Physical Constants:

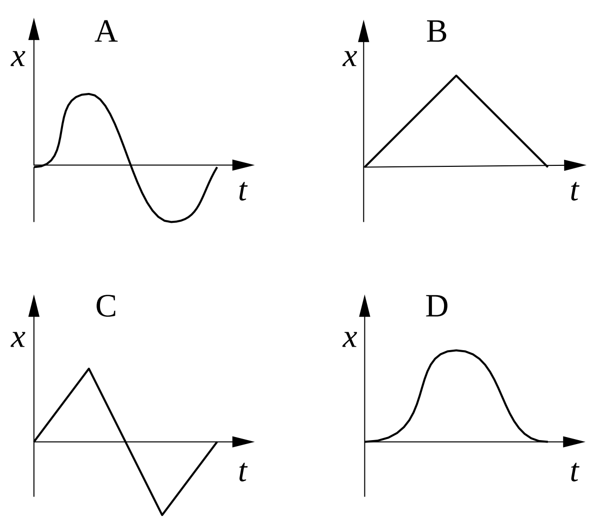
Earth's free-fall acceleration $= g = 9.80\ \text{m/s}^2$
Unless stated otherwise, circle the letter of the single best answer. Each answer is worth 2 points.

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

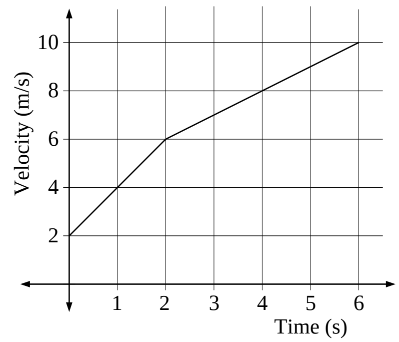
- 0.03
- 0.030
- 70.0
- 0.72
- 0.60×10^{24}
- 1230
- 0.007
- 0.720
- 721
- 3.912×10^{14}

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

2. Starting from rest, a car accelerates down a straight road. A short time later the driver, realizing he's left something behind, applies the brakes, comes to a stop and immediately puts the car in reverse and returns to the original spot and again stops. Which of the below graphs of position vs. time best displays this motion?

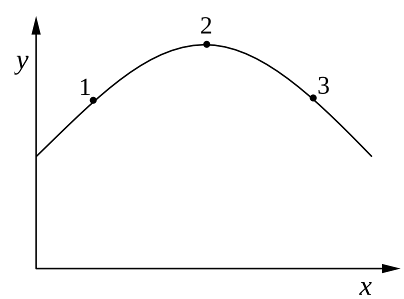


3. The below graph displays the velocity of an object moving along a straight line as a function of time. How far did the object travel between $t = 0$ s and $t = 6$ s?



A. 8 m
B. 10 m
C. 20 m
D. 40 m

4. The below displays the trajectory of a projectile moving only under the influence of gravity (i.e., no air resistance). Which of the below options best describes the acceleration, $\vec{a}$, at the three labeled points? (The acceleration at point 1 is denoted $\vec{a}_1$ and the magnitude of that vector is denoted $|\vec{a}_1|$, etc.)



A. $|\vec{a}_1| > |\vec{a}_2| > |\vec{a}_3|$
B. $|\vec{a}_1| < |\vec{a}_2| < |\vec{a}_3|$
C. $|\vec{a}_1| = |\vec{a}_2| = |\vec{a}_3|$
D. $|\vec{a}_2| = 0$ and $|\vec{a}_1| = |\vec{a}_3|$

5. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's 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):

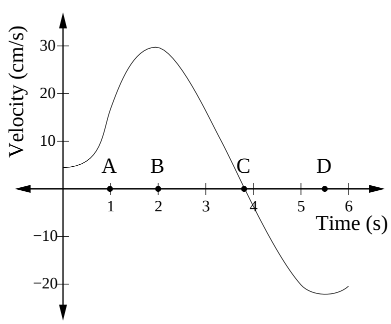
   A. a downward force of gravity along with a steadily decreasing upward force.

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

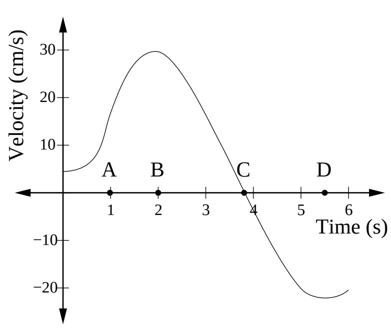
   C. an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.

   D. a constant downward force of gravity only.

6. The below graph displays the velocity, v, of an object as a function of time. Circle the labeled time when the particle has the maximum acceleration. (Note: negative numbers are smaller than any positive number.)



7. As in the previous problem, the below graph displays the velocity, v, of an object as a function of time. Circle the labeled time when the particle has the maximum position.



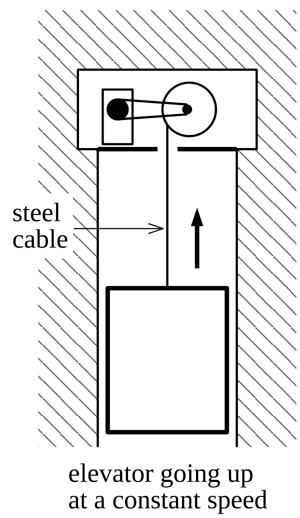
8. A 500 kg elevator is being lifted up an elevator shaft at constant speed by a steel cable as shown below. Assuming all frictional forces on the elevator are zero

   A. the upward force by the cable is larger than the downward force of gravity.

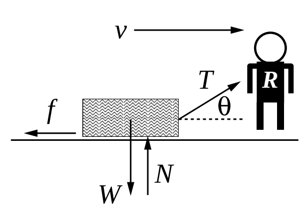
   B. the upward force by the cable is equal to the downward force of gravity.

   C. the upward force by the cable is smaller than the downward force of gravity.

   D. the elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable.



9. Rupert 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. The magnitude of the force of friction on the box is:



   A. $\mu_k mg$

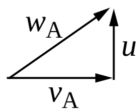
   B. $\mu T \cos\theta$

   C. $T \cos\theta$

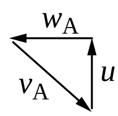
   D. none of the above

10. While the lunch trays are steadily moving down the conveyor belt in the refectory, an ant sitting on a tray decides to go for a final walk before things get very wet. Let $\vec{v}_A$ represent the velocity of the ant relative to the tray, and $\vec{u}$ represent the velocity of the tray as seen by a student standing near the conveyor belt. Which of the below figures properly shows the velocity $\vec{w}_A$ of the ant as seen by the standing student?

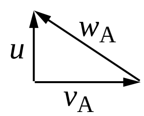
A



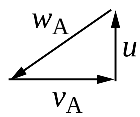
B



C



D



The following questions are worth 10 pts each

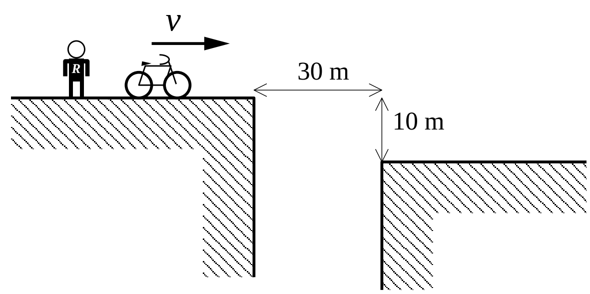
11. Consider a coordinate system in which the y direction points due north and the x direction points due east. The following vectors are given:

$$\begin{aligned} \vec{\mathbf{a}} &= 10 \text{ km } 30^\circ \text{ north of due west} \\ \vec{\mathbf{b}} &= 15 \text{ km } 10^\circ \text{ east of due north} \\ \vec{\mathbf{c}} &= 2 \text{ km due south} \end{aligned}$$

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 for $\vec{\mathbf{d}}$.)

12. You see your roommate 7 m directly below the open dorm window where you are standing. Being well prepared you have a snowball at hand. Taking careful aim, you throw the snowball directly down at a speed of 10 m/s. What is the speed of the snowball when it hits your roommate? How long does it take the snowball to reach the target?

13. 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 30 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?



14. 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 slab 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 slab will accelerate faster than the block (and the block will eventually fall off the back of 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 $T = 50$ N, there will be slippage. Find the acceleration of each mass in this case.