1. A crate of mass $m$ is being pulled by a cord up an incline at a constant speed $v$. What is the direction of the net force on the crate?
   A) Perpendicular to the incline, upward
   B) Parallel to the incline, up the incline
   C) Straight down
   D) Parallel to the incline, down the incline
   E) No direction, because the net force is zero.

   \[ \text{constant speed} \quad \text{straight path} \quad \Rightarrow \quad \text{constant velocity} \]
   \[ \vec{v} = \text{const} \Rightarrow \vec{a} = 0 \Rightarrow \vec{F}_{\text{net}} = 0 \]

2. An interplanetary space probe has an ion engine that produces a constant acceleration of magnitude 0.001g (where g = |acceleration of gravity| = 9.80 m/s²). To 3-place precision, how much does the probe’s speed change in 1 hour, if it starts from rest? Give the answer in km/hr (kilometers per hour). Warning: check your units.
   A) 35.3 km/hr   B) 0.0353 km/hr   C) 127 km/hr   D) 1.27 km/hr
   E) None of these

   \[ \Delta v = a \cdot \Delta t = 0.001 \cdot g \cdot \Delta t = 0.001 \left( 9.8 \frac{m}{s^2} \right) \cdot \frac{3600 \text{s}}{1 \text{hr}} \]
   \[ \Delta v = 3.37 \frac{\text{m}}{\text{s}} \times \frac{10^3 \text{m}}{1 \text{km}} \times \frac{3600 \text{s}}{1 \text{hr}} = 127 \text{ km/hr} \]

3. In a homework problem, a student chooses the tilted xy coordinate axes shown in the diagram. The vector $\vec{A}$, which lies in the xy plane, has magnitude $A$, and makes an angle $\theta$ with the +x direction, as shown. What is the correct expression for $A_y$, the y-component of the vector $\vec{A}$?
   A) $A \sin \theta$   B) $-A \cos \theta$   C) $-A \sin \theta$   D) $A \cos \theta$
   E) None of these
4. Two cars, labeled A and B, are traveling along a long straight road. The road runs east and west. East is chosen as the positive direction; west is the negative direction. Velocity vs. time for the two cars are shown in the graph. Consider the following statements:

During the time period shown in the graph, ..
I. both cars are moving East (in the positive direction).
II. both cars have increasing speed.
III. both cars have positive acceleration, that is, the direction of the acceleration for both cars is in the positive direction (East) for the entire time shown.

How many of the statements must be true given the information in the graph?
A) All are true    B) None are true    C) only one of the statements is true
D) only 2 of the statements are true.

5. An object is acted on by three forces, \( F_1 \), \( F_2 \), and \( F_3 \) (no other forces act). Only \( F_1 \) and \( F_2 \) are shown in the diagram. Also shown in the diagram is the net force. To the nearest 0.1 N, what is the magnitude of the third force \( F_3 \) acting on the object?
A) 4.0 N    B) 2.8 N    C) 5.0 N
D) 13.4 N    E) None of these

6. Two cars, labeled A and B, are moving in the same direction, along a straight road (X-Axis Avenue), in parallel lanes. Car A is moving with constant speed \( v_A \). Car B is moving with constant speed \( v_B \) which is faster than A, \( v_B > v_A \). At time \( t = 0 \), car A is at x-position \( D_A \) and car B is at x-position \( D_B \), where \( D_A > D_B \). (Both positions are measured relative to the same x=0 origin.) At what time \( t > 0 \), does the faster car pass the slower car?
A) Never    B) \( \frac{D_A - D_B}{v_B - v_A} \)    C) \( \frac{D_B - D_A}{v_B - v_A} \)    D) \( \frac{v_B - v_A}{D_B - D_A} \)    E) None of these

\[ x = x_o + v_o \cdot t \]
\[ x_A = D_A + v_A \cdot t \]
\[ x_B = D_B + v_B \cdot t \]
\[ D_A - D_B = (v_B - v_A) \cdot t \]
7. The four graphs below show possible curves of velocity vs. time for a rock moving vertically. Upward is chosen as the positive direction.

Which graphs correspond to the two situations described below?
- a rock in free fall after being thrown upward
- a rock in free fall after being thrown downward

A) thrown upward = graph I  thrown downward = graph IV
B) thrown upward = graph II  thrown downward = graph I
C) thrown upward = graph IV  thrown downward = graph I
D) thrown upward = graph I  thrown downward = graph II
E) thrown upward = graph IV  thrown downward = graph III

8. Two cars, labeled A and B, are on the same straight road, and pointed in the same direction. At t = 0, car A which is moving with constant speed \(v_A\), is passing an intersection at x = 0. At the same time t = 0, car B, is stopped at x = 0, but begins accelerating forward with acceleration of constant magnitude \(a_B\). When, if ever, does car B catch up with car A?

A) Never          B) \(\sqrt{\frac{2a_B}{v_A}}\)          C) \(\sqrt{\frac{2v_A}{a_B}}\)          D) \(\frac{2v_A}{a_B}\)          E) None of these

\[
\begin{align*}
X_A &= v_A \cdot t \\
X_B &= \frac{1}{2} a_B \cdot t^2
\end{align*}
\]

9. A particle moves in the xy plane with a velocity \(\vec{v} = (2t - 8)\hat{i} + (\frac{1}{2}t^2 - 18)\hat{j}\) where t is the time in seconds and units on the numbers are such that the velocity has units of m/s. What is the speed of the particle at the instant when it is moving parallel to the y-axis?

A) 2 m/s       B) 4 m/s       C) (10 m/s)       D) 16 m/s       E) None of these

"moving parallel to y-axis" means \(v_x = 0\)

\[
\begin{align*}
v_x &= 2t - 8 = 0 \Rightarrow t = 4 \text{ s} \\
\vec{v}(t = 4 \text{ s}) &= 0\hat{i} + (\frac{1}{2} \cdot 4^2 - 18)\hat{j} = -10\hat{j}
\end{align*}
\]

vers. A

\[
\text{speed} = |\vec{v}| = 10 \text{ m/s}
\]
10. A rocket in intergalactic space is initially moving with constant velocity \( \vec{v}_0 = 5 \text{ m/s} \hat{i} \). A thruster on the rocket fires, giving the rocket an acceleration of \( \vec{a} = 2 \text{ m/s}^2 \hat{j} \) for 3 seconds, and then the thruster shuts off. What is the final speed of the rocket (to the nearest 0.1 m/s)?

A) 5.0 m/s  B) 5.4 m/s  C) 11.0 m/s  D) 7.8 m/s  E) None of these.

\[
\Delta \vec{v} = \vec{a} \cdot \Delta t = 2 \text{ m/s}^2 \cdot 3 \text{ s} \hat{j} = 6 \text{ m/s} \hat{j}
\]

\[
\vec{v}_1 = 5 \hat{i}
\]

\[
\vec{v}_2 = \sqrt{5^2 + 6^2} = 7.8 \text{ m/s}
\]

11. A radio-controlled car races across a flat plain, with position vector given by

\[
\vec{r} = (2 \cdot t^2 - 5 \cdot t + 4) \hat{i} + (4 \cdot t) \hat{j}
\]

where \( t \) is the time in seconds and units on the numbers are such that the resulting position components are in meters. To 2-place precision, what is the speed of the car at \( t = 2.0 \text{ s} \)?

A) 5.0 m/s  B) 7.0 m/s  C) 4.2 m/s  D) 8.2 m/s  E) None of these

\[
\dot{\vec{r}} = \frac{d\vec{r}}{dt} = \left( 4t - 5 \right) \hat{i} + 4 \hat{j}
\]

\[
\left| \dot{\vec{r}} \right| = \sqrt{3^2 + 4^2} = 5
\]

12. A projectile is fired with initial speed \( v_0 \) at an angle \( \theta \) above the horizontal. Some time \( t \) later it lands on the level ground (same initial and final altitude). What is the correct expression for the time of flight \( t \)?

A) \( \frac{2v_0 g}{\sin \theta} \)  B) \( \frac{2v_0 \sin \theta}{g} \)  C) \( \frac{2v_0^2 \sin \theta \cos \theta}{g} \)

D) \( \frac{v_0}{2g \cos \theta} \)  E) None of these

\[
y = y_0 + v_{0y} t - \frac{1}{2} g t^2
\]

\[
o = v_{0y} \sin \theta - \frac{1}{2} g t
\]

\[
t = \frac{2v_0 \sin \theta}{g}
\]

vers. A
13. A box of mass $m$ is sitting on the floor of an elevator, which is accelerating upward with constant non-zero acceleration of magnitude $a$. The magnitude of the normal force exerted on the box by the floor is $N_{BF}$. The magnitude of the normal force exerted on the floor by the box is $N_{FB}$. What is the correct relationship between $N_{BF}$ and $N_{FB}$?

A) $N_{FB} = N_{BF} - mg$  
B) $N_{FB} = N_{BF} + ma$  
C) $N_{FB} = N_{BF} + mg$  
D) $N_{FB} = N_{BF}$  
E) $N_{FB} = ma + mg - N_{BF}$

$\text{Newton's 3rd Law}$

14. An object of mass $m$ sits on a bathroom scale which is on the floor of an elevator that is moving upward. The elevator is slowing down with a constant acceleration of magnitude $a$. The bathroom scale measures the magnitude $N$ of the normal force on the object from the surface of the scale. [The motion is such that the mass remains in contact with the scale during the acceleration.]

What is the correct expression for the magnitude of the acceleration of the object?

A) $N - mg$  
B) $\frac{N}{m}$  
C) $g - \frac{N}{m}$  
D) $\frac{N}{m} + g$  
E) None of these is correct.

$\sum F_y = ma$  
$mg - N = ma$  
$\Rightarrow a = g - \frac{N}{m}$

15. An astronaut on airless planet X drops a rock into a hole 4 meters deep and finds that the rock hits the bottom in 2.0 s. Then the astronaut drops a rock into a very deep hole and finds that it takes 8.0 s to hit the bottom of the hole. How deep is the very deep hole? HINT: This is planet X, where $g$ is not 9.8 m/s$^2$.

A) 7.5 m  
B) 16.0 m  
C) 17.5 m  
D) 36.0 m  
E) 64.0 m

$\frac{h_2}{h_1} = \frac{\frac{1}{2} \frac{g}{t_2^2}}{\frac{1}{2} \frac{g}{t_1^2}} = \left(\frac{t_2}{t_1}\right)^2 = \left(\frac{8 s}{2 s}\right)^2 = 4^2 = 16$

$h_2 = 16 \cdot h_1 = 16 \cdot 4 m = 64 m$
16. A superball is launched from the edge of a cliff at an angle $\theta$ above the horizontal with initial speed $v_0$. Assume no air resistance.

Suppose the initial velocity of the superball is changed so that the horizontal component is twice as big, but the vertical component is unchanged. Compared to the original time of flight, the time of flight with the new velocity is ..

A) longer. B) shorter C) the same. D) Not enough information is given to answer the question.

time of flight depends on y-motion

17. At $t = 0$, a superball is thrown straight up from the floor with an initial speed $v_0$. At time $t$ later, the ball is on the way down at a height $h$. Upward is chosen as the positive direction. (Assume no air resistance, no friction anywhere.) In order to solve for the time $t$ at which the ball is at height $h$, which equation must you solve?

A) $0 = h + v_0 t - \frac{1}{2} gt^2$ B) $0 = v_0 - gt$
C) $h = v_0 t - \frac{1}{2} gt^2$ D) $\frac{h}{t} = v_0 - gt$ E) None of these

\[ y = y_0 + v_{0y} t + \frac{1}{2} \alpha_y t^2 \]
\[ h = 0 + v_0 t - \frac{1}{2} g t^2 \]

18. An object of mass $m = 2$ kg is acted on by two forces: a force $\vec{F}_1 = (2 \hat{i} + 5 \hat{j})$ N and a second unknown force $\vec{F}_2$. The acceleration of the object is $\vec{a} = (4 \hat{i} + 5 \hat{j})$ m/s$^2$. To 2-place precision, what is $F_{2x}$, the $x$-component of the second force?

A) 1.0 N B) 5.0 N C) 15 N D) 6.0 N E) 10 N

\[ \vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 = m \vec{a} \Rightarrow \]

\[ F_{1x} + F_{2x} = m \alpha_x \]
\[ F_{2x} = m \alpha_x - F_{1x} \]
\[ F_{2x} = 2(4) - 2 = 6 \text{ N} \]

vers. A
19. Two carts are labeled A and B, and each cart is moving with constant acceleration. The velocities of each cart are measured at a start time $t_1$ and a finish time $t_2$. (Same start and finish time for both carts.) The magnitude and direction of the velocity of each cart is shown in the diagram at the two times. How do the magnitudes of the accelerations of the two carts compare?

\[ \begin{array}{c}
\text{2 m/s} & \text{3 m/s} & \text{4 m/s} & \text{1 m/s} \\
\text{A} & \text{A} & \text{B} & \text{B} \\
\text{t}_1 & \text{t}_2 & \text{t}_1 & \text{t}_2 \\
\text{start} & \text{finish} & \text{start} & \text{finish}
\end{array} \]

A) $a_A > a_B$  
B) $a_A < a_B$  
C) $a_A = a_B$  
D) Impossible to tell without more information

\[ \begin{align*}
\mathbf{A} : & \quad \mathbf{\Delta v} = \mathbf{v}_2 - \mathbf{v}_1 \\
\mathbf{B} : & \quad \mathbf{\Delta v} = \mathbf{v}_2 - \mathbf{v}_1
\end{align*} \]

\[ |\mathbf{\Delta v}| = 5 \quad \text{and} \quad |\mathbf{\Delta v}| = 3 \]

20. An object moves along the x-axis with the velocity shown in the graph. What is the magnitude of the displacement of the object $|x - x_o|$ between $t = 1 \text{ s}$ (when its velocity is $v = +2 \text{ m/s}$) and $t = 4 \text{ s}$ (when its velocity is $v = -1 \text{ m/s}$)?

A) 1.0 m  
B) 1.5 m  
C) 3.0 m  
D) 3.5 m  
E) None of these

\[ x = x_o + v_o t + \frac{1}{2} a t^2 \]

\[ (x - x_o) = (2 \frac{m}{s}) \left( 3 \text{ s} \right) + \frac{1}{2} \left( -1 \frac{m}{s^2} \right) \left( 3 \text{ s} \right)^2 = 6 - 4.5 = 1.5 \text{ m} \]

21. Four vectors, $\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$ and $\mathbf{D}$ are shown below. Which one of the following vector equations describes this diagram?

A) $\mathbf{A} + \mathbf{B} + \mathbf{C} + \mathbf{D} = 0$
B) $\mathbf{A} + \mathbf{B} + \mathbf{D} = \mathbf{C}$
C) $\mathbf{A} + \mathbf{B} = \mathbf{C} + \mathbf{D}$
D) $\mathbf{B} + \mathbf{D} = \mathbf{A} - \mathbf{C}$
E) None of these equations matches the diagram

vers. A
22. A train moves along a straight track and its velocity \( v \) vs. time is shown. Which graph below correctly depicts the train's acceleration vs. time?

(E) None of these is qualitatively correct.

23. The velocity of an object undergoing a constant acceleration is shown at two different times. The velocity at the early time is \( v_1 \), the velocity at the later time is \( v_2 \). What is the direction of the acceleration?

(E) None of these. Some other direction or acceleration is zero.

24. At a particular time, an object has the velocity and acceleration vectors with the directions shown in the figure. At this time, does this object have constant speed, increasing speed, or decreasing speed?

A) constant speed  B) increasing speed  C) decreasing speed
D) impossible to tell from the information given.

Like object in free-fall, \( \vec{a} \) has a component in direction of \( \vec{v} \).
25. A glider initially at the bottom of a tilted frictionless air track is given a brief initial shove so that it glides up the track and then glides back down to the bottom of the track. The coordinate system has been chosen as shown, with the positive direction pointed up the track, and the origin \((x = 0)\) located at the middle of the track, halfway between the starting point and the highest point of the glider.

Which graphs correctly show position \(x\) vs. time \(t\) and velocity \(v\) vs. time \(t\)?

A) \(x\) vs. \(t\) is graph 6; \(v\) vs. \(t\) is graph 5
B) \(x\) vs. \(t\) is graph 3; \(v\) vs. \(t\) is graph 1
C) \(x\) vs. \(t\) is graph 2; \(v\) vs. \(t\) is graph 4
D) \(x\) vs. \(t\) is graph 4; \(v\) vs. \(t\) is graph 1
E) \(x\) vs. \(t\) is graph 4; \(v\) vs. \(t\) is graph 5

vers. A