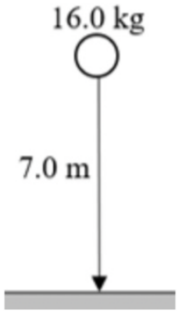
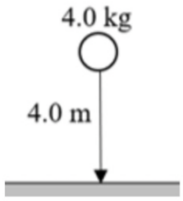
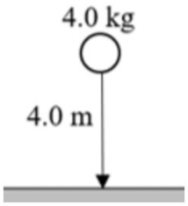
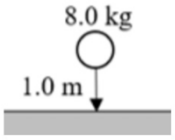
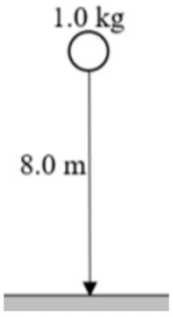
1. Four objects of different masses are dropped from rest from the heights shown below. Air resistance is negligible. Which object will have the largest average speed during its motion?

a. 

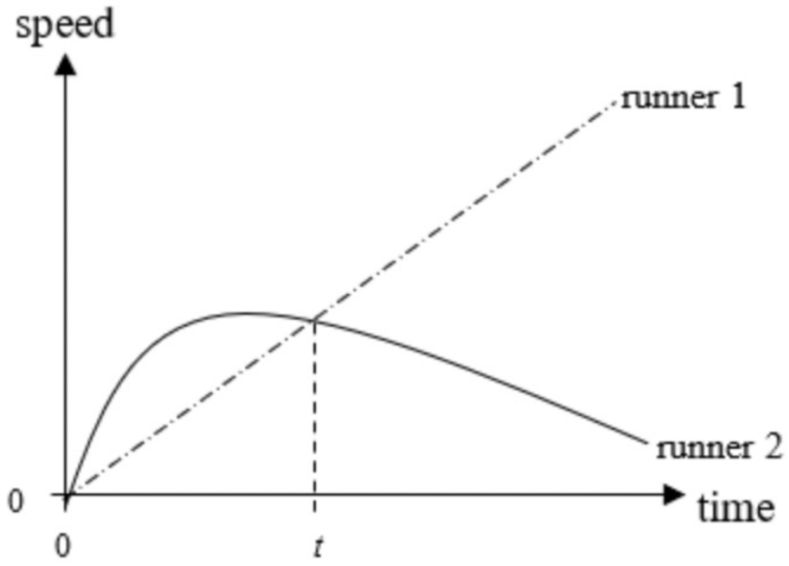

b. 


c. 


d. 


e. 

2. Two runners take part in a marathon. The graph below shows how the speed of each runner changes with time.




Which of the following statements are true at time t?

(i) Runner 1 just overtakes runner 2.
(ii) Both runners are at the same speed.
(iii) Runner 1 runs with zero acceleration.
(iv) Runner 2 is ahead of runner 1.

a. (ii), (iii), and (iv)
b. (ii) and (iv)
c. (i) and (iii)
d. (i) only

3. A truck is moving at a speed of 40 km/h and a car is moving at a speed of 60 km/h. If the truck's kinetic energy is 1.5 times that of the car's, what is the ratio of the truck's mass to the car's mass.

   a. 9:1
   b. 9:8
   c. 9:2
   d. 9:4

4. The area under an object's acceleration versus time graph over a fixed time interval is found to be 10m/s. Which of the following must be true?

   a. The object's change in velocity during the time interval is 10 m/s.
   b. The object's velocity at the end of the time interval is 10 m/s.
   c. The object's average speed during the time interval is 10 m/s.
   d. The object's average velocity during the time interval is 10 m/s.

5. An object moves in a vertical circle, starting at the bottom, with an initial speed of 4.0 m/s. Its speed increases uniformly until it has moved clockwise through an angle of 50 degrees. The average acceleration for this motion is 2.5 $m/s^2$ directed straight upwards. What is the time taken for this motion?

   a. 0.652 s
   b. 0.889 s
   c. 1.91 s
   d. 1.23 s

6. In the year 2050, humans start to live on Mars. In order to launch a satellite of mass 3000 kg from Mars, a space agency plans to use a space gun. The satellite is accelerated uniformly along a vertical tube from rest to 9000 m/s in 0.4 s. What is the applied launch force required to accelerate the satellite, assuming the satellite is launched vertically upwards? ($g = 4\ m/s^2$)

   a. 67512 kN
   b. 67500 kN
   c. 67488 kN
   d. 67530 kN

7. A 70 kg man stands on a scale in an elevator. The elevator accelerates at 3 $m/s^2$ downwards and eventually descends at a constant speed. What does the scale read when the elevator is travelling at the constant speed?

   a. 91 kg
   b. 49 kg
   c. 70 kg
   d. 0 kg

8. Three identical boxes of 5 kg mass each are pulled by three taut ropes along a surface of negligible friction as shown in the figure below. What is the common acceleration $a$ of the boxes and the tension T1 and T2 in the ropes indicated?


   a. $a = 4\ m/s^2; T_1 = 30\ N, T_2 = 0\ N$
   b. $a = 2\ m/s^2; T_1 = 10\ N, T_2 = 20\ N$
   c. $a = 2\ m/s^2; T_1 = 30\ N, T_2 = 30\ N$
   d. $a = 6\ m/s^2; T_1 = 30\ N, T_2 = 0\ N$

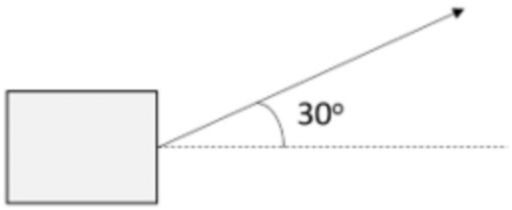
9. A ball of mass 1.5 kg falls straight down and hits the ground with a speed of 1.2 m/s. It rebounds straight up with a speed of 0.5 m/s. If the magnitude of the average force exerted by the ground on the ball while they are in contact is 30.0 N, what is the duration for which the ball and the ground are in contact?

    a. 0.0085 s
    b. 0.0350 s
    c. 0.0697 s
    d. 0.0167 s

10. A negatively charged particle is moved along a horizontal line to the right from position $x = -6.0\ m$ to $x = -3.0\ m$ by an external agent at constant speed. The electric potential at these positions in space are $V(x = -6.0\ m) = -4.0\ V$ and $V(x = -3.0\ m) = -2.0\ V$. Which statement is true about the work done by the external agent in moving the charge between these positions and the electric field component parallel to the direction of motion that the moving charged particle experiences?

    a. The external agent does positive work and the electric field is directed to the right.
    b. The external agent does positive work and the electric field is directed to the left.
    c. The external agent does negative work and the electric field is directed to the right.
    d. The external agent does negative work and the electric field is directed to the left.

11. A 50 kg block is dragged across the floor at a horizontal acceleration of 2 $m/s^2$ by pulling a rope with tension T at an angle of 30 degrees above the horizontal. What is the magnitude of the frictional force R acting on the block by the floor?




a. 283 N
b. 950 N
c. 750 N
d. 183 N

12. A wheel with an initial angular velocity of 5 rad/s is subjected to a constant angular acceleration of $4\,rad/s^2$. What is the time taken for it to complete 2 revolutions?

a. 0.9 s
b. 4.1 s
c. 1.6 s
d. 2.5 s

13. A geostationary satellite orbits at the same angular. velocity as Earth at height H above the surface of the Earth. A man standing on the surface of the Earth, at a distance R from the centre of the Earth, experiences a tangential velocity of U due to Earth's rotation. What is the tangential velocity V of the satellite from the centre of the Earth?

a. $URH$
b. $UR(R+H)$
c. $\frac{U(R+H)}{R}$
d. $\frac{UH}{R}$

14. A solid cylinder of mass 4kg and radius 2m is rolling without slipping on a horizontal surface with a speed of 10 m/s. What is the rotational kinetic energy of the cylinder? (The moment of inertial of a cylinder is $I = \frac{1}{2}mr^2$).

a. 400 J
b. 200 J
c. 100 J
d. 1600 J

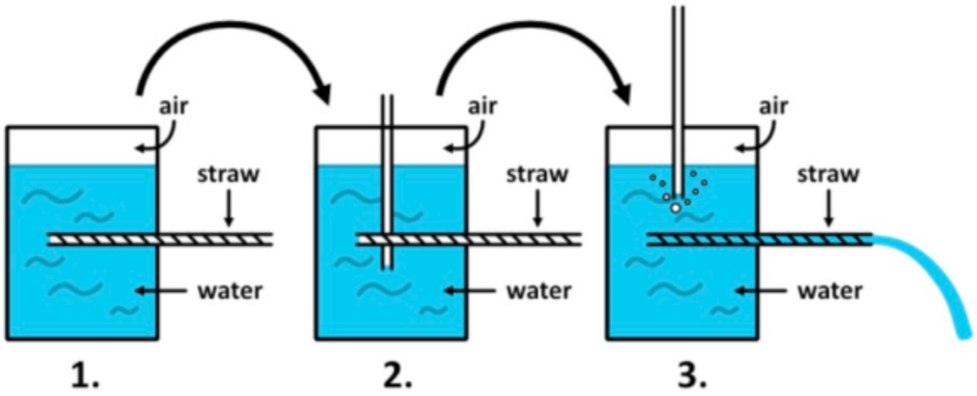
15. A child is riding a free-spinning merry-go-round at the playground. He then moves towards the centre of the merry-go-round. What happens to the merry-go-round (with him as part of the system) due to his motion?

    a. The angular velocity of the merry-go-round remains the same.
    b. The angular velocity of the merry-go-round increases.
    c. The merry-go-round stops rotating.
    d. The angular velocity of the merry-go-round decreases.

16. A sealed cup containing mostly water with a bit of air has a striped straw puncturing the side of the cup. The system has already reached equilibrium such that no more water is flowing out of the striped straw (see diagram part 1). A plain straw is now stuck in so violently through the lid that the lower end of this straw is below the level of the striped straw (see diagram part 2). As expected, the water level in the plain straw is below that of the water surface in the cup.

(i) To what height should the lower end of the plain straw be raised such that the water starts flowing out of the horizontal striped straw (see diagram part 3)?

(ii) If we want to lower the plain straw to stop the flow, will the critical height of its lower end remain the same as before (as in diagram part 2)?




a. (i) Once you raise it above the striped straw, water starts flowing as air can enter and displace the water. (ii) The height you need to stop the flow is lower now as the water outside the straw now needs to reach equilibrium and will continue to flow.

b. (i) Once you raise it above the striped straw, water starts flowing as air can enter and displace the water. (ii) The height you need to stop the flow is lower depending on how much water was let out.

c. (i) Once you raise it above the striped straw, water starts flowing due to the pressure difference. (ii) Once it is below the striped straw the flow stops.

d. (i) Once you raise it above the striped straw, water starts flowing due to the pressure difference. (ii) It can be lowered to a point above the striped straw as the dynamic pressure of the flow lowers the pressure of the water.

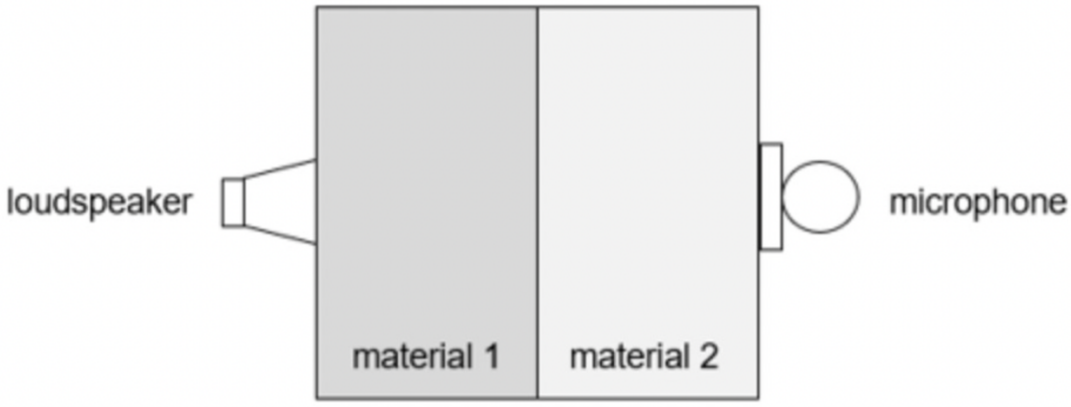
17. Water flows from left to right through a horizontal pipe of circular cross-section at a speed of 4 m/s and a pressure of 200,000 Pa at position A. The cross-sectional area of the pipe narrows at point B (the cross-section of the pipe remains circular all throughout) and the speed of water there increases of 8 m/s. Ignoring gravity, viscous effects and other energy losses, what is the pressure of water at position B?


a. 24,000 Pa
b. 224,000 Pa
c. 176,000 Pa
d. 100,000 Pa

18. What changes when a transverse wave passes from one medium to another?

a. Speed, wavelength
b. Speed, wavelength, frequency
c. Speed, frequency
d. Wavelength, frequency

19. The sound from a loudspeaker passes through two materials to a microphone. Which combination of materials (material 1, material 2) gives the shortest time for the sound to reach the microphone?




a. Air, air
b. Air, aluminum
c. Water, air
d. Water, aluminum

20. Two identical linearly polarizing filters are placed one behind another, in front of a beam of natural light with intensity $I_0$, with their transmission aces crossed at a relative angle of 90 degrees. What is the maximum possible intensity of light that can be transmitted through the setup if 20 additional filters are placed in between these two filters?

a. $0.445\ I_0$
b. $0.439\ I_0$
c. $0.889\ I_0$
d. $0.878\ I_0$

21. A wave is described by the equation below. What is its period?

$$y(t) = 3\cos 2\pi t + 3\sqrt{2}\cos 3\pi t + \sqrt{2}\cos 4\pi t$$

a. 4 s
b. 2 s
c. 3 s
d. 5 s

22. Plates 1, 2, and 4 are charged plastic plates. Plate 3 is an electrically neutral copper plate. When plates 1 and 2 are brought close to each other, they repel. When plate 2 is brought close to plates 3 or 4, it is attracted. How do plates 2 and 4, and plates 3 and 4 interact when brought close together?

a. Plates 2 and 4 attract, plates 3 and 4 attract.
b. Plates 2 and 4 repel, plates 3 and 4 repel.
c. Plates 2 and 4 repel, plates 3 and 4 attract.
d. Plates 2 and 4 attract, plates 3 and 4 repel.

23. A neutral conducting block has four empty spaces, J, K, L, M within it. An external charge of +3q is now placed in space J. Three other charges are placed in spaces K, L, M. A charge of +6q has now collected on the outer surface of the block. Which of the following combination of charges for spaces K, L, M is possible?

    a. -q, +3q, +2q
    b. +q, -2q, +4q
    c. -3q, +2q, +3q
    d. -3q, +2q, +q

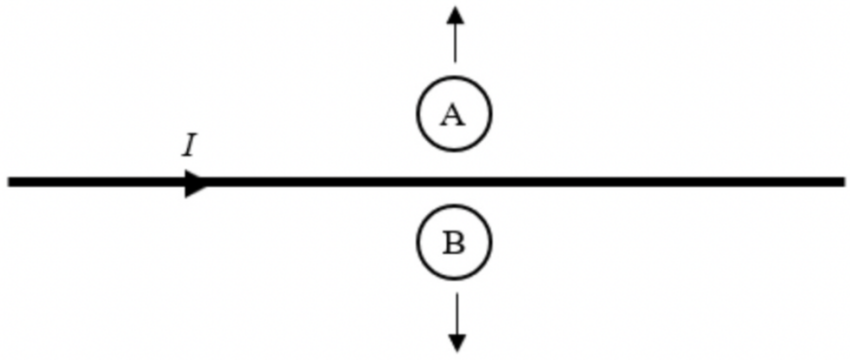
24. Two charged particles are placed near the origin of the coordinate system. Particle 1 carries charge -q and is on the x-axis at $x = +d$. Particle 2 carries an unknown charge Q and is on the y-axis at $y = +D$. The magnitude of the electric field at the origin is $|E| = \frac{q}{2\pi\epsilon_0 d^2}$ and the electric potential at the origin is $V = +\frac{3q}{8\pi\epsilon_0 d}$. What is the charge of particle 2?

a. $+\frac{25\sqrt{3}}{12}q$
b. $-\frac{25\sqrt{3}}{6}q$
c. $-\frac{25\sqrt{3}}{12}q$
d. $-\frac{25\sqrt{3}}{6}q$

25. There is a point charge Q at the centre and at each corner of a regular hexagon. The hexagon has sides of length a. What is the total electric potential energy of this configuration?

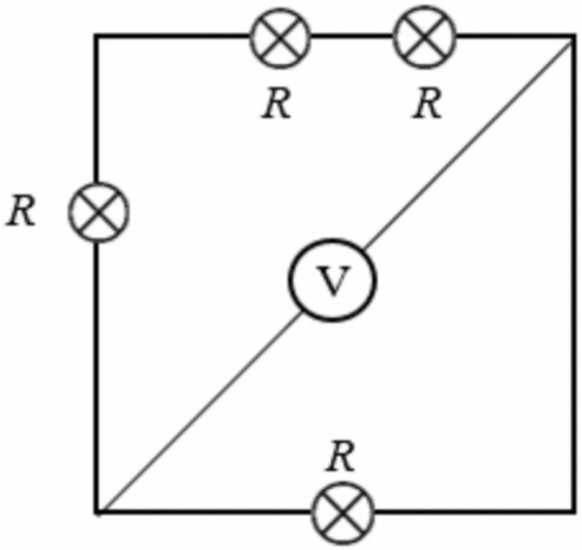
a. $\frac{11}{4}\frac{Q^2}{a\pi\epsilon_0}$
b. $\frac{5.48}{4}\frac{Q^2}{a\pi\epsilon_0}$
c. $\frac{21.9}{4}\frac{Q^2}{a\pi\epsilon_0}$
d. $\frac{43.9}{4}\frac{Q^2}{a\pi\epsilon_0}$

26. Two small loops of wires A and B are located close to a straight wire which carries a conventional current in the direction shown. Both loops are moved away from the straight wire. What are the orientations of the conventional current generated in each loop while this occurs?




| | Loop A | Loop B |
|---|---|---|
| a. | Clockwise | Anticlockwise |
| b. | Anti-clockwise | clockwise |
| c. | No current | No current |
| d. | Anti-clockwise | Anti-clockwise |

27. A magnetic field directed into the plane of the page is decreasing in time, producing a constant electromotive force E in the square loop enclosing the field in the figure below. The square loop has 3 identical lightbulbs, each of resistance R. An ideal voltmeter is connected to the corners, as shown, through the centre of the loop. What is the magnitude of the voltmeter's reading?

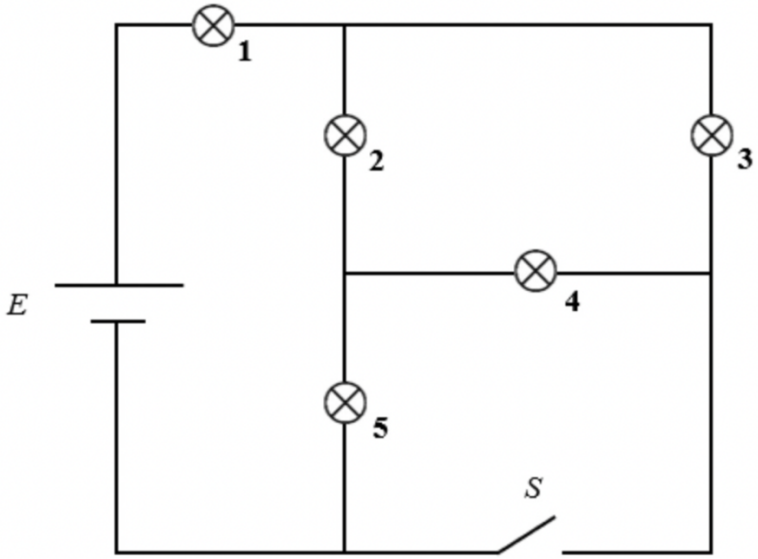



a. E/4
b. E
c. E/2
d. E/6

28. 400 turns of wire are wrapped on a square frame with sides of 9.0 cm. A uniform magnetic field is applied perpendicularly to the plane of the coil. If the field changes uniformly from 0.50 T to 0 T in 6.0 s, find the average value of the induced electromotive force in the wire.

a. 0.27 V
b. 3 V
c. 0.16 V
d. 2700 V

29. For the circuit shown, the five light bulbs have identical resistance R (labelled bulbs 1 to 5) and the battery is assumed to be ideal with an electromotive force of E. Which of the following statements describe(s) what happens after the switch is closed?




(i) Bulb 1 becomes brighter.
(ii) Bulbs 2 & 4 will be equally bright.
(iii) Bulbs 3 & 4 will be equally bright.
(iv) Bulbs 4 & 5 will be equally bright.

a. (i) and (iv)
b. All of the options
c. (i), (ii), and (iv)
d. (i) only

30. A 100g lead bullet travelling at 300 m/s penetrates an ice block at $0°C$ and stops within the ice block. The temperature of the bullet decreases by $250°C$. How much ice has melted?

Specific heat capacity of lead and water is $0.128$ and $4.18\ kJ/kg\ K$. The latent heat of fusion of ice is $336\ kJ/kg$.

a. 9.52 g
b. 1830 g
c. 13.4 g
d. 22.9 g

31. The specific heat capacity of aluminium is 0.9 kJ/kg K. A 3 kg mass of aluminium is heated for 60 seconds by a 200W heater. Which option gives the possible rise in temperature of the aluminium?

a. $4.6\ °C$
b. $3.8\ °C$
c. $45.0\ °C$
d. $6.0\ °C$

32. A scuba diver in a lake makes a spherical bubble with a radius of R at a depth of 15 m. The radius of the bubble when it reaches the surface is 4.07 cm. What is the value of R? Take the lake water to have a density of 1000 kg/$m^3$ and the same temperature throughout.

    a. 3.59 cm
    b. 2.60 cm
    c. 1.66 cm
    d. 3.02 cm

33. Which of the following statements about absolute zero is true?

    a. All particles, including electrons of the atoms, stop moving.
    b. The substance cannot get any colder.
    c. Particles will have zero volume.
    d. Internal energy of the system reaches zero.

34. A fully-inflated bicycle tyre at $25°C$ has a pressure of 150 kPa, as measured by a pressure gauge. This means that the pressure in the type is 150 kPa above atmospheric pressure. After cycling under the hot sun, the temperature of the air in the tyre increases by $15°C$, without a significant change in tyre volume. What is the increase in the pressure gauge reading?

    a. 7.55 kPa
    b. 163 kPa
    c. 90.0 kPa
    d. 13.0 kPa

35. Alice is on a train that is moving at a constant velocity. She threw a package to Bob who is standing beside the train track below the train window. Bob observes that the package falls vertically and catches the package. What action did Alice perform?

    a. Alice threw the package straight down the window of the moving train.
    b. More information is needed to decide.
    c. Alice threw the package towards the front of the moving train.
    d. Alice threw the package towards the back of the moving train.

36. A projectile of mass $4m$ is launched from the ground and explodes at the top of its trajectory at a horizontal distance $x$ from the starting point of the motion, breaking into two pieces of mass $m_1 = m$; $m_2 = 3m$. If $m_1$ lands back at the starting point, how far would $m_2$ land back on the ground with respect to the starting point?

    a. $8x/3$
    b. $2x/3$
    c. $3x$
    d. $2x$

37. A canoe, carrying two boys, is initially stationary in water. The boys in the canoe started throwing and catching a heavy ball back and forth between them. Assuming the air and water resistances are negligible, which statement about the centre of mass of the entire system of the canoe (including the ball and the boys) is correct?

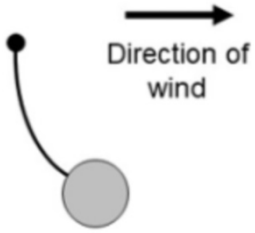
    a. The centre of mass moves in the direction opposite the motion of the ball in the air.
    b. The centre of mass remains stationary at the same position all the time.
    c. The centre of mass moves in the same direction as the motion of the ball in the air.
    d. The centre of mass oscillates in simple harmonic motion horizontally.

38. Two boxes of mass $m$ and $2m$, starting from rest, were pushed for the same amount of time and using the same amount of force. What would be the ratio of the final momentum of the lighter box to that of the heavier box?

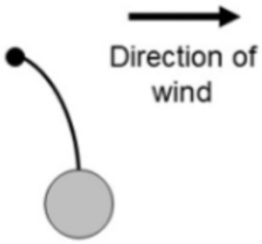
    a. 1:2
    b. 1:1
    c. 2:1
    d. 4:1

39. A pendulum (consisting of a thread and a bob), originally at rest, experiences a strong and constant wind acting on the entire pendulum to the right. The wind is sufficiently strong to displace the pendulum. The thread has a finite and significant total mass, but the mass of the bob is larger than the mass of the thread. Which of the following diagrams correctly depicts the equilibrium position of the pendulum?

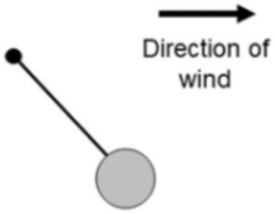
a.



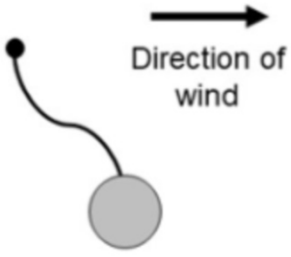

b.



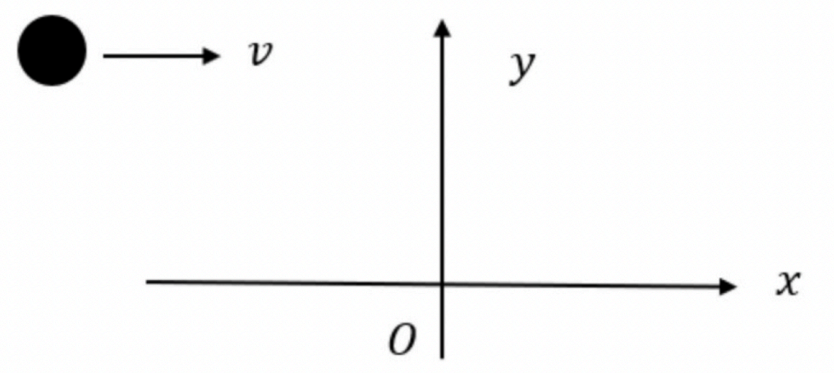

c.




d.



40. A particle is moving in the x-y plane with a constant velocity. What can we conclude about the angular momentum of the particle at any given time about the origin?



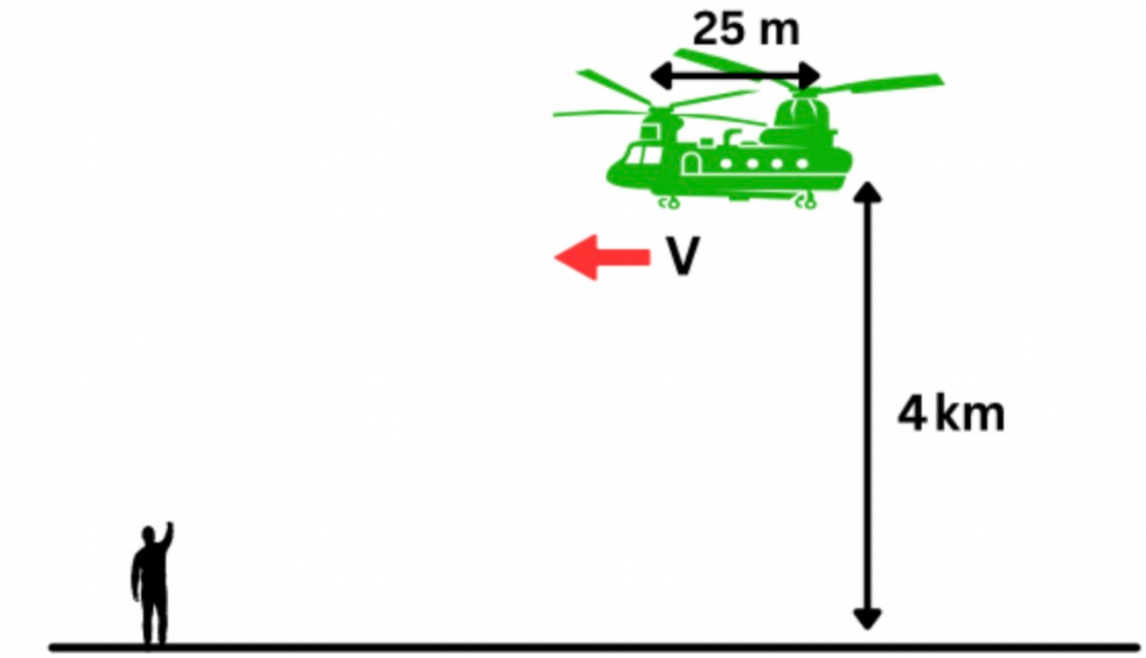

a. The angular momentum increases then decreases.
b. The angular momentum is a non-zero constant.
c. The angular momentum is 0.
d. The angular momentum decreases then increases.

41. Suppose we have a spring of length L with differing spring constants for extension and compression. For extensions it has spring constant $k_!$, for compressions $k_2$. A mass M attached at the end of the spring extends it by a distance $x_0$. What is the period of oscillation?

a. $2\pi\sqrt{\frac{M}{k_1+k_2}}\frac{x_0^2}{L^2}$
b. $2\pi\left(\sqrt{\frac{M}{k_1}}+\sqrt{\frac{M}{k_2}}\right)$
c. $\pi\left(\sqrt{\frac{M}{k_1}}+\sqrt{\frac{M}{k_2}}\right)$
d. $\pi\left(\sqrt{\frac{M}{k_1}}+\sqrt{\frac{M}{k_2}}\right)\frac{x_0^2}{L^2}$

42. A chinook helicopter flies at a height of 4 km overhead. The distance between the two rotor masts is 25m (diagram not to scale). You observe that the intensity of sound keeps fluctuating, and note that the time between successive intensity maxima is 5 seconds. The sound produced has a frequency of 60 Hz when it reaches your ears, and the speed of sound at the surface is $340\ m/s$. Assume the wavefront propagates in a circular fashion, and that the rotors are point sources of sound.

What is the approximate horizontal speed at which the chinook is travelling with respect to the ground, given that it is travelling straight towards you?




a. 90 m/s
b. 170 m/s
c. 225 m/s
d. 181 m/s

[Note: The actual separation between rotor blades is about 10m. How does this affect your answer?]

43. An alpha particle has specific charge $+a$ and is moving along the x-axis with velocity $+v_0\,\hat{x}$. It enters a region of electric potential $\phi(x) = x^2, x \in [0, d]$. What is the minimum value of $d$ to bring the alpha particle to momentary rest and what is the time T that elapsed between the alpha particle entering and leaving the region?

a. $d = \frac{v_0\sqrt{2a}}{2a}, T = \frac{\sqrt{2a}}{2\pi a}$
b. $d = \frac{v_0\sqrt{2a}}{4a}, T = \frac{\pi\sqrt{2a}}{4a}$
c. $d = \frac{v_0\sqrt{2a}}{2a}, T = \frac{\pi\sqrt{2a}}{2a}$
d. $d = \frac{v_0\sqrt{2a}}{4a}, T = \frac{\sqrt{2a}}{4\pi a}$

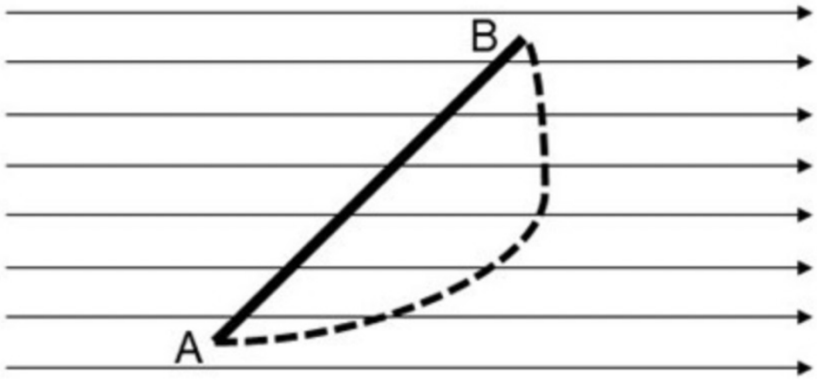
44. We have a solid hemisphere with charge Q uniformly distributed throughout the hemisphere. What is the average electric potential at a distance $r$ from the centre of the hemisphere as shown in the diagram?


a. $\frac{Q}{4\pi\epsilon_0 R}$
b. $\frac{Q}{2\pi\epsilon_0 r}$
c. $\frac{Q}{4\pi\epsilon_0 r}$
d. $\frac{Q}{2\pi\epsilon_0 R}$

45. A positive point charge $+q$ is located at vertex A of an equilateral triangle whose sides have length $a$. A negative point charge $-q$ is located at each of the two vertices B and C. Now, a point charge $Q$ is placed at the centre of the triangle, at $\left(-\frac{a}{4}.-a\frac{\sqrt{3}}{3}\right)$. What is the value of $Q$ so that the total electrical force acting on the point charge at vertex A is zero?

a. $+\frac{\sqrt{3}}{12}q$
b. $-\frac{\sqrt{3}}{3}q$
c. $-\frac{\sqrt{3}}{12}q$
d. $+\frac{\sqrt{3}}{3}q$

46. The diagram shows two separate segments of wire (represented by solid and dotted lines) that are carrying a current $I$ from point A to B in the presence of a uniform magnetic field indicated by the arrows. Which of the following statements about the force due to the external magnetic field on the wires is correct?




a. The force acting on the solid line wire is bigger than the force acting on the dotted line wire.
b. The force acting on the dotted line wire is bigger than the force acting on the solid line wire.
c. The force acting on both wires are zero.
d. The force acting on both wires are the same, but non-zero.

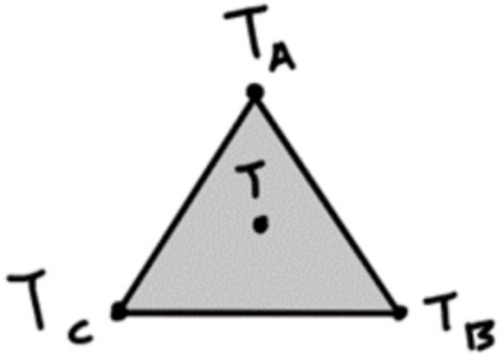
47. An electromagnetic wave has a magnetic field give in Cartesian coordinates in the expression below.

$$\boldsymbol{B}(x, y, z, t) = (6.0 \times 10^{-6}) \cos(2.21 \times 10^{7}\, z - 6.63 \times 10^{15}\, t)\ \hat{x}$$

At $x = y = z = 0, t = 0$, what is the direction of the electric field associated with this wave?

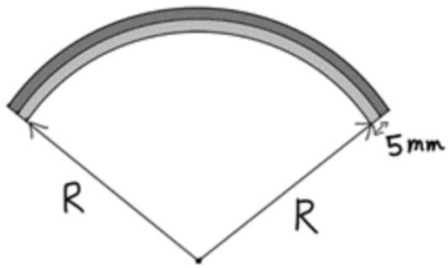
a. $+y$
b. $-x$
c. $+z$
d. $-y$

48. What is the temperature at the centre of an equilateral triangle where the 3 vertices are heated to maintain constant temperatures at the edges?




a. Average of the temperature at the 3 vertices.
b. Average of the temperature throughout the entire face.
c. Average of the temperature along the 3 edges.
d. All of the options.

49. Two strips each of length 30 cm and thickness 5 mm have different thermal expansion coefficients and are welded together to form a bimetallic strip. One has a linear thermal expansion coefficient of $2.0 \times 10^{-5}\, K^{-1}$, while the other has a coefficient of $3.0 \times 10^{-5}\, K^{-1}$. The temperature increases by 50 K. Find the radius of curvature of the bimetallic strip, given it becomes an arc as shown.




a. 20.0 m
b. 16.7 m
c. 1.80 m
d. 10.0 m

50. When you fire a laser beam into a transparent material like glass, it is known that the laser beam will travel at some speed less than the speed of light. According to special relativity, this means that the speed of the laser beam through the medium will change based on the motion of an observer. For example, someone moving in the direction of the beam will observe it travelling slower! What can you conclude from this?

a. The index of refraction is a function of the motion of the observer.
b. There is no issue, the speed of light only must be constant in all frames for someone travelling within the same optical medium.
c. We cannot assume that the Maxwell's equations are the same in all frames, so the speed of light can change in the observer's frame.
d. Special relativity contradicts itself as the speed of light must be a constant in all frames. That is why we have general relativity.