Circle the letter of the single best answer. Each question is worth 1 point

Physical Constants:

Earth's free-fall acceleration $= g = 9.80$ m/s^2

1. The position, x, of a certain particle is given by the equation:

$$x = a\cos(bt^2) + ct^3$$

where t is the time. The dimensions (L = length, T = time) of a, b and c are respectively:

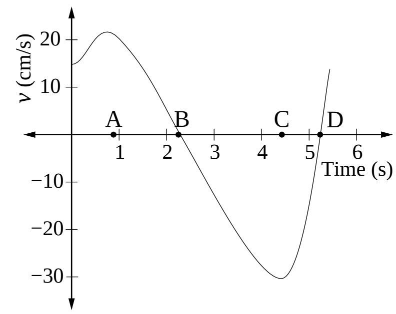
A. $L, \quad L/T^2, \quad T^3$
B. $L/T^2, \quad L/T^2, \quad L/T^3$
C. $L, \quad L\cdot T^2, \quad T^3$
D. $L, \quad 1/T^2, \quad L/T^3$

2. How many of the below numbers display exactly 3 significant digits?

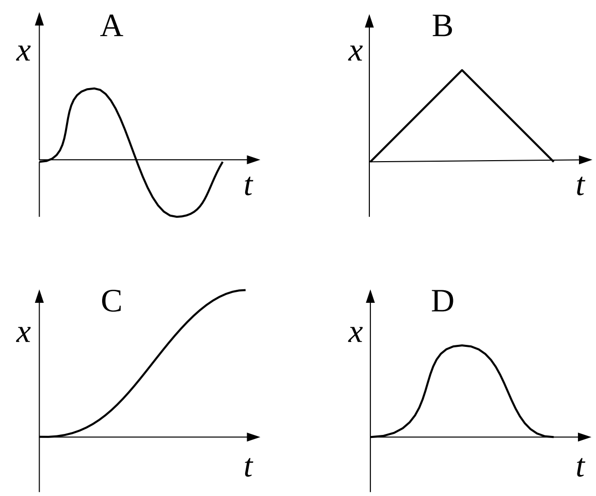
- 0.090
- 70.0
- 0.72
- 720
- 0.63×10^4
- 5.02
- 0.00742
- 0.720
- 7210
- 39.1×10^{14}

A. five
B. six
C. seven
D. none of the above

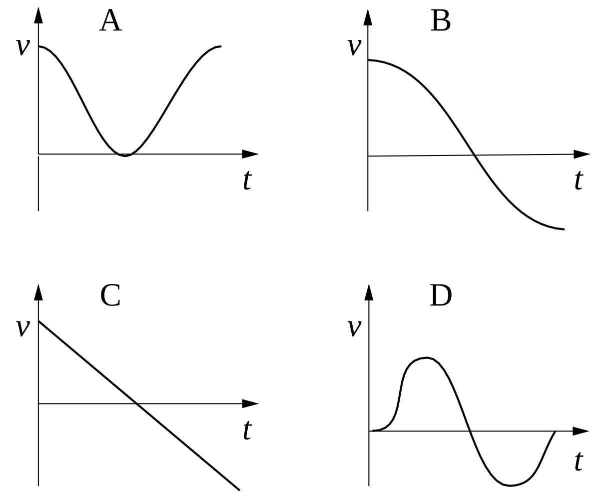
3. (Mark two letters!) The below graph displays the velocity, v, of an object as a function of time. Mark with an X the labeled time when the object has achieved its maximum x position. Circle the labeled time when the particle has the maximum acceleration. (Note: negative numbers are smaller than any positive number.)



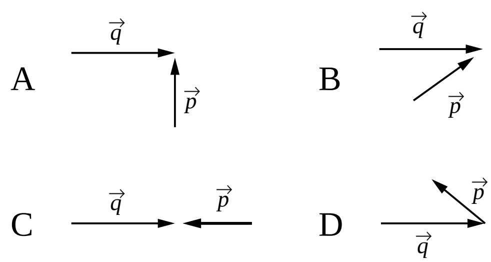
4. Starting from rest, a car accelerates down a straight road. A short time later the driver applies the brakes, and the car comes to a stop. Which of the below graphs of position vs. time best displays this motion?



5. A boy throws a stone straight up. Which of the below graphs best displays the velocity of the stone during its up-and-down flight?



6. The below displays the vectors $\vec{\mathbf{p}}$ and $\vec{\mathbf{q}}$ in various orientations. The vectors always have the same length, only the orientation is changing. Circle the case in which $|\vec{\mathbf{q}} + \vec{\mathbf{p}}|$ is the largest.

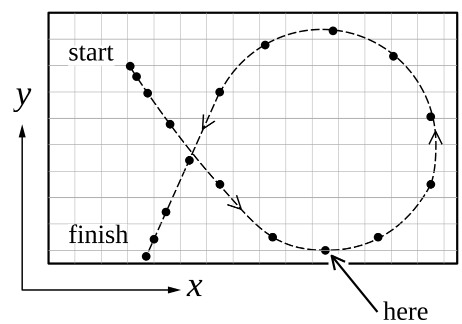


7. An ice dancer glides through a totally dark arena. A flashing strobe locates her at successive seconds (shown below as dots). Consider the following statements made about her motion at a particular time (marked "here" in the below diagram).

   I. Her x velocity, v_x, is constant.
   II. Her y velocity, v_y, is zero, but increasing.
   III. Her x acceleration, a_x, is zero
   IV. Her y acceleration, a_y, is zero

   Which statement(s) is(are) false?

   A. I
   B. II
   C. III
   D. IV
   E. More than one of the above
   F. None of the above.



8. Rupert escapes from a dorm by sliding down rope. As he slides down the rope faster and faster, he becomes frightened and grabs harder on the rope, increasing the tension in the rope. As soon as the upward tension in the rope becomes equal to his weight...

   A. Rupert will stop
   B. Rupert will slow down
   C. the rope will break
   D. none of the above

9. Romeo throws a pebble at Juliet's window. It bounces off; no harm done. Bluto throws a brick at Olive Oyl's window. It crashes through breaking the window.

   A. The pebble's force on the window is less than the window's force on the pebble, so no harm is done.

   B. The brick's force on the window is greater than the window's force on the brick, so the window breaks.

   C. Both of the above.

   D. None of the above.

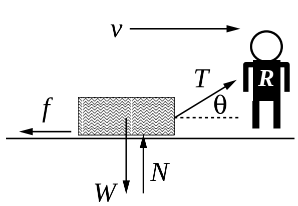
10. A crate rests in the middle of the floor in an otherwise empty van going west on I-94 at 70 mph. Suddenly a cute fawn jumps onto the road directly in front of the van; the driver hits the brakes and comes to a stop, missing the fawn. Throughout this process the crate remains at the same spot in the middle of the van's floor. During the braking...

    A. the net force on the crate points towards the front of the truck.

    B. the net force on the crate points towards the back of the truck.

    C. the net force on the crate is zero.

11. Rhonda pulls a box of mass m across a horizontal surface at a constant velocity v, by pulling on a rope with tension T at an angle θ. Other forces ($W = mg$: gravity, N: normal force, f: friction) also act in the directions indicated. Which of the following relations among the force magnitudes must be true?



    A. $T = f$ and $N = W$

    B. $T > f$ and $N > W$

    C. $T > f$ and $N = W$

    D. $T > f$ and $N < W$

12. Rhonda throws a steel ball straight up. Consider the motion of the ball only after it has left her hand but before it touches the ground and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):

    A. a downward force of gravity along with a steadily decreasing upward force.

    B. a steadily decreasing upward force from the moment the ball leaves Rhonda's hand until it reaches its highest point; on the way down there is a steadily increasing downward force.

    C. an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.

    D. a constant downward force of gravity only.

The following questions are worth 10 pts each

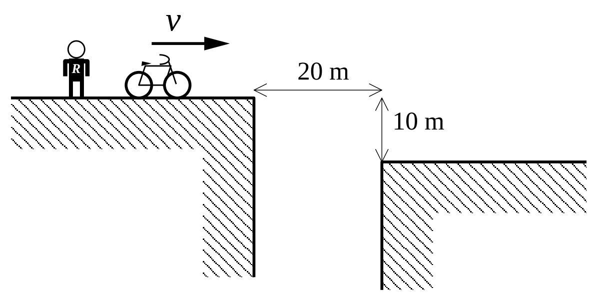
13. Consider a coordinate system in which the y direction points due north and the x direction points due east. The following vectors are given:

$$\begin{aligned}\vec{\mathbf{a}} &= 10 \text{ km } 30^\circ \text{ north of due east}\\ \vec{\mathbf{b}} &= 5 \text{ km } 10^\circ \text{ south of due west}\\ \vec{\mathbf{c}} &= 2 \text{ km due south}\end{aligned}$$

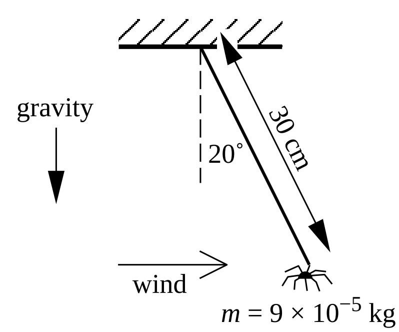
Sketch (approximately) each of the above vectors and display how all four arrows can be arranged to find $\vec{\mathbf{d}} = \vec{\mathbf{a}} + \vec{\mathbf{b}} - \vec{\mathbf{c}}$ graphically. Resolve the vectors into (x, y) components and calculate $\vec{\mathbf{a}} + \vec{\mathbf{b}} - \vec{\mathbf{c}}$ using the component forms. Express the resultant vector, $\vec{\mathbf{d}}$, in magnitude and direction form. (Display on your drawing the angle you are reporting.)

14. A long straight road in North Dakota stretches for 100 miles in a straight line with occasional stop signs. Starting from rest at a stop sign, you accelerate at 1 m/s^2 for 20 seconds, maintain your speed for the next 60 seconds, and then hit the brakes (de)accelerating at -4 m/s^2 until you are again stopped at a stop sign. Sketch a graph of your velocity vs. time. What distance separates the two stop signs? Convert your answer to miles where 1 mile = 1609 m.

15. In the movie *Godzilla vs. Terminator*, the Terminator — riding a bike at super human speed — is being chased by Godzilla. Tension builds as the pair approach a huge earthquake crack. Both crack rims are level but 20 m apart with a drop of 10 m. In the script the Terminator bike-sprints to the crack edge and just barely hits the far rim. In the real-world, stuntman Rupert decides that it would be wise to hire a physicist to calculate how fast he must be going horizontally on the bike to make the crack-jump. What is the slowest bike speed that would result in a safe landing on the far rim?



16. A spider of mass $m = 9 \times 10^{-5}$ kg hangs straight down on a 30 cm long thread she has just created. What is the tension in the thread? A steady breeze from the south pushes the hanging spider towards the north so that the thread makes an angle of 20° with the vertical. What is the tension in the thread now? Please draw a free body diagram for each situation!



17. A large slab ($M = 10$ kg) sits on frictionless surface. A block ($m = 1$ kg) rests on top of the slab. The surface between the slab and the block has a coefficient of static friction of $\mu_s = 0.4$ and a coefficient of kinetic friction $\mu_k = 0.3$. The block is pulled with a horizontal force T. If T is sufficiently small the block+slab will move together as one object; if T is larger, there will be slippage and the block will accelerate faster than the slab (and will eventually be pulled off the slab).

   A. Draw free body diagrams for each mass separately. Show and name all forces acting each mass. Show the direction of the acceleration (if there is any).

   B. *For each mass separately* and for both the x and y directions, write down the equations that follow from Newton's second law ($F_{\text{net}} = ma$).

   C. If $T = 15$ N, there will be slippage. Find the acceleration of each mass in this case.