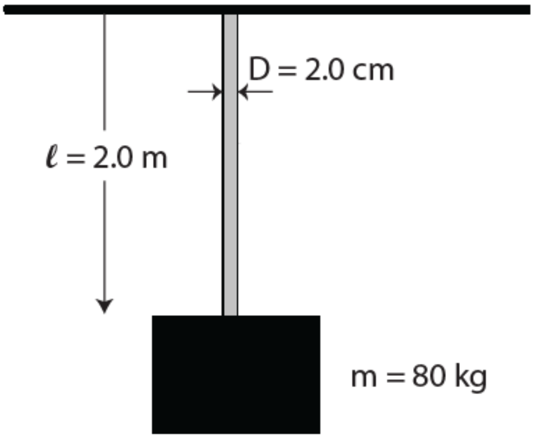
Q1.

Figure 1 shows a solid cylindrical steel rod of length $\ell = 2.0$ m and diameter D = 2.0 cm. What will be increase in its length when m = 80 kg block is attached to its bottom end? (Young's modulus of steel = 1.9×10^{11} Pa)

Fig#



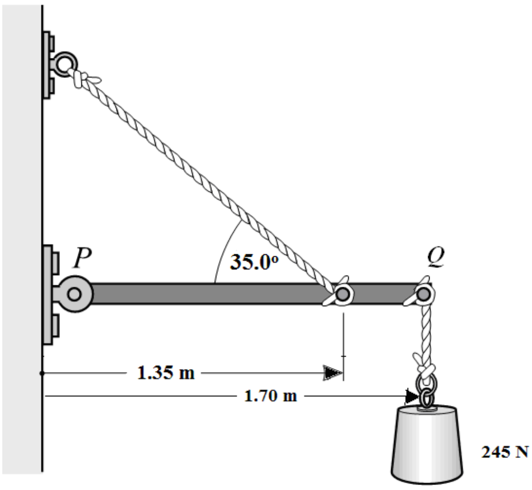
Answer:

$$\Delta L = \frac{FL}{AY} = \frac{mg\ell}{AY} = \frac{(80)(9.8)(2)}{\pi (0.01)^2 (1.9\ 10^{11})} = 0.0000262689 \text{ m}$$

A) 2.6×10^{-5} m
B) 1.3×10^{-5} m
C) 4.8×10^{-5} m
D) 7.2×10^{-5} m
E) 3.5×10^{-5} m

Q2.

In F**ig. 2,** *PQ* is a horizontal uniform beam weighing 155 N. It is supported by a string and a hinge at point *P*. A 245 N block is hanging from point *Q* at the end of the beam. Find the horizontal component of net force on the beam from the hinge.



Answer:

Toque about P implies:

$$\left(T\ \sin 35^o\right)(1.35)-(155)\left(\frac{1.7}{2}\right)-(245)(1.7)=0$$

$$\Rightarrow T\ =\frac{131.75+416.5}{(1.35)\sin 35^o}=708\text{ N}$$

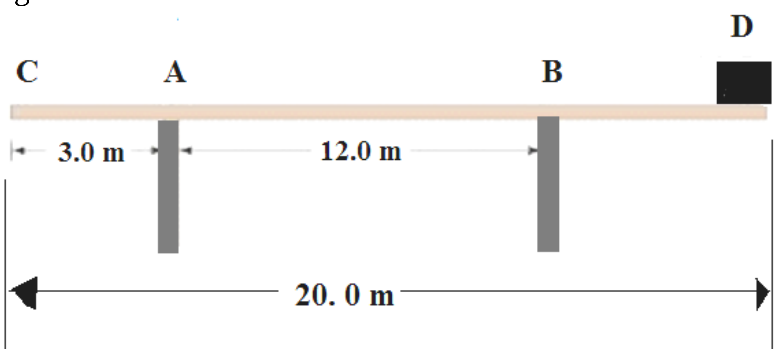
The force on x-axis implies:

$$F_H\ =T\ \cos 35^o\ =708\left(\cos 35^o\right)=579.98\text{ N}\approx 580\text{ N}$$

A) 580 N
B) 310 N
C) 491 N
D) 164 N
E) 200 N

Q3.
A 20.0 m long uniform beam weighing 550 N rests on supports "A" and "B", as shown in **Figure 3**. Find the magnitude of the force that the support "A" exerts on the beam when the block of weight 200 N is placed at **D**.

Fig#



Answer:
The torque about point B implies:

$$-M_D \times 5 + M_{beam} \times 5 - F_A \times 12 = 0$$

$$F_A = \frac{-200 \times 5 + 550 \times 5}{12} = 145.8 \text{ N} \approx 146 \text{ N}$$

A) 146 N
B) 241 N
C) 501 N
D) 315 N
E) 185 N

Q4.
At what height above earth's surface would the gravitational acceleration be 0.980 m/s^2?

Answer:

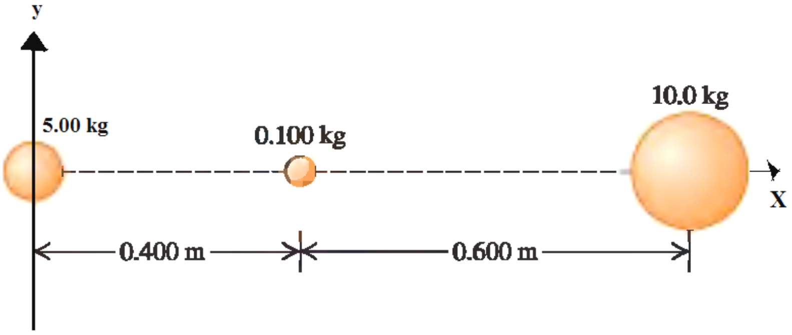
$$\frac{GM}{(R_E + h)^2} = \frac{g}{10} = \frac{GM\ /R_E^2}{10} \Rightarrow h = \sqrt{10}R_E - R_E = 1.38 \times 10^7$$

$RE = 6.37\ 10^6$; $h = \sqrt{10}\ RE - RE = 1.37737 \times 10^7$ m

A) 1.38×10^7 m
B) 1.12×10^7 m
C) 7.12×10^7 m
D) 5.82×10^8 m
E) 4.05×10^8 m

Q5.
In **Figure 4**, what is the net gravitational force exerted on the 5.00 kg uniform sphere by the other two uniform spheres?

Fig#



Answer:

The gravitational force is attractive:

$$\vec{F} = \vec{F}_1 + \vec{F}_2 = GM_5\left(\frac{M_{0.1}}{r_{0.1}^2} + \frac{M_{10}}{r_{10}^2}\right) = 6.67\times10^{-11}\times5\times\left(\frac{0.1}{.4^2} + \frac{10}{1^2}\right) = +3.54\ \times10^{-9}\ \text{N}$$

$$G = 6.67\ 10^{-11}\ ;\ F = G\,5\left(\frac{0.1}{.4^2} + \frac{10}{1^2}\right) = 3.54344\ \times10^{-9}$$

A) $+3.54\times10^{-9}\ \hat{i}$ N

B) $+2.32\times10^{-11}\ \hat{i}$ N

C) $-2.32\times10^{-11}\ \hat{i}$ N

D) $-1.45\times10^{-13}\ \hat{i}$ N

E) $+1.45\times10^{-13}\ \hat{i}$ N

Q6.

A rocket is launched from the surface of a planet of mass M = 2.20 × 10^{28} kg and radius R = 5.35 × 10^{6} m. What minimum initial speed is required if the rocket is to rise to a height of 6R above the surface of the planet? (Neglect the effects of the atmosphere).

Answer:

Conservation of total energy implies:

$$\frac{1}{2}mv^2 - \frac{GmM}{R} = 0 - \frac{GmM}{7R}$$

$$\Rightarrow \ v = \sqrt{\frac{2GM}{R}(1-\frac{1}{7})} = \sqrt{\frac{2\times 6.67\times 10^{-11}\times 2.2\times 10^{28}}{5.35\times 10^{6}}(1-\frac{1}{7})} = 6.86\times 10^{5} \text{ m/s}$$

$$G = 6.67\ 10^{-11}\ ;\ M = 2.2\ 10^{28}\ ;\ R = 5.35\ 10^{6}\ ;\ V = \sqrt{\frac{2\,G\,M\,(1-1/7)}{R}} = 685708.$$

A) 6.86 × 10^{5} m/s
B) 3.44 × 10^{5} m/s
C) 2.18 × 10^{6} m/s
D) 8.20 × 10^{6} m/s
E) 9.45 × 10^{5} m/s

Q7.

A satellite of mass 200 kg is placed in Earth orbit at height of 200 km above the earth surface. How long does the satellite take to complete one circular orbit?

Answer:

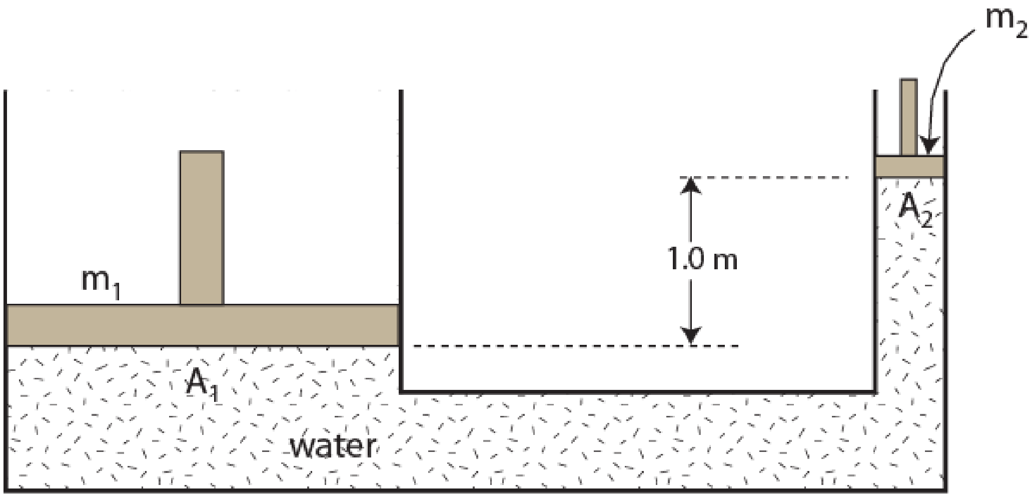
$$T = \sqrt{\frac{4\pi^2}{GM_E}(R_E + h)^3}$$

$$T = \sqrt{\left(\frac{4\,\pi^2}{6.67\ 10^{-11}\ \ 5.98\ 10^{24}}\right)(6.37\ 10^{6} + 200\ 10^{3})^3} \Big/ 60 \Big/ 60 = 1.47168$$

A) 1.47 hours
B) 2.77 hours
C) 8.14 hours
D) 9.56 hours
E) 7.38 hours

Q8.
In a hydraulic press, shown in **Figure 5**, the large piston has a cross sectional area of A_1 = 150 cm^2 and mass m_1 = 450 kg. The small piston has a cross sectional area of A_2 = 10 cm^2 and mass m_2. If the height difference between the two pistons is 1.0 m, what is the mass m_2? [Note: The fluid in the hydraulic press is water]

Fig#



Answer:

The pressures at points A and B must be the same so that
p (due to A_1) = p (due to A_2) + p (due to water height of 1.0 m)

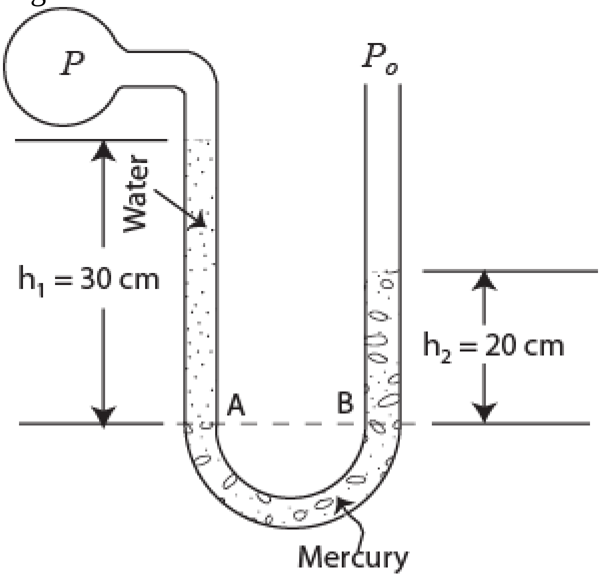
$$\frac{450\times 9.8}{150\times 10^{-4}} = \frac{m_2\times 9.8}{10\times 10^{-4}} + (1.0\times 10^3)(9.8)(1)$$

$$\Rightarrow m_2 = 29 \text{ kg}$$

A) 29 kg
B) 33 kg
C) 15 kg
D) 40 kg
E) 11 kg

Q9.
Figure 6 shows an open-tube manometer containing water and mercury. The height of water in the left column above the interface A is 30 cm while the height of mercury in the right column above B is 20 cm. The right column is open to the atmosphere P_o. Find the pressure P in the bulb. (Take $P_o = 1.01 \times 10^5$ Pa and $\rho\,(\text{mercury}) = 1.36 \times 10^4\ \text{kg/m}^3$).

Fig#



Answer:

The pressures on either side of the junction must be equal. This requires:

$$p + \rho_1 g h_1 = p_o + \rho_2 g h_2$$

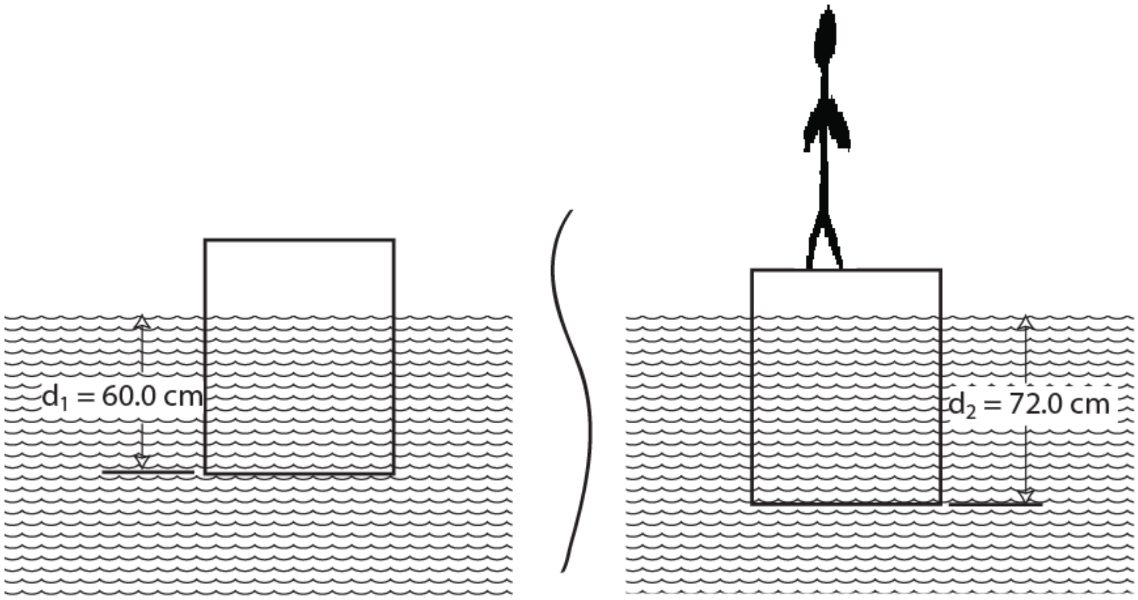
$$p + (1.0\times10^3)(9.8)(0.3) = (1.01\times10^5) + (13.6)(1.0\times10^3)(9.8)(0.2)$$

$$\Rightarrow p = 1.2498\times10^5\ \text{N/m}^2 = 1.25\times10^5\ \text{Pa}$$

A) 1.25×10^5 Pa
B) 0.55×10^5 Pa
C) 0
D) 4.29×10^5 Pa
E) 2.46×10^5 Pa

Q10.
A rectangular block, of area A and mass 500 kg, floats in still water with its submerged depth $d_1 = 60.0$ cm. When a man stands on the block, the submerged depth of the block becomes $d_2 = 72.0$ cm (see Figure 7). What is the man's mass?

Fig#



Answer:
Using the equilibrium conditions

$$\rho_w A d_1 g = Mg$$
$$\rho_w A d_2 g = (M + m) g$$

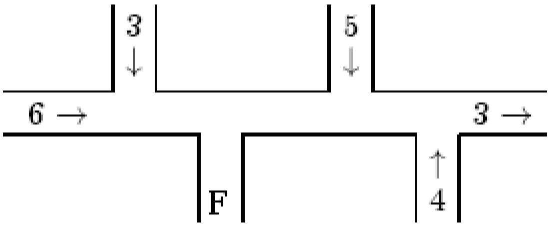
Dividing the above two equations and solve for m one finds:

$$m = \left(\frac{d_2}{d_1} - 1\right) M = \left(\frac{7.2}{6.0} - 1\right) 500 = 100 \text{ kg}$$

A) 100 kg
B) 200 kg
C) 150 kg
D) 500 kg
E) 250 kg

Q11.
Figure 8 shows a pipe of uniform cross section in which water is flowing. The directions of flow and the volume flow rates (in cm^3/s) are shown for various portions of the pipe. The direction of flow and the volume flow rate in the portion marked F are:

Fig#

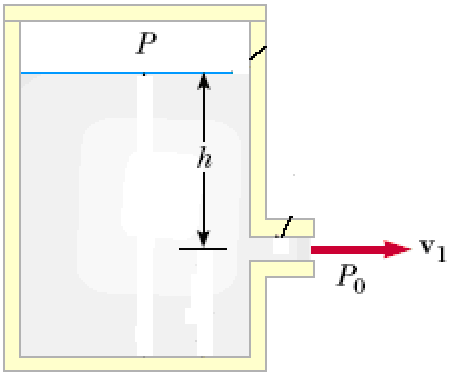


A) $\downarrow$ and 15 cm^3/s
B) $\downarrow$ and 9 cm^3/s
C) $\uparrow$ and 7 cm^3/s
D) $\rightarrow$ and 3 cm^3/s
E) $\uparrow$ and 6 cm^3/s

Q12.

A closed large tank containing a liquid of density $\rho = 1.50 \times 10^3$ kg/m^3 has a small hole in its side (See **Figure 9**) and is open to the atmosphere, P_o. The air above the liquid is maintained at a pressure of $P = 3P_o$. Determine the speed, v_1, of the liquid as it leaves the hole when the liquid's level is at a height $h = 3.00$ m above the hole. (take $P_o = 1.01 \times 10^5$ Pa)

Fig#



Answer:

Because area at P >> area at Po, the liquid is approximately at rest at the top of the tank. Applying Bernoulli's equation at the top of the liquid and at the hole, we have:

$$P_o + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P + \rho g y_2$$

$$\Rightarrow v_1 = \sqrt{\frac{2(P - P_0)}{\rho} + 2gh}, \qquad h = y_2 - y_1$$

$$v_1 = \sqrt{\frac{4(1.01 \times 10^5)(9.8)}{1.5 \times 10^3} + 2 \times 9.8 \times 3} = 18.1 \text{ m/s}$$

A) 18.1 m/s
B) 21.7 m/s
C) 29.1 m/s
D) 10.5 m/s
E) 5.50 m/s

Q13.
A simple harmonic oscillator has amplitude of 3.50 cm and a maximum speed of 28.0 cm/s. What is its speed when the displacement of the oscillator is 1.75 cm?

Answer:

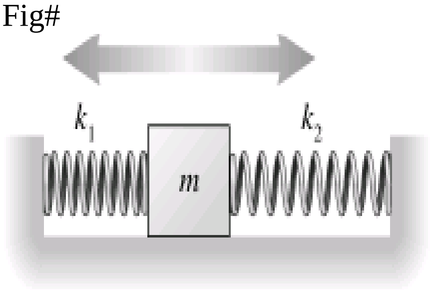
$$X_m = 3.50 \text{ cm}, \; \omega X_m = 28 \text{ cm/s} \Rightarrow \omega = 8,$$

$$\text{v} = \omega\sqrt{X_m^2 - X} = 8\sqrt{0.035^2 - 0.017^2} = 0.242 \text{ m/s}$$

A) 24.2 cm/s
B) 12.0 cm/s
C) 14.2 cm/s
D) 15.0 cm/s
E) 17.0 cm/s

Q14.
A 2.0 kg block on a frictionless horizontal table is connected to two springs whose opposite ends are fixed to walls, as shown in **Figure 10**. If the spring constants $k_1 = 7.6$ N/m and $k_2 = 5.0$ N/m, what is the angular frequency of oscillation of the block?

Fig#



Answer:
When displaced from equilibrium, the net force exerted by the springs is $-(k_1 + k_2)x = -k_{eff}\,x$ acting in a direction so as to return the block to its equilibrium position (x = 0). Since the acceleration $a = d^2x/dt^2$, Newton's second law yields

$$m\frac{d^2x}{dt^2} = -(k_1 + k_2)x$$

A) 2.5 rad/s
B) 3.5 rad/s
C) 0.56 rad/s
D) 0.40 rad/s
E) 1.3 rad/s

Q15.

The position of a 2.00 kg block, attached to spring and executing simple harmonic motion, is given by the equation:

$$x = (12.3\text{ cm})\cos\left[(1.26\text{ s}^{-1})t\right].$$

where t is the time in seconds. What is the total mechanical energy of the spring-block system at t = 0.815 s?

Answer:

$$x = (12.3\text{ cm})\cos\left[(1.26\text{ s}^{-1})t\right]$$

$$\Rightarrow v = \frac{dx}{dt} = -(12.3 \times 1.26)\sin\left[(1.26\text{ s}^{-1})t\right] = -15.498\sin(1.26\times 0.815\text{ rad}) =$$

```
(*Problem 15 *)
x = 12.3/100 Cos[1.26 t]  ; v = ∂t (x) /. {t → 0.815}
                                                        = -0.132616
y = 12.3/100 Cos[1.26 t] /. {t → 0.815}
                                             = 0.0636493
ω = 1.26; m = 2; k = ω^2 m ;
Ee = 1/2 k y^2 + 1/2 m v^2
                             = 0.0240188
```

A) 2.40×10^{-2} J
B) 4.48×10^{-2} J
C) 1.12×10^{-2} J
D) 8.96×10^{-2} J
E) 6.72×10^{-2} J

Q16.
A simple pendulum of length **L** and mass **M** has frequency ***f***. In order to increase its frequency to **2*f*** we have to**:**

A) decrease its length to L/ 4
B) increase its length to 2L
C) decrease its length to L/2
D) increase its length to 4L
E) decrease its mass to M/4

Q17.
The value of $\hat{i} \cdot \left(\hat{k} \times \hat{j}\right)$ is:

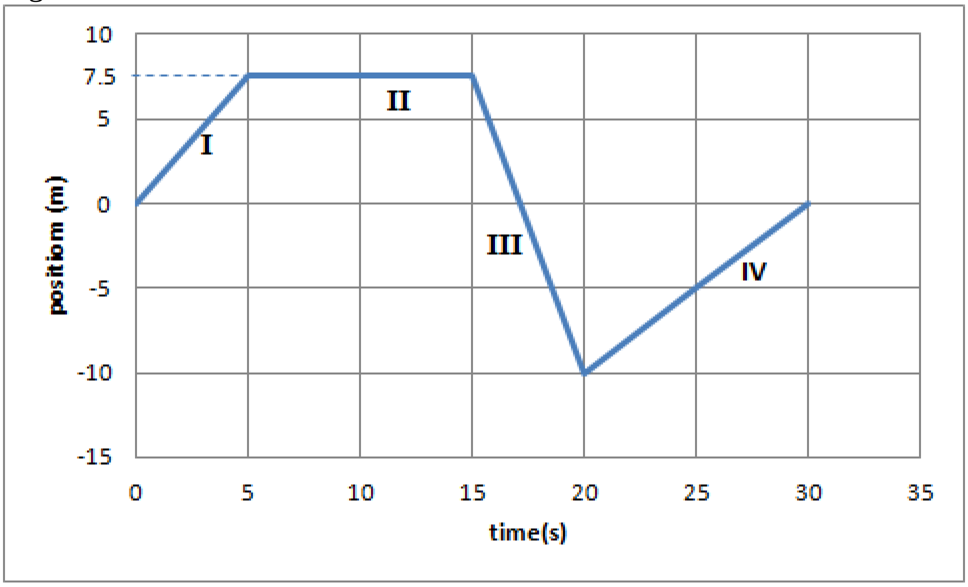
Answer:

$$\hat{i} \cdot \left(\hat{k} \times \hat{j}\right) = \hat{i} \cdot \left(-\hat{i}\right) = -1$$

A) −1
B) +1
C) zero
D) 3
E) $\hat{i}$

Q18.
An object is moving along a straight line in the positive *x* direction. **Figure 11** shows its position from the starting point as a function of time. Various segments of the graph are identified by the roman numerals I, II, III, and IV. Which segment(s) of the graph represent(s) **a constant velocity** of +1.0 m/s?

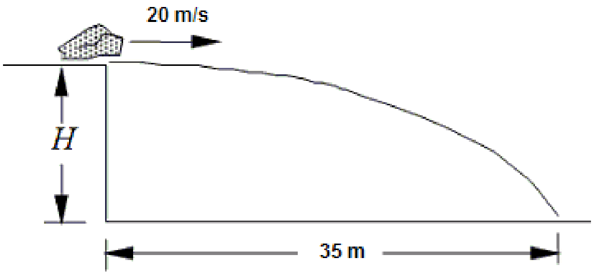
Fig#



A) IV
B) II
C) III
D) I
E) I and III

Q19.
A rock is thrown horizontally at a speed of 20 m/s from the edge of a cliff of height ***H***. The rock strikes the ground 35 m from the foot of the cliff as shown in **Figure 12**. What is the **height *H*** of cliff edge? Neglect air resistance.

Fig#



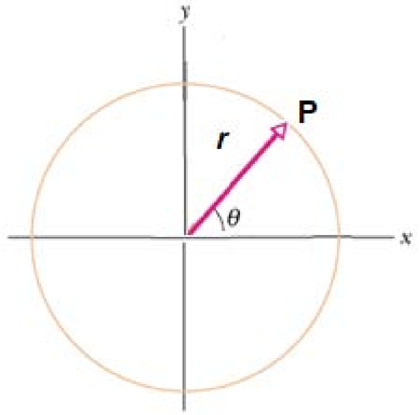
Answer:

$$35 = 20t \Rightarrow t = 3.5/2;$$

$$-H = \frac{1}{2}gt^2 = 4.9(1.75)^2 = 15 \text{ m}$$

A) 15 m
B) 11 m
C) 21 m
D) 17 m
E) 19 m

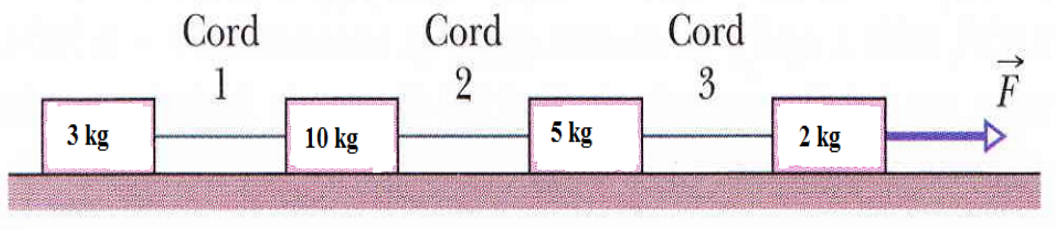
Q20.
Figure 13 shows a particle **P** moving in a horizontal circle with uniform angular velocity about the origin of an **xy coordinate system**. At what values of θ, the y-component of the particle acceleration $\boldsymbol{a_y}$ have maximum magnitude. (θ is measured counter clockwise from the positive x-axis)



A) 90° and 270°
B) 0° and 90°
C) 90° and 180°
D) 0° and 180°
E) 0° and 270°

Q21.
Figure 14 shows four blocks connected with three cords, being pulled to the right on a horizontal frictionless floor by a horizontal force F. Rank the cords according to their tension, **Greatest to least**.

Fig#



Answer:

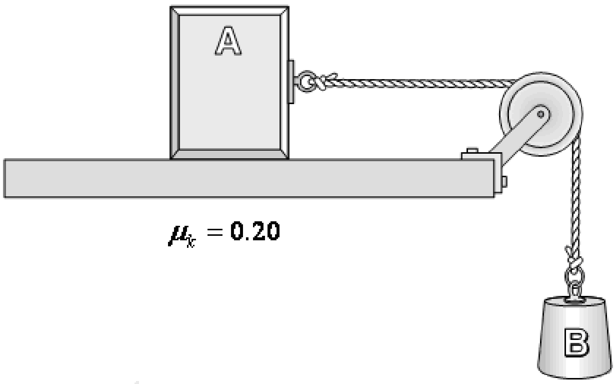
$$a = 20/20 = 1\ \text{m/s}^2;$$
$$2a = 20 - T_3 \Rightarrow T_3 = 18\ \text{N};$$
$$5a = 18 - T_2 \Rightarrow T_2 = 13\ \text{N};$$
$$10a = 13 - T_1 \Rightarrow T_1 = 3\ \text{N};$$

A) 3,2,1
B) All tie
C) 2,1,3
D) 1 and 2 tie then 3
E) 1,3,2

Q22.

In **Figure 15**, blocks "A" and "B" have masses of $m_A = 25.0 \text{ kg}$ and $m_B = 25.0 \text{ kg}$, respectively. **Find the magnitude of the acceleration of mass "A"** if the coefficient of kinetic friction between the block "A" and the horizontal table is $\mu_k = 0.20$. Assume the pulley is massless and frictionless.

Fig#



Answer:

The equation of motion for the system will be:

$$(M_A + M_B)a = M_B g - f_k = M_B g - f_k = M_B g - \mu_k M_A g$$

$$\Rightarrow a = \frac{M_B g - \mu_k M_A g}{(M_A + M_B)} = \frac{1}{2}(1 - \mu_k)g = \frac{1}{2}(0.8)9.8 = 3.92 \text{ m/s}^2$$

A) 3.92 m/s^2
B) 4.65 m/s^2
C) 1.05 m/s^2
D) 2.57 m/s^2
E) 9.80 m/s^2

Q23.

At time $t = 0$ a 2.0-kg particle has a velocity of $(4.0\,\hat{\text{i}} - 3.0\,\hat{\text{j}})$ m/s. At $t = 3.0$ s its velocity is $(5.0\,\hat{\text{j}})$ m/s. During this time interval the **work done** on it was:

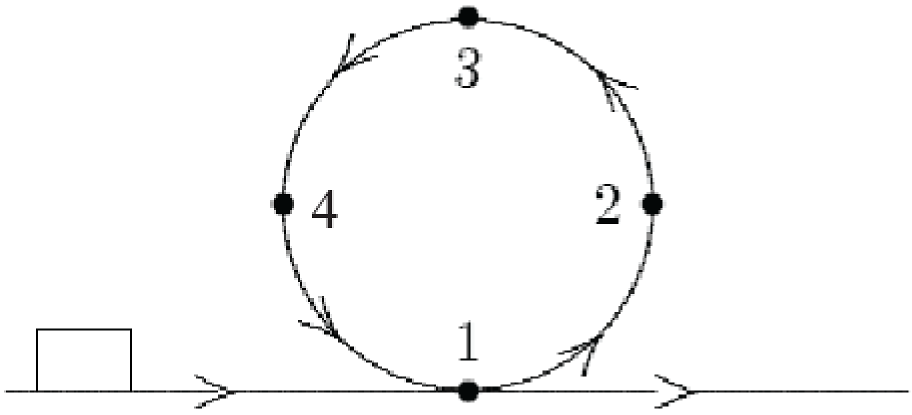
Answer:

$$W = \Delta K = \frac{m}{2}(v_f^2 - v_i^2) = \frac{m}{2}\left[(5.0\,\hat{\text{j}})^2 - (4.0\,\hat{\text{i}} - 3.0\,\hat{\text{j}})^2\right] = 0$$

A) 0 J
B) 2.0 J
C) 25 J
D) 50 J
E) 12 J

Q24.
A block is moving along a frictionless horizontal track when it enters the circular vertical loop as shown in **Figure 16**. The block passes points 1, 2, 3, 4, 1 before returning to the horizontal track. Which one of the following statements describes the block at point 3 correctly?

Fig#



A) Its speed is a minimum
B) The forces on it are balanced
C) It is not accelerating
D) Its mechanical energy is a minimum
E) It experiences a net upward force

Q25.
A block of mass $m = 4.0$ kg, initially moving to the right on a horizontal frictionless surface at a speed $v = 2.0$ m/s, is heading towards a spring of spring constant $k = 200$ N/m. At the instant when the kinetic energy of the block is equal to the potential energy of the spring, the spring is compressed by a distance of:

Answer:

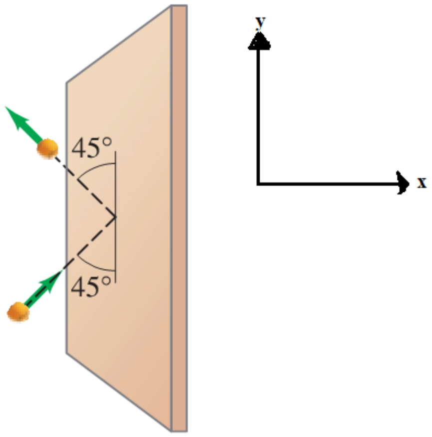
$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 + \frac{1}{2}kx^2 = kx^2$$

$$\Rightarrow \quad x = \sqrt{\frac{mv^2}{2k}} = \sqrt{\frac{4\times 4}{2\times 200}} = 0.2 \text{ m} = 20 \text{ cm}$$

A) 20 cm
B) 10 cm
C) 15 cm
D) 5.0 cm
E) 100 cm

Q26.
A tennis ball of mass m = 0.060 kg and speed 25 m/s strikes a wall at 45^{o} angle and rebound with the same speed at 45^{o} as shown in **Figure 17**. What is the magnitude and direction of the impulse given to the ball?

Fig#



Answer:

$$\Delta p = mv_{final} - mv_{initial} = m(-v \sin 45^{o} - v \sin 45^{o})\,\hat{x} = -2mv \sin 45^{o}\,\hat{x} = -2.12\,\hat{x}$$

A) 2.1 kg .m /s , negative x-axis
B) 5.4 kg. m/s , negative x-axis
C) 1.0 kg .m/s, positive x-axis
D) 2.1 kg. m/s, positive y-axis
E) 5.4 kg.m/s, negative y-axis

Sec# Center of Mass and Linear Momentum - Collision and Impulse
Grade# 50

Q27.
If the total momentum of a system is changing:

A) a net external force must be acting on the system
B) particles of the system must be exerting forces on each other
C) The center of mass must be at rest
D) the center of mass must have constant velocity
E) none of the other answers

Q28.
A disc, initially rotating at an angular speed of 120 rev/min about an axis passing through its symmetry axis, slows down with constant deceleration and stops 30 s later. How many revolutions did the disc make during this 30 s interval?

Answer:

$$\Delta\theta = \frac{\omega + \omega_o}{2}\Delta t = \frac{120+0}{2}\left(\frac{30}{60}\right) = 30$$

A) 30
B) 40
C) 10
D) 15
E) 25

Q29.
A disk has a radius of 1.90 m. An applied torque of 96.0 N· m gives the disk an angular acceleration of 6.20 rad/s^2 about its central axis. What is the mass of the disk?

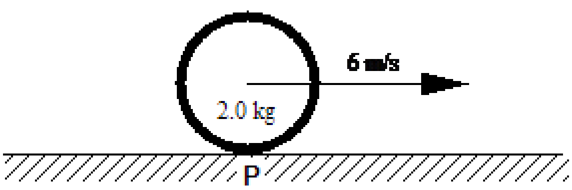
Answer:

$$\tau_o = I_o\alpha \Rightarrow 960 = \frac{1}{2}MR^2\alpha \Rightarrow M = \frac{2\times 960}{R^2\alpha} = \frac{2\times 96.0}{(1.9)^2\,6.2} = 8.578 \text{ kg}$$

A) 8.58 kg
B) 21.5 kg
C) 14.3 kg
D) 110 kg
E) 172 kg

Q30.
Figure 18 shows a hoop with mass M = 2.0 kg rolling without slipping on a horizontal surface so that its center proceeds to the right with a constant speed of 6.0 m/s. Which one of the following statements is **true** concerning the direction of angular momentum of this hoop about the contact point P?

Fig#



A) It points into the paper.
B) It points out of the paper.
C) It points to the left.
D) It points to the right
E) It points up.