the net force must be zero, since the velocity is constant.

E) None of these
**CTN-15.** A moving van collides with a sports car in a high-speed head-on collision. Crash!

![Diagram of a moving van colliding with a sports car](image)

During the impact, the truck exerts a force $F_{\text{truck}}$ on the car and the car exerts a force $F_{\text{car}}$ on the truck. Which of the following statements about these forces is true?

A) The force exerted by the truck on the car is the same size as the force exerted by the car on the truck: $F_{\text{truck}} = F_{\text{car}}$

B) $F_{\text{truck}} > F_{\text{car}}$

C) $F_{\text{truck}} < F_{\text{car}}$

**Answer:** $F_{\text{truck}} = F_{\text{car}}$  By Newton’s 3rd Law.

**CTN-16.** A book sits on a table. Everything is at rest. The normal force from the table on the book is equal in magnitude to the weight of the book.

![Diagram of a book on a table](image)

$N =$ "normal" force

$W =$ mg

Are the normal force and the weight force members of an "action-reaction" pair from Newton's 3rd Law?

A) Yes  B) No  C) Impossible to answer

**Answer:** No. These two forces ($N$ and $W$) are acting on the same object, the book. In the action-reaction pair of forces from NIII, the forces act on different objects.
In the 1600's, Otto Van Güricke, a physicist in Magdeburg, fitted two hollow bronze hemispheres together and removed the air from the resulting sphere with a pump. Two eight-horse teams could not pull the hemispheres apart, even though the hemispheres fell apart when air was re-admitted. Suppose von Güricke had tied both teams of horses to one side and bolted the other side to a heavy tree trunk. In this case the tension in the rope would be...

A) twice  B) exactly the same as  C) half.

of what it was before.

Answer: twice  This one is tricky. The two eight-horse teams, one on each side, exert exactly the same force on the hemispheres as if there was just one 8-horse team on one side and the other side was tied to an immovable tree truck. (The two 8-horse teams were used merely for dramatic effect.)
CTN-18.
Skinny and Fatty are having a tug-of-war. So far, no one is winning.

Q1) What is the direction of the force of friction from the floor on Skinny's feet \( \vec{F}_S \)?
A) Right \( \rightarrow \)  
B) Left \( \leftarrow \)

Q2) How large is the force of friction on Skinny's feet \( \vec{F}_S \) compared to the force of friction \( \vec{F}_F \) on Fatty's feet?
A) \( F_S > F_F \)  
B) \( F_S = F_F \)  
C) \( F_S < F_F \)

Hint for Q2: The free-body diagrams for Skinny and Fatty looks like:

\[
\begin{align*}
\vec{F}_S & \quad \vec{F}_{\text{Rope on S}} & \vec{F}_{\text{Rope on F}} & \vec{F}_F \\
\leftarrow \rightarrow & \rightarrow \rightarrow & \leftarrow \rightarrow \\
\text{Skinny} & \quad \text{Fatty}
\end{align*}
\]

Answers: The direction of the force from the floor on Skinny’s feet is to the left. (The force from Skinny’s feet on the floor is to the right.) \( F_S = F_F \)

\[
\begin{align*}
F_S &= F_{\text{R on S}}, & F_F &= F_{\text{R on F}}, \\
F_{\text{R on S}} &= F_{\text{R on F}} \\
\end{align*}
\]

\[
F_S = F_F
\]
CTN-19.
An Atwood's machine is a pulley with two masses connected by a string as shown. The mass of object A, \( m_A \), is twice the mass of object B, \( m_B \). The tension \( T \) in the string on the left, above mass A, is...

\[
\text{A) } T = m_A g \\
\text{B) } T = m_B g \\
\text{C) Neither of these.}
\]

Answer: Neither of these. Both A and B are accelerating. A is accelerating down and B is accelerating up. So the net force on each is non-zero. The net force on A must be down and the net force on B must be up.

CTN-20.
A mass \( m \) is pulled along a frictionless table by constant force external force \( F_{\text{ext}} \) at some angle above the horizontal. The magnitudes of the forces on the free-body diagram have not been drawn carefully, but the directions of the forces are correct.

\[
\text{Which statement below must be true?} \\
\text{A) } N < mg \\
\text{B) } N > mg \\
\text{C) } N = mg
\]

Answer: \( N < mg \) Draw a FBD and note that the acceleration is to the right. The vertical component of \( F_{\text{ext}} \) is helping to hold up the weight of the mass, so \( N \) is smaller than \( mg \). In detail: Since \( a_y = 0 \), we must have \( \Sigma F_y = 0 \). Taking up as the +y direction, we have \( N + F_{\text{ext}} \sin \theta - mg = 0 \), \( N = mg - F_{\text{ext}} \sin \theta \).
CTN-21. In a tilted xy coordinate system, the weight vector \( mg \) is straight down. The coordinates are tilted at an angle \( \theta \) as shown. What is \( W_x \), the x-component of the weight \( mg \)?

A) \( +mg \sin \theta \)
B) \( -mg \cos \theta \)
C) \( -mg \sin \theta \)
D) \( +mg \)
E) 0

Answer: \( +mg \sin \theta \)
CTN-22. A mass $m$ is accelerates downward along a frictionless inclined plane. The magnitudes of the forces on the free-body diagram have not been drawn carefully, but the directions of the forces are correct.

Which statement below must be true?

A) $N < mg$
B) $N > mg$
C) $N = mg$

Answer: $N < mg$ Carefully draw a FBD and note that the acceleration is parallel to the track, down the incline.

A student chooses a tilted coordinate system as shown, and then proceeds to write down Newton’s 2nd Law in the form $\sum F_x = m a_x$, $\sum F_y = m a_y$. What is the correct equation for the y-direction $\sum F_y = m a_y$?

A) $N - mg \sin \theta = ma$
B) $N - mg \cos \theta = ma$
C) $mg \sin \theta = ma$
D) $N - mg \cos \theta = 0$
E) $N + mg = ma$

Answer: $N - mg \cos \theta = 0$ Notice that $N = mg \cos \theta$, and $\cos \theta < 1$ so $N < mg$
A mass $m$ is pulled along a rough table at constant velocity with an external force $F_{\text{ext}}$ at some angle above the horizontal. The magnitudes of the forces on the free-body diagram have not been drawn carefully, but the directions of the forces are correct.

Which statement below must be true?

A) $F_{\text{ext}} > F_{\text{fric}}$, $N > mg$.
B) $F_{\text{ext}} < F_{\text{fric}}$, $N < mg$.
C) $F_{\text{ext}} > F_{\text{fric}}$, $N < mg$.
D) $F_{\text{ext}} < F_{\text{fric}}$, $N > mg$.
E) None of these.

Answer: $F_{\text{ext}} > F_{\text{fric}}$, $N < mg$. Notice that the net force is zero.

What is the correct $y$-equation (given the choice of axes shown)?

A) $+N - mg \sin \theta = ma$
B) $+N - F_{\text{ext}} \sin \theta - mg = 0$
C) $+N - mg + F_{\text{ext}} \sin \theta = 0$
D) $+N - mg + F_{\text{ext}} \cos \theta = 0$

Answer: $+N - mg + F_{\text{ext}} \sin \theta = 0$
A mass $m$ is pulled along a frictionless table with a constant external force $F_{ext}$ at some angle above the horizontal. The magnitudes of the forces on the free-body diagram have not been drawn carefully, but the directions of the forces are correct.

The magnitude of the net force on the block is

A) $+N + F_{ext} + mg$

B) $+N + F_{ext} \sin \theta - mg$

C) $+N + F_{ext} \cos \theta - mg$

D) $+F_{ext} \cos \theta$

E) None of these.

Answer: $+F_{ext} \cos \theta$

What is the correct y-equation (given the choice of axes shown)?

A) $+N - mg \sin \theta = ma$

B) $+N - F_{ext} \sin \theta - mg = 0$

C) $+N - mg + F_{ext} \sin \theta = 0$

D) $+N - mg + F_{ext} \cos \theta = 0$

Answer: $+N - mg + F_{ext} \sin \theta = 0$
CTN-25. (Vector review)

The vector $\vec{B}$ is shown. Axes and positive direction have been chosen as shown. What is $B_x$?

A) $B_x = B \cos \theta$

B) $B_x = B \sin \theta$

C) Neither of these.

Answer: Neither of these. $B_x = -B \sin \theta$
CTN-26.
The graph shows velocity vs. time for a train moving along a straight track. The graph shows that the train is …
A) speeding up all the time.
B) slowing down all the time.
C) speeding up initially, but then slows down.
D) slowing down initially, but then speeds up.
E) is moving with constant speed.

Answer: speeding up all the time. The speed v is always increasing. Notice that this is a graph of v vs. t, NOT x vs. t

CTN-27.
We showed that \( a = g \sin \theta \) is the magnitude of the acceleration of a glider on an air track tilted at an angle \( \theta \). Using the coordinate system shown (the usual xy coordinates), what is \( a_y \), the y-component of the acceleration of the glider?

A) \(-g\)  
B) \(-g \sin \theta \cos \theta\)  
C) \(-g \tan \theta\)  
D) \(-g \sin^2 \theta\)  
E) None of these

Answer: \( a_y = -a \sin \theta = -g \sin^2 \theta \)