

Physics

Solutions to Sample Exam 2

1. a. ☐ b. ☐ c. ☒ d. ☐
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1. Problem

A runner completes a marathon (42.195 km) with an average pace of 7 minutes and 15 seconds per kilometre. What is the runner's time for the marathon? (Answers are formatted as hours : minutes : seconds)

- a. 07 : 13 : 24
- b. 06 : 17 : 30
- c. 05 : 05 : 55
- d. 06 : 30 : 02

Solution

First, calculate the speed in kilometres per second.

$$v = \frac{1 \text{ km}}{420 \text{ s} + 15 \text{ s}} = 0.002\,298\,9 \text{ km/s}$$

Then, calculate the time using the formula for constant velocity motion.

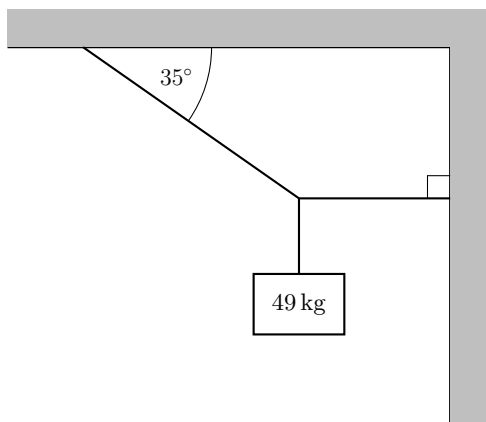
$$t = \frac{d}{v} = \frac{42.195 \text{ km}}{0.002\,298\,9 \text{ km/s}} = 18\,355 \text{ s}$$

Finally, convert the number of seconds into hours, minutes, and seconds. (60 s = 1 minute and 60 minutes = 1 hour)

$$18\,355 \text{ s} = 5 \text{ hours}, 5 \text{ minutes}, 55 \text{ seconds}$$

2. Problem

A box of mass 49 kg hangs down from three attached cords secured to the ceiling and wall as shown in the diagram. Find the maximum tension in any one of the three cords.



- a. 827 N
- b. 837 N
- c. 751 N
- d. 629 N

Solution

The vertical cord can only apply a vertical force and the horizontal cord can only apply a horizontal force. However, the angled cord must oppose both the vertical force and the horizontal forces from the other two cords. Therefore, the maximum tension is found in the angled cord.

Let T be the tension in the angled cord. The vertical component of this tension, T_y , must be equal to the weight of the box, mg .

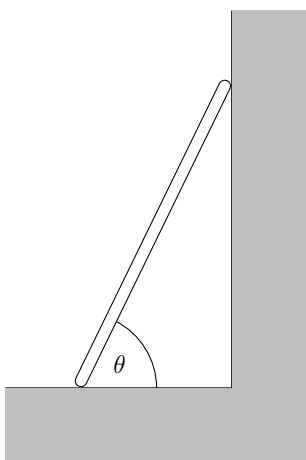
$$T_y = T \sin \theta = mg$$

Solving for T :

$$T = \frac{mg}{\sin \theta} = \frac{(49 \text{ kg})(9.8 \text{ N/kg})}{\sin(35^\circ)} = 837 \text{ N}$$

3. Problem

A uniform ladder of mass 5 kg and length 5 m leans against a frictionless wall. Let θ be the angle that the ladder makes with the ground. If the coefficient of static friction between the ladder and the ground is 0.25 , what is the minimum value of θ at which the ladder will not slip?



- a. 53°
- b. 63°
- c. 43°
- d. 33°

Solution

Let F_G be the force from the ground, F_f be the force of friction that the ground exerts on the bottom of the ladder, and $\mu = 0.25$ be the coefficient of static friction between the ladder and the ground.

The horizontal component of F_G comes from the friction between the ladder and the ground:

$$F_f = F_{G,x}$$

The vertical component of F_G is the normal force used to calculate the friction force. It is also the only force that balances the vertical gravitational force on the ladder:

$$F_f = \mu F_{\text{normal}} = \mu F_{G,y} = \mu mg$$

Therefore, combining the two equations, we have:

$$F_{G,x} = \mu mg$$

To find the values of $F_{G,y}$, we need to consider the net torque about the axis passing through the bottom of the ladder. Let the weight of the ladder be mg , the force from the wall be F_W , and the length of the ladder be d .

$$\tau_{\text{net}} = dF_W \sin \theta - \frac{d}{2}mg \cos \theta = 0$$

Solving for F_W , we get:

$$F_W = \frac{mg \cos \theta}{2 \sin \theta}$$

Notice that as θ decreases, F_W increases and the corresponding friction force has to increase as well to keep the ladder from slipping. Since the only horizontal forces are from the ground and the wall, we must have

$$F_W = F_{G,x} = \mu mg = \frac{mg \cos \theta}{2 \sin \theta}$$

Some algebra to rearrange the equation so that we can solve for θ :

$$\frac{1}{2\mu} = \frac{\sin \theta}{\cos \theta} = \tan \theta$$

$$\theta = \tan^{-1} \left(\frac{1}{2\mu} \right) = \tan^{-1} \left(\frac{1}{0.5} \right) = 63^\circ$$

4. Problem

A person weighing 552 N stands with one foot on each of two bathroom scales. Which statement is correct about this situation?

- a. None of the other statements are true.
- b. The sum of the two scale readings should be 552 N
- c. Each scale should read 552 N
- d. Each scale should read 276 N

Solution

Since the person is at rest, the net force on the person must be zero. The normal force on the person from the two scales must cancel out the person's weight. Therefore, the sum of the two scale readings should be equal to the person's weight.

5. Problem

A rocket moves through outer space with a constant velocity of 9.8 m/s toward the Andromeda galaxy. What is the net force acting on the rocket?

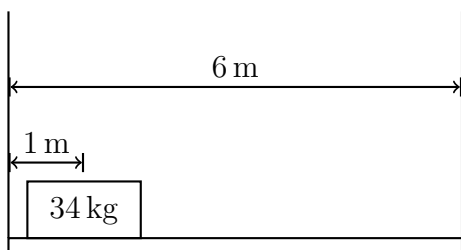
- a. A force equal to its weight on Earth, mg .
- b. A force equal to the gravity acting on it.
- c. The net force is zero.
- d. Cannot be determined without more information.

Solution

Since the rocket is moving with constant velocity, its acceleration is zero and the net force acting on the rocket must also be zero.

6. Problem

A scaffold of negligible mass is hanging horizontally from wires on each end. The scaffold is 6 m long. A 34 kg box sits 1 m from the left end. What is the tension in each wire?



- left tension = 167 N; right tension = 167 N
- left tension = 278 N; right tension = 55.5 N
- left tension = 28.4 N; right tension = 5.66 N
- left tension = 55.5 N; right tension = 278 N

Solution

The net force on the scaffold must be zero. Let T_1 be the tension in the left wire and T_2 be the tension in the right wire:

$$T_1 + T_2 - mg = 0$$

The net torque about the axis going through the point in the platform right below the centre of the box must also be zero. We choose this axis to eliminate the torque from the weight of the box. Let $d_1 = 1$ m and $d_2 = 5$ m:

$$T_1 d_1 - T_2 d_2 = 0$$

Solving the above system of linear equations by elimination or substitution gives:

$$T_1 = \left(\frac{d_2}{d_1 + d_2} \right) mg = \left(\frac{5}{6} \right) (34 \text{ kg})(9.8 \text{ N/kg}) = 278 \text{ N}$$

$$T_2 = \left(\frac{d_1}{d_1 + d_2} \right) mg = \left(\frac{1}{6} \right) (34 \text{ kg})(9.8 \text{ N/kg}) = 55.5 \text{ N}$$

7. Problem

A car traveling at speed v is able to stop in a distance d . Assuming the same constant acceleration, what distance does this car require to stop when it is traveling at speed $9v$?

- $9d$
- d
- $81d$
- $\sqrt{9}d$

Solution

Solve $v_f^2 = v_i^2 + 2ad$ for d and set $v_f = 0$ to get

$$d = -\frac{v_i^2}{2a}$$

Therefore, the braking distance is proportional to the square of the initial velocity. If the initial velocity is multiplied by 9, then the car would need 9^2 times the distance to stop.

8. Problem

True or false? It is possible to have zero acceleration and still be moving.

- a. True
- b. False

Solution

True. An object with a constant nonzero velocity has zero acceleration and is still moving.

9. Problem

A boy and a girl are balanced on a massless seesaw. The boy's mass is 47 kg and the girl's mass is 38 kg. If the boy is sitting 1.6 m from the pivot, how far from the pivot must the girl be sitting on the other side of the seesaw?

- a. 1.8 m
- b. 2.0 m
- c. 1.6 m
- d. 1.4 m

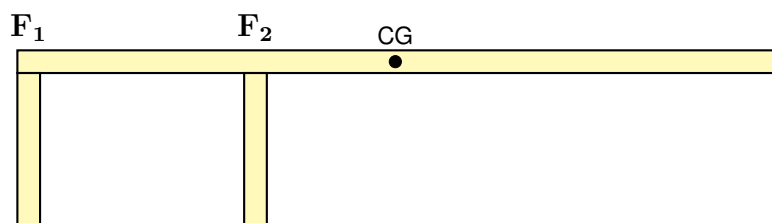
Solution

Since the torque on the seesaw is balanced, we must have $m_b d_b = m_g d_g$ where m_b is the mass of the boy, d_b is the distance of the boy from the pivot, and m_g and d_g are corresponding quantities for the girl. Solving for d_g gives:

$$d_g = \left(\frac{m_b}{m_g} \right) d_b = \left(\frac{47 \text{ kg}}{38 \text{ kg}} \right) 1.6 \text{ m} = 2 \text{ m}$$

10. Problem

A cantilever is held in static equilibrium by two vertical supports as shown in the figure. The beam is fastened to the supports with screws so that each support could apply an upward or downward force. The centre of gravity (CG) of the beam is to the right of the second support. In which direction must F_1 and F_2 point to keep the beam in static equilibrium?



- a. F_1 and F_2 both point upward
- b. F_1 and F_2 both point downward
- c. F_1 points upward while F_2 points downward
- d. F_1 points downward while F_2 points upward

Solution

The net force and the net torque (around any axis) on the beam must be zero in order for the beam to be in static equilibrium.

In order to oppose the downward force of gravity on the beam, the vector sum of F_1 and F_2 must point upward. Then, considering the torque about the centre of gravity of the beam, F_1 and F_2 must

point in opposite directions and F_2 must be greater than F_1 for the torques to cancel out (since F_2 is closer to the axis). Therefore, F_2 must point up and F_1 must point down.

11. Problem

The acceleration of gravity on the Moon is one-sixth of that on Earth. If you hit a baseball on the Moon with the same speed and angle that you would on Earth, the ball would land

- the same distance away
- one-sixth as far
- 6 times as far
- 36 times as far

Solution

The air time of the ball can be calculated from the formula $v_f = v_i + at$ with $v_f = -v_i$.

$$t = -\frac{2v_i}{a}$$

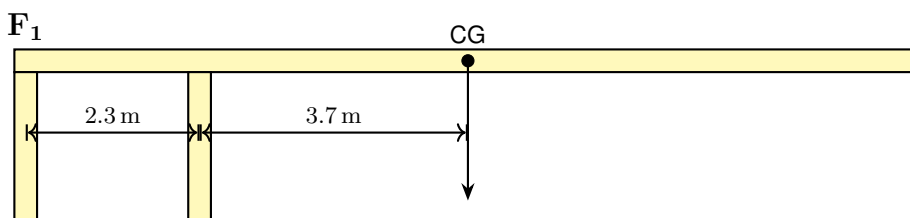
On Earth, the time is $t_{Earth} = -2v_i/g_{Earth}$. On the Moon, $g_{Moon} = g_{Earth}/6$ so

$$t_{Moon} = -\frac{2v_i}{g_{Earth}/6} = 6 \times \frac{-2v_i}{g_{Earth}} = 6t_{Earth}$$

The air time of the ball is 6 times greater on the Moon than on Earth. Since the horizontal velocity is the same, the ball will travel six times as far.

12. Problem

A cantilever beam is held in static equilibrium by two vertical supports separated by 2.3 m. The beam's mass is 65 kg and its centre of gravity (CG) is 3.7 m from the second support. What is the magnitude of the force applied by the first support, F_1 ?



- 600 N
- 1800 N
- 100 N
- 1000 N

Solution

The net force on the beam must be zero. Assuming that F_1 points down and F_2 points up:

$$-F_1 + F_2 - mg = 0$$

The net torque about the centre of gravity (CG) must be zero. Let $d_1 = 6$ m be the distance from the CG to the first support and $d_2 = 3.7$ m be the distance from the CG to the second support:

$$d_1 F_1 - d_2 F_2 = 0$$

Solving the above system of linear equations for F_1 (by substitution or elimination) gives:

$$F_1 = \left(\frac{d_2}{d_1 - d_2} \right) mg = \left(\frac{3.7}{6 - 3.7} \right) (65 \text{ kg})(9.8 \text{ N/kg}) = 1000 \text{ N}$$

13. Problem

Suppose an object travels at a constant velocity of 2.05 m/s . How much time would it take for the object to travel a distance of 71.1 m ?

- a. 0.03 s
- b. 15.3 s
- c. 146 s
- d. 34.7 s

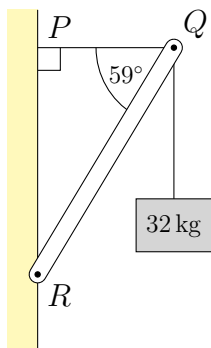
Solution

Use the formula for constant velocity motion.

$$t = \frac{d}{v} = \frac{71.1 \text{ m}}{2.05 \text{ m/s}} = 34.7 \text{ s}$$

14. Problem

A uniform beam QR , 1.0 m long with negligible mass, is mounted by a hinge on a wall and held in position by a horizontal wire PQ as shown in the figure. The beam supports a load of mass 32 kg hanging vertically down from point Q . What is the magnitude of the force on the hinge at point R ?



- a. 3180 N
- b. 3000 N
- c. 366 N
- d. 3200 N

Solution

Since the mass of the beam is negligible, only two forces apply a torque on the beam about the hinge point R : the tension in the horizontal wire, T_{PQ} , and the force from the hanging load, mg .

To calculate the torque from these two forces, we need to calculate the component of the force that is perpendicular to the beam. For the horizontal wire, this means multiplying by $\sin(59^\circ)$ while for the vertical wire, this means multiplying by $\cos(59^\circ)$.

The net torque must be zero since the beam is in static equilibrium. Let r be the length of the beam. Then, the equation for the net torque is:

$$\tau_{net} = rT_{PQ} \sin(59^\circ) - rm g \cos(59^\circ) = 0$$

The factors of r cancel out (so the length of 2.0 m was not needed). Solving for T_{PQ} , we get

$$T_{PQ} = \frac{mg \cos(\theta)}{\sin(\theta)}$$

To keep the beam in static equilibrium, the net force must also be zero. This means that the force on the hinge must be equal to the sum of the forces applied by the tension in the wire and the hanging mass. Since the two forces are perpendicular, we can use the Pythagorean theorem to calculate the magnitude of their sum.

$$F_{hinge} = \sqrt{(mg)^2 + (mg)^2 \frac{\cos^2(\theta)}{\sin^2(\theta)}} = mg \sqrt{1 + \frac{\cos^2(\theta)}{\sin^2(\theta)}} = mg \sqrt{\frac{\sin^2(\theta)}{\sin^2(\theta)} + \frac{\cos^2(\theta)}{\sin^2(\theta)}}$$

Using the Pythagorean identity ($\sin^2 \theta + \cos^2 \theta = 1$), we can simplify further:

$$F_{hinge} = mg \sqrt{\frac{\sin^2(\theta) + \cos^2(\theta)}{\sin^2(\theta)}} = mg \sqrt{\frac{1}{\sin^2(\theta)}} = \frac{mg}{\sin(\theta)}$$

Plugging in the numbers from the problem, we get:

$$F_{hinge} = \frac{(32 \text{ kg})(9.8 \text{ m/s}^2)}{\sin(59^\circ)} = 366 \text{ N}$$

15. Problem

What is the magnitude of the average velocity of a runner who completes one lap around an outdoor track (400 m) in 100 s?

- a. 0 m/s
- b. 0.25 m/s
- c. 4.0 m/s
- d. 4.0×10^4 m/s

Solution

The average velocity is a vector quantity defined as the total displacement divided by the time interval. Since the runner returns to their starting position after running one lap, the total displacement is zero and the average velocity is also zero.

16. Problem

An F1 car accelerates from 0 to 60 miles per hour in 2.1 s. What is the acceleration of the car in SI base units? (1 mile = 1609.34 m)

- a. 10.9 m/s^2
- b. 12.8 m/s^2
- c. 28.6 m/s^2
- d. 6.77 m/s^2

Solution

First, convert 60 mph to m/s.

$$60 \text{ mph} \times \frac{1609.34 \text{ m}}{1 \text{ mi}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 26.8223 \text{ m/s}$$

Then, divide by the time.

$$a = \frac{v_f - v_i}{t} = \frac{26.8223 \text{ m/s} - 0}{2.1 \text{ s}} = 12.8 \text{ m/s}^2$$

17. Problem

A 5 kg ball and a 10 kg ball are both dropped off a cliff at the same time. If air drag can be ignored, then the 10 kg ball falls

- a. 50 % faster than the 5 kg ball.
- b. with double the velocity of the 5 kg ball.
- c. with double the acceleration of the 5 kg ball.
- d. with the same acceleration as the 5 kg ball.

Solution

The acceleration due to gravity on the surface of the Earth does not depend on the object's mass. All objects in free fall move with the same acceleration if air drag can be ignored.

18. Problem

What is the maximum height reached by a ball thrown straight up with an initial velocity of 32.7 m/s? Assume that the ball is thrown on the surface of the Earth and that it undergoes constant acceleration due to gravity (ignore air resistance).

- a. 54.6 m
- b. 33.2 m
- c. 30.4 m
- d. 31.6 m

Solution

Use the formula $v_f^2 = v_i^2 + 2ad$ with $a = g = -9.8 \text{ m/s}^2$ and $v_f = 0$ (the velocity of the ball at its maximum height is zero). Solve for d :

$$d = \frac{-v_i}{2a} = \frac{-32.7 \text{ m/s}}{2(-9.8 \text{ m/s}^2)} = 54.6 \text{ m}$$

19. Problem

Can an object's velocity change direction when its acceleration is constant?

- a. No, because the object is always speeding up.
- b. No, because the object is always speeding up or slowing down, but it can never turn around.
- c. Yes, a rock thrown straight up is an example.
- d. Yes, a car that starts from rest, speeds up, slows to a stop, and then backs up is an example.

Solution

Yes, a rock thrown straight up is an example. The direction of the rock's velocity changes from up to down while its acceleration is always 9.8 m/s^2 down.

20. Problem

True or false? When you throw a ball to your friend, the ball's acceleration is zero when it reaches its maximum height.

- a. True
- b. False

Solution

False. The acceleration of the ball is always 9.8 m/s^2 down.

21. Problem

Which of the following is a scalar quantity?

- a. speed
- b. velocity
- c. displacement
- d. acceleration

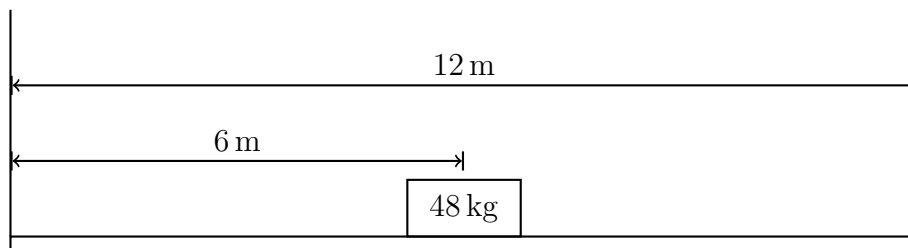
Solution

A scalar quantity is fully described by magnitude only. A vector quantity is fully described by both magnitude and direction. Distance, speed, and time are scalars. Acceleration, displacement, and velocity are vectors.

- a. scalar
- b. vector
- c. vector
- d. vector

22. Problem

A scaffold of negligible mass is hanging horizontally from wires on each end. The scaffold is 12 m long. A 48 kg box sits 6 m from the left end. What is the tension in the left wire?



- a. 14 300 N
- b. 235 N
- c. 105 000 N
- d. 199 N

Solution

To avoid needing to know the tension in the right wire, we can calculate the torque about the rotation axis going through the right side of the scaffold. Let T_1 be the tension in the left wire, $d_B = 6 \text{ m}$, and $d_L = 12 \text{ m}$. Then,

$$T_1 d_L = mg d_B$$

Solving for T_1 :

$$T_1 = \left(\frac{d_B}{d_L} \right) mg = \left(\frac{6}{12} \right) (48 \text{ kg})(9.8 \text{ N/kg}) = 235 \text{ N}$$

23. Problem

Ball 1 is dropped from the top of a building. One second later, ball 2 is dropped from the same building. If air resistance can be ignored, then as time progresses (and while the balls are still in free fall), the difference in their speeds

- a. increases.
- b. remains constant.
- c. decreases.
- d. cannot be determined from the given information.

Solution

Since both balls are accelerating at the same rate, the difference in their velocities will remain constant. Using the formula $v_f = v_i + at$, with $a = g$ and $v_i = 0$, we see that

$$\Delta v = v_1 - v_2 = gt_1 - gt_2 = g(t_1 - t_2)$$

and both $g = 9.8 \text{ m/s}^2$ and $(t_1 - t_2) = 1 \text{ s}$ remain constant.

Note that if air resistance is an important factor, then the difference would change until both balls are falling at their terminal velocity.

24. Problem

Suppose that several projectiles are launched. Which one will be in the air for the longest time?

- a. The one with the furthest horizontal range.
- b. The one with the greatest maximum height.
- c. The one with the greatest initial speed.
- d. None of the above.

Solution

Since horizontal and vertical motions can be analyzed separately, only the vertical motion matters for the longest air time. The projectile with the greatest maximum height will stay up in the air for the longest time.

25. Problem

What is stress?

- a. The strain per unit length.
- b. The applied force per cross-sectional area.
- c. The ratio of the change in length to the original length.
- d. The same as force.

Solution

Strain is the ratio of the change in length to the original length.

$$\text{strain} = \frac{\Delta L}{L_0}$$

26. Problem

Two displacement vectors have magnitudes of 5 m and 7 m, respectively. When these two vectors are added, the magnitude of the sum

- a. is larger than 12 m
- b. is 12 m
- c. is 2 m
- d. could be as small as 2 m, or as large as 12 m

Solution

If the two vectors point in the same direction, then the magnitude of their sum is 12 m. If the two vectors point in opposite directions, then the magnitude of their sum is 2 m. Otherwise the magnitude of their sum is somewhere between 2 m and 12 m

27. Problem

What is the magnitude of the slope of a position-time graph?

- a. displacement
- b. velocity
- c. rate
- d. speed

Solution

The magnitude of the slope of a position-time graph is the speed of the object.

28. Problem

A car travels 42 km at 33 km/h and 177 km at 108 km/h. What is the average speed for this trip?

- a. 83 km/h
- b. 75 km/h
- c. 89 km/h
- d. 47 km/h

Solution

The average speed is the total distance divided by the total time.

$$v_{avg} = \frac{d_{total}}{t_{total}} = \frac{d_1 + d_2}{d_1/v_1 + d_2/v_2} = \frac{42 \text{ km} + 177 \text{ km}}{\frac{42 \text{ km}}{33 \text{ km/h}} + \frac{177 \text{ km}}{108 \text{ km/h}}} = 75 \text{ km/h}$$

29. Problem

Which of the following are vectors? *Select all that apply.*

- a. speed
- b. acceleration
- c. distance
- d. velocity

Solution

A scalar quantity is fully described by magnitude only. A vector quantity is fully described by both magnitude and direction. Distance, speed, and time are scalars. Acceleration, displacement, and velocity are vectors.

- a. scalar
- b. vector
- c. scalar
- d. vector

30. Problem

True or false? When a ball is thrown straight up, its velocity at the top is zero.

- a. True
- b. False

Solution

True. The velocity must be zero for an instant at the top as the velocity changes from up to down.

31. Problem

Identify the following quantity as being either a scalar or a vector: 28°C

- a. scalar
- b. vector
- c. both scalar and vector
- d. neither scalar nor vector

Solution

A scalar has only magnitude (a number with units). A vector has both magnitude and direction.

32. Problem

An object is released from rest and falls straight down without friction. Which of the following is true concerning its motion?

- a. Its acceleration is constant.
- b. Its velocity is constant.
- c. Neither its acceleration nor its velocity is constant.
- d. Both its acceleration and its velocity are constant.

Solution

Only acceleration is constant for an object in free fall.

33. Problem

Two balls are thrown from the top of a building. One is thrown straight up while the other is thrown straight down, both with same initial speed. If air resistance can be ignored, how do their speeds compare when they hit the ground?

- a. The ball thrown up is going faster.
- b. The ball thrown down is going faster.
- c. Both balls are going the same speed.
- d. It is impossible to determine with the given information.

Solution

The ball thrown straight up will have the same speed when it returns to the initial height. Therefore, both balls will be going the same speed when they hit the ground. (The ball thrown downward would hit the ground first because it did not travel the path up and back to the initial height. However, both balls still hit the ground with the same speed.)

34. Problem

Which of the following is a vector quantity?

- a. acceleration
- b. speed
- c. distance
- d. time

Solution

A scalar quantity is fully described by magnitude only. A vector quantity is fully described by both magnitude and direction. Distance, speed, and time are scalars. Acceleration, displacement, and velocity are vectors.

- a. vector
- b. scalar
- c. scalar
- d. scalar

35. Problem

An object is moving to the left and speeding up. Which choice best describes its velocity and acceleration? (Assume right is positive.)

- a. velocity is positive; acceleration is negative.
- b. velocity is negative; acceleration is positive.
- c. velocity and acceleration are both positive.
- d. velocity and acceleration are both negative.

Solution

Velocity is positive if the object is moving to the right.

Velocity is negative if the object is moving to the left.

Acceleration is positive if the object is moving to the right and speeding up or moving to the left and slowing down.

Acceleration is negative if the object is moving to the right and slowing down or moving to the left and speeding up.

36. Problem

Consider a ball that is thrown upwards and which then falls back down. If up is the positive direction, then the ball's acceleration

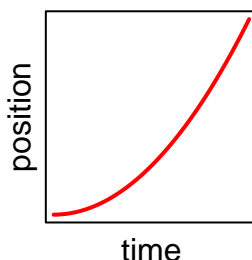
- a. is always positive.
- b. is always negative.
- c. starts positive, then becomes negative.
- d. starts negative, then becomes positive.

Solution

The acceleration due to gravity is always downwards, which is the negative direction.

37. Problem

Which choice best matches the given position-time graph? Assume that position is increasing to the right.



- a. moving to the right and speeding up.
- b. moving to the right and slowing down.
- c. moving to the left and speeding up.
- d. moving to the left and slowing down.

Solution

The object is moving to the right if its position is increasing and moving to the left if its position is decreasing. The object is speeding up if the tangent line is becoming more vertical and slowing down if the tangent line is becoming more horizontal.

This graph describes an object that is moving to the right and speeding up.

38. Problem

A scalar quantity is fully described by

- a. magnitude alone
- b. direction alone
- c. both magnitude and direction
- d. none of these

Solution

A scalar quantity is fully described by magnitude alone.

39. Problem

A ball is thrown straight up, reaches a maximum height, then falls back down to its initial height. Which of the following is true while the ball is going up?

- a. Its velocity and acceleration both point up.
- b. Its velocity and acceleration both point down.
- c. Its velocity points up while its acceleration points down.
- d. Its velocity points down while its acceleration points up.

Solution

The velocity points up while the ball is going up. The acceleration always points down.

40. Problem

A heavy child and a lightweight child are balanced on a massless seesaw. If both children move forward so that they are at half of their original distance from the pivot, what will happen to the seesaw?

- a. The side the heavy child is sitting on will tilt downward.
- b. The seesaw will still be balanced.
- c. It is impossible to determine without knowing the masses and distances.
- d. The side the lightweight child is sitting on will tilt downward.

Solution

Since the seesaw is initially balanced, we must have

$$\tau_{net} = m_1 d_1 - m_2 d_2 = 0$$

Halving both distances will result in

$$\tau_{net} = m_1 (d_1/2) - m_2 (d_2/2) = \frac{1}{2}(m_1 d_1 - m_2 d_2) = \frac{1}{2}(0) = 0$$

Therefore, the seesaw will remain balanced.

41. Problem

How many seconds would it take the Sun's light to reach Earth? The speed of light in vacuum is 3.00×10^8 m/s. The Sun is 1.5×10^{11} m from the Earth.

- a. 0 s
- b. 2.0×10^{-3} s
- c. 5.0×10^2 s
- d. 4.5×10^{19} s

Solution

Use the formula for constant velocity motion.

$$t = \frac{d}{v} = \frac{1.5 \times 10^{11} \text{ m}}{3 \times 10^8 \text{ m/s}} = 5.0 \times 10^2 \text{ s}$$

42. Problem

A runner completes a marathon (42.195 km) in 5 hours, 1 minutes, and 51 seconds. What is the runner's average speed for the marathon in m/s?

- a. 2.1 m/s
- b. 3.62 m/s
- c. 2.33 m/s
- d. 0.73 m/s

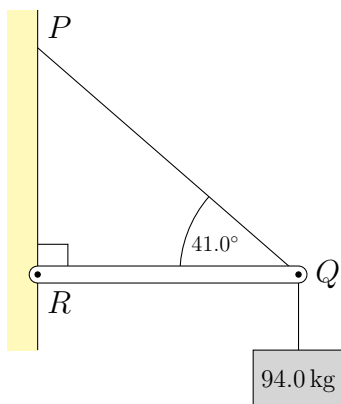
Solution

The average speed is the total distance divided by the total time.

$$\begin{aligned}d &= (42.195 \text{ km})(1000 \text{ m/km}) = 42\,195 \text{ m} \\t &= (5 \text{ h} \times 3600 \text{ s/h}) + (1 \text{ min} \times 60 \text{ s/min}) + 51 \text{ s} = 18\,111 \text{ s} \\v &= \frac{d}{t} = \frac{42\,195 \text{ m}}{18\,111 \text{ s}} = 2.33 \text{ m/s}\end{aligned}$$

43. Problem

A 3.0 m long uniform beam of mass 5.00 kg, QR , is mounted by a hinge on a wall and held in a horizontal position by wire PQ , forming a 41.0° angle at point Q as shown in the figure. A load of mass 94.0 kg hangs vertically down from point Q . What is the magnitude of the tension in wire PQ ?



- a. 144 N
- b. 2880 N
- c. 167 N
- d. 1440 N

Solution

The net torque about the hinge point R must be zero because the beam is in static equilibrium. The weight of the beam, the tension in the wire, and the hanging load each apply a torque to the beam. The force of gravity on a uniform beam can be modeled as a force, $F_g = mg$, acting on the centre of the beam. Let l be the length of the beam, θ be the angle at point Q , T be the tension in wire, m be the mass of the beam, and M be the mass of the hanging load.

$$\tau_{net} = lT \sin(\theta) - \frac{lmg}{2} - lMg = 0$$

Solving for T , we get

$$T = \frac{g}{\sin(\theta)} \left(\frac{m}{2} + M \right) = \frac{9.80 \text{ N/kg}}{\sin(41.0^\circ)} \left(\frac{5.00 \text{ kg}}{2} + 94.0 \text{ kg} \right) = 1440 \text{ N}$$

44. Problem

A book weighs 8 N at the surface of the Earth. When held at rest on top of your head, the net force on the book is

- a. 0 N
- b. 8 N
- c. -8 N
- d. 9.8 N

Solution

Since the book is at rest, its acceleration is zero and the net force acting on it must be zero.

45. Problem

Two scales are separated by 6.0 m, and a plank of mass 4.0 kg is placed between them. Each scale is observed to read 2.0 kg. A rock is placed somewhere on the plank, after which the left scale reads 50.0 kg and the right scale reads 80.0 kg. How far from the left scale was the rock placed?

- a. 5.2 m
- b. 3.7 m
- c. 5.3 m
- d. 4.6 m

Solution

The first condition for static equilibrium is that the net force on the plank must be zero. This implies that the mass of the rock is the sum of the two scale readings minus the plank's mass:

$$m_{\text{rock}} = 50 \text{ kg} + 80 \text{ kg} - 4 \text{ kg} = 126 \text{ kg}$$

The second condition for static equilibrium is that the net torque on the plank must be zero. You can choose any axis to calculate the torque. Let's arbitrarily choose the left scale as the pivot. Also, let s be the separation between the two scales and x be the distance of the rock from the left scale. Then,

$$\frac{s}{2} m_{\text{plank}} + x m_{\text{rock}} - s m_{\text{right}} = 0$$

Solving for x , we get:

$$x = \frac{s}{m_{\text{rock}}} \left(m_{\text{right}} - \frac{m_{\text{plank}}}{2} \right) = \frac{6 \text{ m}}{126 \text{ kg}} \left(80 \text{ kg} - \frac{4 \text{ kg}}{2} \right) = 3.7 \text{ m}$$