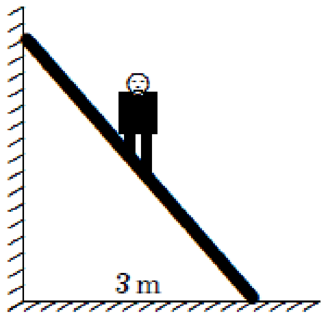
Solution to phys101-T112-Final Exam

Q1. An 800-N man stands halfway up a 5.0-m long ladder of negligible weight. The base of the ladder is 3.0m from the wall as shown in **Figure 1**. Assuming that the wall-ladder contact is frictionless, then the magnitude of normal force of the wall on the ladder is:

Fig#



Answer:
The moment about the lower contact point gives:

$$mg\,(1.5) = N\,(4) \Rightarrow N = 300 \text{ N}$$

A) 300 N
B) 150N
C) 400 N
D) 600 N
E) 800 N

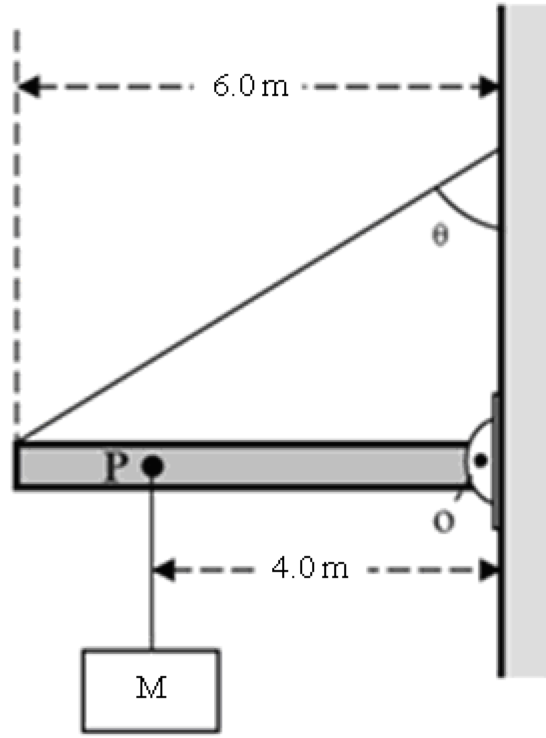
Q2. A cube with edges exactly 2.0 m long is made of material with a bulk modulus of 3.5 $\times 10^9$ N/m^2. When it is subjected to a pressure of 7.0 $\times$ 10^5 Pa its change in the volume is:

Answer:

$$B = -\frac{P}{\Delta V / V} \Rightarrow \Delta V = -\frac{PV}{B} = -\frac{7.0 \text{ x } 10^5 \times 8}{3.5\text{x}10^9} = -1.6\times10^{-3} \text{ m}^3$$

A) -1.6×10^{-3} m^3
B) -1.2×10^{-3} m^3
C) -3.2×10^{-3} m^3
D) -4.8×10^{-4} m^3
E) -8.0×10^{-4} m^3

Q3. A uniform beam of length 6.0 m and mass 150 kg is pivoted to a vertical wall at point O and is suspended horizontally by a rope of negligible mass making an angle $\theta = 60°$ with the wall as shown in **Figure 2**. An unknown mass M is hanged at point P, 4.0 m away from the pivot point O. If the system is in equilibrium as shown with the tension in the rope equal to 2.15□10^3 N, what is the value of mass M?
Fig#

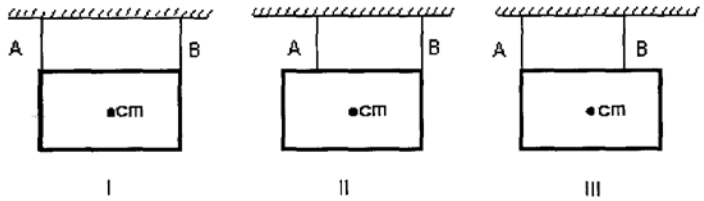


Answer:
The moment at O implies:

$$mg\,(4) + Mg\,(3) = T\ \cos\theta(6) \Rightarrow m = \frac{6\times 2.15\times 10^3 \cos 60^o - 150\times 3\times 9.8}{4\times 9.8} = 52.0\ \text{kg}$$

A) 52 kg
B) 39 kg
C) 127 kg
D) 100 kg
E) 23 kg

Q4. A picture is to be hung from the ceiling by means of two wires as shown in **Figure 3**. Order the following arrangements of the wires according to the tension in wire B, from least to greatest.
Fig#



A) II, I, III
B) I, II, III
C) III, I, II
D) I, III, II
E) III, II, I

Q5. A satellite is put in a circular orbit about Earth with radius = 8 R_E and period of T_1. The satellite had been moved to another circular orbit of radius 2 R_E , and its period became T_2 . The ratio T_1 / T_2 will be equal to:

Answer:

Kepler's law implies:

$$\frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2} = \left(\frac{8}{2}\right)^{3/2} = 2^3 = 8$$

A) 8.00
B) 0.125
C) 0.250
D) 0.50
E) 4.00

Q6. A planet X has radius and mass equal to $\frac{R_E}{4}$ and $\frac{M_E}{8}$ respectively, where R_E and M_E are Earth's radius and mass. If the escape velocity of an object from the surface of Earth is 11.2 km/s, then escape velocity of the same object from the surface of the planet X would be:

Answer:

$$V_{escape} = \sqrt{\frac{2GM}{R}} \Rightarrow \frac{V_{escape}(Moon)}{V_{escape}(Earth)} = \sqrt{\frac{\frac{2GM_M}{R_M}}{\frac{2GM_E}{R_E}}} = \sqrt{\frac{M_M}{M_E}\frac{R_E}{R_M}} = \sqrt{\frac{1}{8}\frac{4}{1}} = \sqrt{\frac{1}{2}}$$

$$V_{escape}(Moon) = \frac{1}{\sqrt{2}} V_{escape}(Earth) = \frac{1}{\sqrt{2}}(11.2) = 7.92 \text{ km/s}$$

A) 7.92 km/s
B) 15.8 km/s
C) 5.60 km/s
D) 22.4 km/s
E) 1.01 km/s

Q7. In space, sphere A of mass 20.0 kg is located at the origin of an x axis and sphere B of mass 10.0 kg is located on the axis at x = 0.80 m. Sphere B is released from rest while sphere A is held at the origin. What is the kinetic energy of B when it has moved 0.20 m toward A?

Answer:

Conservation of the total energy implies:

$$-G\frac{mM}{0.8} = -G\frac{mM}{0.6} + K \Rightarrow K = GMm\left(\frac{1}{0.6} - \frac{1}{0.8}\right) = 5.6 \times 10^{-9} \text{ J}$$

A) 5.6×10^{-9} J
B) 5.0×10^{-8} J
C) 8.3×10^{-8} J
D) 3.9×10^{-9} J
E) 1.8×10^{-9} J

Q8. If the radius of a star were to reduce by 50%, while it's mass remain the same, the acceleration due to gravity on the star's surface would:

A) increase by a factor of 4
B) decrease by a factor of 4
C) increase by a factor of 8
D) decrease by a factor of 8
E) decrease by a factor of 16

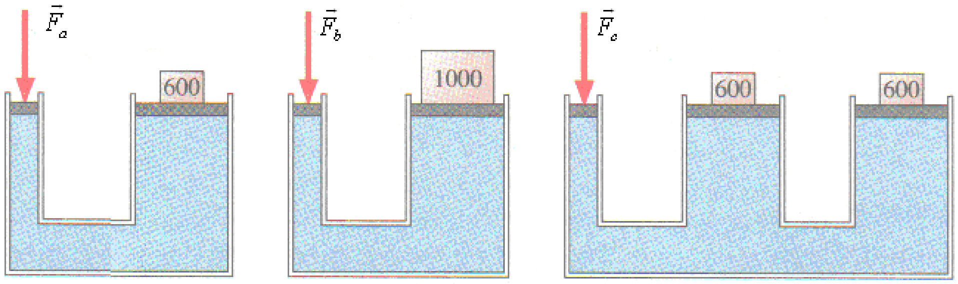
Q9. A column of oil of height 70.0 cm supports a column of an unknown liquid as suggested in the **Figure 4** (not drawn to scale). Assume that both liquids are at rest and that the density of the oil is $8.40\square10^2$ kg/m^3. Determine the density of the unknown liquid.
Fig#

Answer:

$$P_o + \rho_L g h_L = P_o + \rho_R g h_R \Rightarrow \rho_R = \frac{\rho_L h_L}{h_R} = \frac{8.40\times10^2\times70}{27} = 2.2\times10^3 \text{ kg/m}^3$$

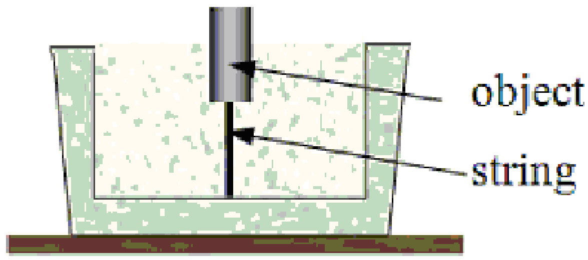
A) 2.2×10^3 kg/m^3
B) 3.3×10^2 kg/m^3
C) 2.6×10^3 kg/m^3
D) 3.6×10^3 kg/m^3
E) 4.9×10^3 kg/m^3

Q10. For the hydraulic lift systems shown in **Figure 5**, rank in order from largest to smallest, the magnitudes of the forces $\vec{F}_a$, $\vec{F}_b$ and $\vec{F}_c$ required to balance the masses? The masses are in kilograms.



A) $|\vec{F}_b| > |\vec{F}_a| = |\vec{F}_c|$
B) $|\vec{F}_a| > |\vec{F}_b| > |\vec{F}_c|$
C) $|\vec{F}_a| = |\vec{F}_b| = |\vec{F}_c|$
D) $|\vec{F}_b| < |\vec{F}_a| < |\vec{F}_c|$
E) $|\vec{F}_c| > |\vec{F}_b| > |\vec{F}_a|$

Q11. **Figure 5** shows a 2.00-kg block tied, by string, to a bottom of a container filled to the rim with water. If the displaced water has a mass of 5.00 kg, find the tension in the string.
Fig#



Answer:
Draw the free body diagram, then we can have

$$mg + T = m_w g \Rightarrow T = (m_w - m)g = (5-2)9.8 = 29.4 \quad \text{N}$$

A) 29.4 N
B) 10.2 N
C) 22.8.N
D) 7.00 N
E) 100 N

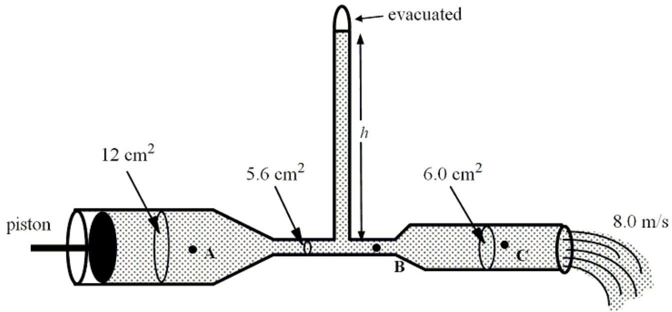
Q12. A bucket with 0.0189-m^3 is to be filled through a pipe with 0.00780 m radius. If the water flows through the pipe end with a speed of 0.610 m/s, how long does it take to fill the bucket completely?
Answer:

$$R_v = vA = \frac{dV}{dt} \quad \Rightarrow \quad dt = \frac{dV}{vA} = \frac{(0.0189)}{0.61 \times \pi \times (0.0078)^2} = \underline{162 \text{ s}}.$$

A) 162 s
B) 170 s
C) 119 s
D) 280 s
E) 490 s

Q13. A glass tube has several different cross-sectional areas with the values indicated in the **Figure 6**. A piston at the left end of the tube exerts pressure so that mercury within the tube flows from the right end with a speed of 8.0 m/s. Three points within the tube are labeled A, B, and C. What is the total pressure at point A? Atmospheric pressure is 1.01×10^5 N/m^2; and the density of mercury is 1.36×10^4 kg/m^3.

Fig#



Answer:

First use the continuity equation

$$\Rightarrow v_A A_A = v_C A_C \quad \Rightarrow \quad v_A = \left(\frac{A_C}{A_A}\right) v_C = \left(\frac{8}{12}\right) 6 = \underline{4.0 \text{ m/s}}.$$

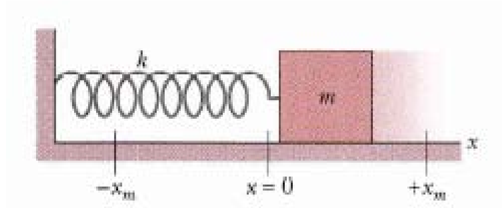
The pressures on either side of the junction must be equal. This requires:

$$p + \frac{1}{2}\rho v_A^2 = p_o + \frac{1}{2}\rho v_C^2$$

$$\Rightarrow p = p_o + \frac{1}{2}\rho\left(v_C^2 - v_A^2\right) = (1.01\times10^5) + \frac{1}{2}13600(8^2 - 4^2) = 4.27\times10^5 \text{ Pa}$$

A) 4.27×10^5 Pa
B) 2.02×10^5 Pa
C) 2.25×10^5 Pa
D) 3.26×10^5 Pa
E) 1.01×10^5 Pa

Q14. In **Figure 7**, the horizontal block-spring system has a kinetic energy of K = 5.0 J and an elastic potential energy of U = 3.0 J, when the block is at x = + 2.0 cm. What are the kinetic and elastic potential energy when the block is at $x = -x_m$?



Answer:

Conservation of total energy implies:

$$(K+U)_{x=2} = (K+U)_{x=\pm 2}$$

$$\Rightarrow 5+3 = 0+U \Rightarrow U = 8$$

A) K = 0 and U = 8J
B) K = 5J and U = 3J
C) K = 5J and U = -3 J
D) K = 8J and U = 0
E) K = 0 and U = -8 J

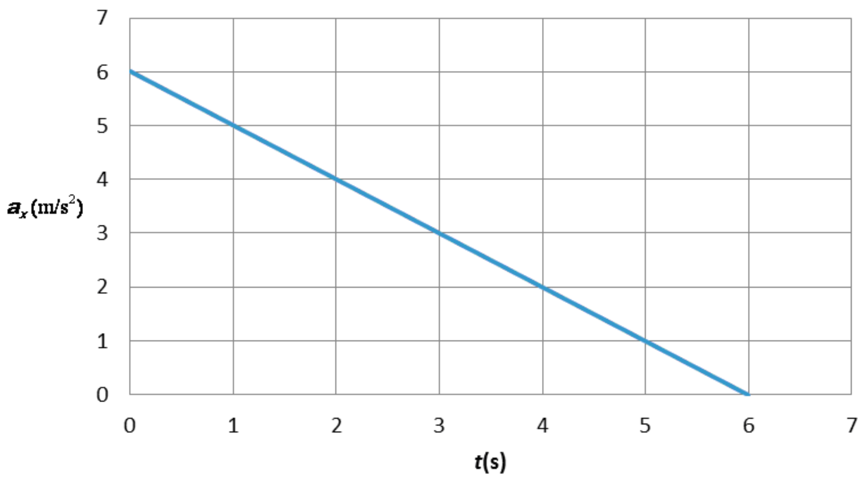
Q15. A thin rod of length L = 1.5 m and mass M is pivoted at one end of the rod and is made to oscillate as a physical pendulum with frequency f. The value of f is:

Answer:

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{mgh}{I}} = \frac{1}{2\pi}\sqrt{\frac{mg\left(L/2\right)}{\frac{1}{3}mL^2}} = \frac{1}{2\pi}\sqrt{\frac{3g}{2L}} = \frac{1}{2\pi}\sqrt{\frac{3\times 9.8}{2\times 1.5}} = 0.5 \text{ Hz}$$

A) 0.50 Hz
B) 2.5 Hz
C) 0.25 Hz
D) 1.0 Hz
E) 2.0 Hz

Q16. At $t = 0$, a particle is located at $x = 25.0$ m and has a velocity of 12.5 m/s in the positive x direction. The acceleration (a_x) of the particle varies with time (t) as shown in **Figure 8**. What is the velocity of the particle at $t = 5.00$ s?
Fig#



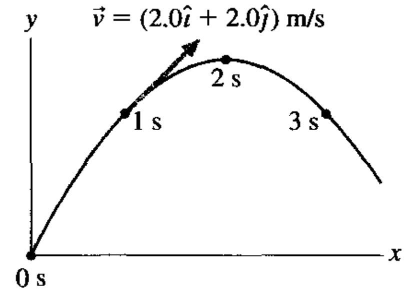
Answer:

$$v_f - v_i = area(0 \to 5s) = \frac{1}{2}(1+6)5 = 17.5$$

$$\Rightarrow v_f = v_i + 17.5 = 12.5 + 17.5 = +30.0 \text{ m/s}$$

A) +30 m/s
B) –15 m/s
C) +15 m/s
D) 0
E) –1.2 m/s

Q17. **Figure 9** shows the trajectory of ball in Planet X. The ball's position is shown at 1.0 s intervals until t = 3.0 s. At t = 1.0 s, the ball's velocity is $\left(2.00\ \hat{i} + 2.00\ \hat{j}\right)$m/s . It reaches the maximum height at t = 2.0 s. What is the value of g (in m/s^2) on this planet?



Answer

$$v_x = 2.0 \text{ m/s};$$
$$v_y(t) = v_{oy} - gt \Rightarrow v_y(2) = 2.0 - g(1) = 0$$
$$\Rightarrow g = 2 \text{ m/s}^2$$

A) 2
B) 3
C) 4
D) 9.8
E) 1

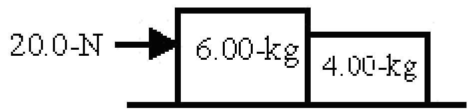
Q18. A 2.00-kg stone is tied to a 0.500-m string and whirled at a constant speed of 4.00 m/s in a vertical circle. The tension in the string at the bottom of the circle is:
Answer:
At the bottom of the circle the free body diagram implies:

$$m\frac{v^2}{r} = T - mg \Rightarrow T = mg + m\frac{v^2}{r} = 2(9.8 + \frac{4^2}{0.5}) = 83.6 \text{ N, up}$$

A) 83.6 N, up
B) 44.4 N, up
C) 9.80 N, up
D) 44.4 N, down
E) 83.6 N, down

Q19. A 6.00-kg block is in contact with a 4.00-kg block on a frictionless surface as shown in **Figure 10**. The 6.00-kg block is being pushed by a 20.0-N force toward the 4.00-kg block. What is the magnitude of the force of the 6.00-kg block on the 4.00-kg block

Fig#



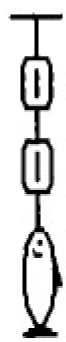
Answer:

$$ma = F \Rightarrow 10\,a = 20 \Rightarrow a = 2\ \mathrm{m/s^2},$$
$$\Rightarrow F_{4,6} = 4\,a = 8\ \mathrm{N}$$

A) 8.00 N
B) 12.0 N
C) 6.00 N
D) 4.00 N
E) 10.0 N

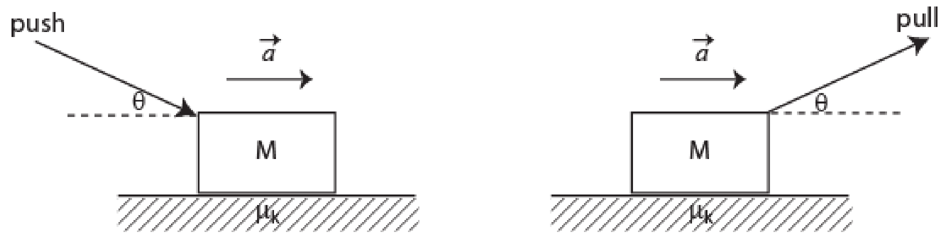
Q20. A 16-kg fish is weighed with two identical, massless, spring scales, each of negligible weight, as shown in **Figure 11**. What will be the readings on the scales?

Fig#



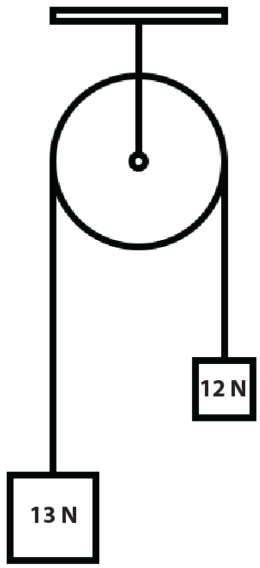
A) The sum of the two readings will be 32 kg
B) The bottom scale will read 16 kg, and the top scale will read zero
C) The top scale will read 16 kg, and the bottom scale will read zero.
D) Each scale will show a reading greater than zero and less than 16 kg, but the sum of the two readings will be 16 kg
E) Each scale will read 8 kg.

Q21. When you travel, you always exert less force to pull a block M instead of pushing it, see **Figure 12**. That is F(pull) < F(push). Why?
Fig#



A) Because the normal force becomes less while pulling
B) Because the normal force becomes more while pulling
C) Because the normal force becomes zero while pulling
D) Because the gravitational forces decreases while pulling
E) No scientific reason it is just a habit.

Q22. A 13-N weight and a 12-N weight are connected by a massless string over a massless, frictionless pulley as shown in **Figure 13**. The downward acceleration of 13-N weight is: (g is acceleration due to gravity)



Answer:

$$a = \frac{(m_2 - m_1)}{(m_2 + m_1)} g = \frac{1}{25} g$$

A) g/25
B) g/12
C) g/13
D) g
E) g/2

Q23. At t = 0, a force F acts on 2-kg particle that has an initial velocity of $\left(4.0\,\hat{i} - 3.0\,\hat{j}\right)$ m/s . The velocity became $\left(2.0\,\hat{i} + 3.0\,\hat{j}\right)$ m/s at t = 3 s. During this time interval the work done by the external force was:

Answer:

$$W = \Delta K = \frac{m}{2}\left(v_f^2 - v_i^2\right) = \frac{2}{2}(13 - 25) = -12 \text{ J}$$

A) –12 J
B) – 4 J
C) –18 J
D) – 40 J
E) $\left(4.0\,\hat{i} + 36.0\,\hat{j}\right)$ J

Q24. A 2.0-kg block is attached to a horizontal ideal spring with a spring constant of 200 N/m. When the spring in its equilibrium position, the block is given a speed of 5.0 m/s. What is the maximum **extension** of the spring?

Answer:

$$\frac{m}{2}\left(v_i^2\right) = \frac{1}{2}kx^2 \Rightarrow x = \pm v\sqrt{\frac{m}{k}} = 5\sqrt{\frac{2}{200}} = 0.5 \text{ m}$$

A) 0.50 m
B) 0.05 m
C) 0.25 m
D) 10 m
E) 0.12 m

Q25. At $t = 0$, a horse pulls a cart with a force of 180 N at an angle of 30° above the horizontal and moves horizontally at a speed of 1.20 m/s. What is the instantaneous power (in Watts) of the force at $t = 0$?

Answer:

$$P = \vec{F}\vec{v} = 180 \times 1.2\cos 30^o = 187 \text{ Watts}$$

A) 187
B) 150
C) 108
D) 216
E) 0

Q26. Particle 1 with mass 2.0 kg and velocity $v_{1i} = \left(5.0\,\hat{i}\right)$ m/s m/s undergoes a one-dimensional elastic collision with particle 2 with mass 2.0 kg and velocity $v_{2i} = \left(-6.0\,\hat{i}\right)$ m/s. After the collision, the final velocities of particle 1 (v_{1f}) and particle 2 (v_{2f}) are:

Answer:

Use the equations in the formula sheet, we can have:

v1f = (- 6.0 i) m/s, v2f = (5.0 i) m/s

A) $v_{1f} = \left(-6.0\,\hat{i}\right)$ m/s, $v_{2f} = \left(5.0\,\hat{i}\right)$ m/s
B) $v_{1f} = \left(6.0\,\hat{i}\right)$ m/s, $v_{2f} = \left(-5.0\,\hat{i}\right)$ m/s
C) $v_{1f} = \left(-11.0\,\hat{i}\right)$ m/s, $v_{2f} = \left(0.0\,\hat{i}\right)$ m/s
D) $v_{1f} = \left(0.0\,\hat{i}\right)$ m/s, $v_{2f} = \left(11.0\,\hat{i}\right)$ m/s
E) $v_{1f} = \left(-6.0\,\hat{i}\right)$ m/s, $v_{2f} = \left(-5.0\,\hat{i}\right)$ m/s

Q27. A 2.00 kg particle has the xy coordinates (-1.20 m, 0.500 m), and a 4.00 kg particle has the xy coordinates (0.600 m, -1.0 m). Both lie on a horizontal plane. At what (x,y) coordinates must you place a 3.00 kg particle such that the center of mass of the three-particle system has the coordinates (0.00 m, 0.00 m)?

Answer:

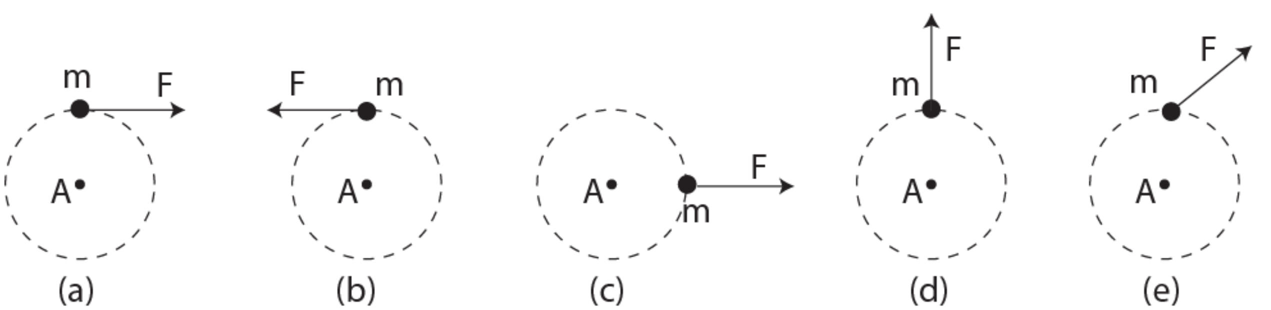
$$X_{com} = \frac{m_1 x_1 + m_2 x_2 + m_3 x_3}{m_1 + m_2 + m_3} \Rightarrow 0 = \frac{2(-1.2) + 4(0.6) + 3x_3}{2+4+3} \Rightarrow x_3 = 0$$

$$y_{com} = \frac{m_1 y_1 + m_2 y_2 + m_3 y_3}{m_1 + m_2 + m_3} \Rightarrow 0 = \frac{2(0.5) + 4(-1.0) + 3y_3}{2+4+3} \Rightarrow y_3 = 1\text{ m}$$

A) (0.0, 1.0) m
B) (1.0, 2.0) m
C) (0.5, -1.0) m
D) (-1.2, 1.0) m
E) (-0.5, -1.5) m

Q28. Five objects of mass m are under a force F at a distance from an axis of rotation perpendicular to the page through the point A, as shown in **Figure 14**. The one (or ones) that has zero torque about the axes through A is:

Fig#



A) c, d
B) b, a
C) a, e
D) d
E) e

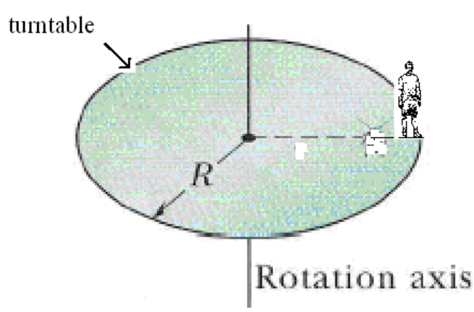
Q29. A wheel rotates through an angle of 315° as it slows down uniformly from 90.0 rev/min to 30.0 rev/min. What is the magnitude of the angular acceleration of the wheel?

Answer:

$$\omega_f^2 = \omega_i^2 + 2\alpha(\Delta\theta) \Rightarrow \alpha = \frac{\omega_f^2 - \omega_i^2}{2\Delta\theta} = \frac{\left(\frac{90\times 2\pi}{60}\right)^2 - \left(\frac{30\times 2\pi}{60}\right)^2}{2\left(\frac{315\times 2\pi}{360}\right)} = 7.18\ \text{rad/s}^2$$

A) 7.18 rad/s^2
B) 2.34 rad/s2
C) 6.50 rad/s2
D) 8.35 rad/s2
E) 10.9 rad/s2

Q30. Figure XX shows a boy of mass M= 50 kg stands at rest on the rim of a stationary turntable holding a rock of mass 2.0 kg in his hand. The turntable has a radius of R =1.2 m and a rotational inertia of I = 36 kg·m^2 about its axis. The boy then throws the rock horizontally in a direction tangent to the rim of the disk. Now the turntable starts to rotate with the boy with an angular speed of ω. If the speed of the rock relative to the ground is 5.0 m/s, find ω.



Answer:

Conservation of angular momentum implies:

$$L_i = L_f$$

Mvr (rock) + Iw (disk) + m r2 (boy) =0

2 □5 □1.2 = 36□w + 50□1.2□w

Solve for w we have 0.11 rad/s

A) 0.11 rad/s
B) 0.33 rad/s
C) 0.16 rad/s
D) 0.22 rad/s
E) 0.38 rad/s