Q1.

A runner in a 100 m race leaves the starting point with a speed of 6 m/s and accelerates at a constant rate. He attains his maximum speed of 10 m/s after 40 meters, and then continues at that speed for the rest of the race. His time for the whole race is:

A) 11 seconds
B) 8 seconds
C) 21 seconds
D) 5 seconds
E) 15 seconds

Ans:

$$40 = \frac{6+10}{2} t_1 \rightarrow t_1 = \frac{40}{8} = 5\ s$$

$$t_2 = \frac{60}{10} = 6\ s$$

$$t = t_1 + t_2 = 5 + 6 = 11\ s$$

Q2.

Ahmad, Mahmoud, and Fahd are standing in a field. Mahmoud is 14.0 m due West of Ahmad. Fahd is 36.0 m from Mahmoud in a direction 37^o South of East from Mahmoud's location. How far is Fahd from Ahmad?

A) 26.2 m
B) 50.0 m
C) 22.0 m
D) 38.6 m
E) 47.9 m

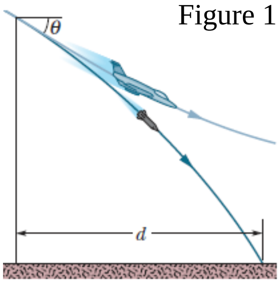
Ans:

$$d = \sqrt{14^2 + 36^2 - 2 \times 14 \times 36 \times \cos(37^o)} = 26.2\ m$$

Q3.

A jet fighter has a speed of 290.0 km/h and is diving at an angle of $\theta = 30^o$ below the horizontal when the pilot releases a missile (**Figure 1**). The horizontal distance between the release point and the point where the missile strikes the ground is d = 700 m. How high was the release point?

Figure 1



A) 897 m
B) 768 m
C) 954 m
D) 776 m
E) 966 m

Ans:

$$v_0 = 290 \frac{km}{h}\ ;\ \theta = -30^o$$

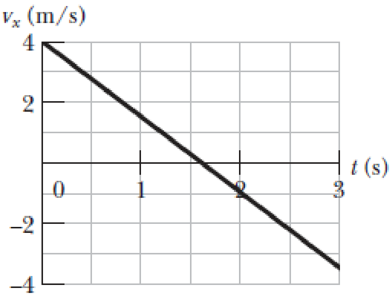
$$d = 700\ m = v_0 \times cos(\theta) \times t \rightarrow t = \frac{700}{v_0 \times cos(\theta)}$$

$$0 - y_0 = v_0 \times sin(\theta) \times t - \frac{1}{2} g t^2 \rightarrow y_0 = 897\ m$$

Q4.

A box of mass 5.00 kg is sent sliding up a frictionless ramp at an angle of θ to the horizontal. **Figure 2** gives, as a function of time t, the component v_x of the box's velocity along an x axis that extends directly up the ramp. What is the magnitude of the normal force on the box from the ramp?

Figure 2



A) 47.4 N
B) 55.9 N
C) 34.9 N
D) 25.7 N
E) 49.0 N

Ans:

$$a = -g \times sin(\theta) = -2.50 \frac{m}{s^2} \rightarrow \theta = 14.8^o$$

$$F_N = mg \times cos(\theta) = 47.4\ N$$

Q5.

An initially stationary box of sand is to be pulled across a floor by means of a cable in which the tension should not exceed 1100 N. The coefficient of static friction between the box and the floor is 0.35. What should be the angle between the cable and the horizontal in order to pull the greatest possible amount of sand?

A) 19^o
B) 15^o
C) 29^o
D) 31^o
E) 27^o

Ans:

$$Along\ x: T \times cos(\theta) - f = m \times a$$

$$Along\ y: T \times sin(\theta) + F_N - m \times g = 0$$

$$a = 0;\ f = f_{s,max} = \mu_S F_N$$

$$m = \frac{T}{g}\left(cos(\theta) + \frac{sin(\theta)}{\mu_S}\right)$$

$$\frac{dm}{d\theta} = 0 = \frac{T}{g}\left(cos(\theta_m) - \frac{sin(\theta_m)}{\mu_S}\right) \rightarrow tan(\theta_m) = \mu_S \rightarrow \theta_m = 19^o$$

Q6.

A man is pulling a box on a rough surface at constant velocity by applying a force $\vec{F}$ that makes an angle of 60^o with the horizontal. If the friction force does 200 J of work on the box as the box is moved 8.0 m, what is the magnitude of the force $\vec{F}$?

A) 50 N
B) 20 N
C) 80 N
D) 16 N
E) 40 N

Ans:

$$F \times cos(60^o) \times 8 = 200 \rightarrow F = 50\ N$$

Q7.

A 0.30 kg object is tied to a string with length 2.5 m; the other end of the string is tied to a rigid support. The object is held straight out horizontally from the point of support, with the string pulled taut (stretched), and is then released. What is the speed of the object at the lowest point of its motion?

A) 7.0 m/s
B) 5.0 m/s
C) 3.0 m/s
D) 2.5 m/s
E) 9.0 m/s

Ans:

$$\frac{1}{2}mv^2 = mgh \rightarrow v = \sqrt{2gh} = 7.0\ m/s$$

Q8.

A chair is pulled away as a person is moving downward to sit on it, causing the victim to land on the floor. Suppose the person falls by 0.50 m, the mass that moves downward is 70 kg, and the collision on the floor lasts 0.082 s. What is the average force acting on the victim from the floor during the collision?

A) 2.7×10^3 N
B) 3.9×10^3 N
C) 5.2×10^3 N
D) 1.9×10^3 N
E) 4.6×10^3 N

Ans:

$$mgh = \frac{1}{2}mv^2 \rightarrow v = \sqrt{2gh}$$

$$Impulse = \Delta p = mv = m \times \sqrt{2gh}$$

$$\bar{F} = \frac{\Delta p}{\Delta t} = \frac{m \times \sqrt{2gh}}{\Delta t} = 2.7 \times 10^3\ N$$

Q9.

A meter stick is held vertically with one end on the floor and is then allowed to fall. Find the speed of the other end just before it hits the floor, assuming that the end on the floor doe not slip. Consider the stick to be a thin rod.

A) 5.42 m/s
B) 3.45 m/s
C) 2.59 m/s
D) 4.87 m/s
E) 6.27 m/s

Ans:

$$\frac{1}{2}mgl = \frac{1}{2}I\omega^2 \rightarrow \omega = \sqrt{\frac{mgl}{I}}$$

$$v = \omega l = \sqrt{\frac{mgl^3}{I}}$$

$$I = \frac{1}{3}ml^2 \rightarrow v = \sqrt{3gl} = 5.42\ m/s$$

Q10.

A particle, located at $\vec{r} = 6\hat{i} + 8\hat{j}$, is acted upon by a force $\vec{F} = (-30\hat{i} + 40\hat{j})$ N. What is the torque acting on the particle about a point at $x = 12$ m on the x axis?

A) Zero
B) $(480\hat{k})$ N.m
C) $-(480\hat{k})$ N.m
D) $(500\hat{k})$ N.m
E) $-(500\hat{k})$ N.m

Ans:

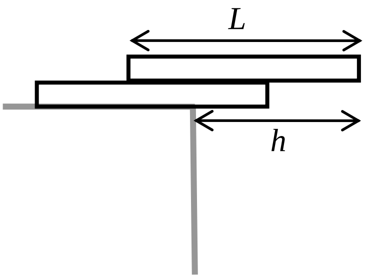
$$\vec{\tau} = (\vec{r} - \vec{r}_0) \times \vec{F} = (6\hat{\imath} + 8\hat{\jmath} - 12\hat{\imath}) \times (-30\hat{\imath} + 40\hat{\jmath}) = 0$$

Q11.

Two uniform and identical bricks of length L are stacked on top of one another as shown in **Figure 3**. In terms of L, what is the maximum overhang h such that the stack is in equilibrium?

A) $3L/4$
B) $7L/8$
C) $L/2$
D) $5L/6$
E) $2L/3$

Figure 3



Ans:

A

Q12.

Khalifa Towers in Dubai is one of the tallest buildings in the world. Its center of gravity (c.g.) is:

A) a little below its center of mass
B) a little above its center of mass
C) exactly on its center of mass
D) close to the top of the building
E) below the first floor

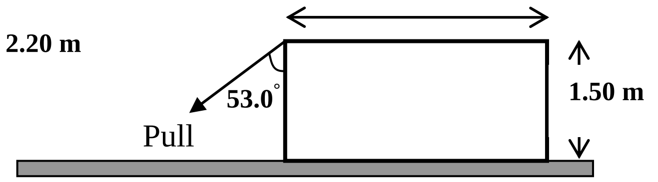
Ans:

A

Q13.

A worker wants to turn over a uniform, 1250 N, rectangular crate by pulling at 53^o on one of its vertical sides, as shown in **Figure 4**. The floor is rough to prevent the crate from slipping. What pull is needed to just start the crate to tip?

Figure 4



A) 1.15×10^3 N
B) 2.25×10^3 N
C) 3.35×10^3 N
D) 4.45×10^3 N
E) 5.55×10^3 N

Ans:

$$-1250\times\frac{2.20}{2}+Pull\times sin(53^o)\times1.50=0\rightarrow Pull=1.15\times10^3 N$$

Q14.

In **Figure 5**, three 5.00 kg spheres are located at distances d_1 = 0.300 m and d_2 = 0.400 m. What are the magnitude and direction (relative to the positive direction of the x axis) of the net gravitational force on sphere B due to spheres A and C?

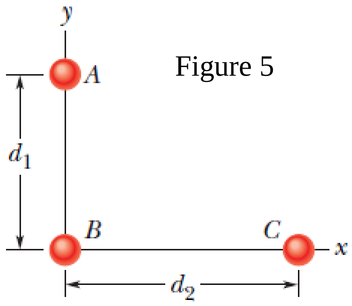


Figure 5

A) 2.13×10^{-8} N, 60.6°
B) 1.13×10^{-8} N, 60.6°
C) 3.13×10^{-8} N, 60.6°
D) 4.13×10^{-8} N, 30.3°
E) 2.13×10^{-8} N, 30.3°

Ans:

$$Using\ F = \frac{GmM}{r^2}\ we\ find$$

$$Upward\ force\ on\ B\ at\ origin = 1.85 \times 10^{-8}\ N$$

$$Rightward\ force\ on\ B\ at\ origin = 1.04 \times 10^{-8} N$$

$$Coverting\ to\ polar\ coordinates\ (magnitude, angle)\ we\ get$$

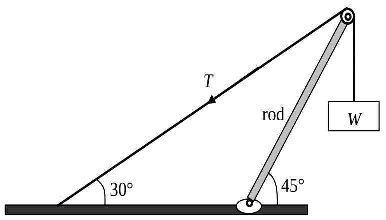
$$Magnitude\ of\ force = 2.13 \times 10^{-8}\ N$$

$$Direction\ of\ force\ wrt + x\ axis = 60.6^o$$

Q15.

In the arrangement of **Figure 6**, let W be the weight of the suspended box. The strut (rod) is uniform and has weight W also. The tension T in the cable in terms of W is:

Figure 6



A) 4.1W
B) 3.1W
C) 2.1W
D) 1.1W
E) 5.1W

Ans:

Let L be the length of the rod.

$$T \times sin(15^o) \times L = W \times cos(45^o) \times \left(\frac{L}{2} + L\right) \rightarrow T = 4.1W$$

Q16.

A 2.0 m long steel rod has a cross sectional area of 0.30 cm^2. It is hung by the upper end from a support, and a 550 kg object is hung from its lower end. What is the elongation of the rod? Young's modulus of steel is 20×10^{10} Pa.

A) 1.8 mm
B) 2.8 mm
C) 3.8 mm
D) 4.8 mm
E) 5.8 mm

Ans:

$$Y=\frac{F/A}{\Delta L/L}\rightarrow \Delta L=\frac{F}{A}\times\frac{L}{Y}=1.8\ mm$$

Q17.

The Sun and Earth each exert a gravitational force on the Moon. What is the ratio F_{Sun}/F_{Earth} of these two forces? (Mass of Sun = 1.99×10^{30} kg, Mass of Earth = 5.98×10^{24} kg, Average Sun-Moon distance = 1.50×10^{11} m, Average Earth-Moon distance = 3.82×10^{8} m)

A) 2.16
B) 3.16
C) 4.16
D) 5.16
E) 6.16

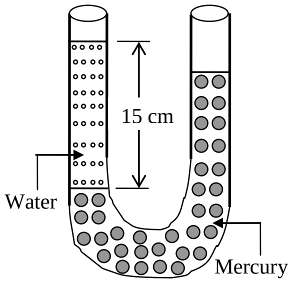
Ans:

$$\frac{F_{Sun}}{F_{Earth}}=\frac{M_S}{M_E}\times\left(\frac{R_{EM}}{R_{SM}}\right)^2=2.16$$

Q18.

Figure 7 shows a U-shaped tube open to the air at both ends. The tube contains some mercury (density = 13.6×10^{3} kg/m^3). A quantity of water is carefully poured into the left arm of the tube until the vertical height of the water column is 15.0 cm. What is the gauge pressure at the water-mercury interface?

Figure 7



A) 1470 Pa
B) 2581 Pa
C) 3690 Pa
D) 4701 Pa
E) 5812 Pa

Ans:

$$p=p_A+\rho gh\rightarrow p-p_A=1470\ Pa=Gauge\ Pressure$$

Q19.

One model of a certain planet has a core of radius R and mass M surrounded by an outer shell of inner radius R, outer radius $2R$, and mass $4M$. If $M = 4.1\times10^{24}$ kg and $R = 6.0\times10^{6}$ m, what is the gravitational acceleration of a particle at points R and $3R$ from the center of the planet?

A) 7.6 m/s^2, 4.2 m/s^2
B) 8.6 m/s^2, 4.2 m/s^2
C) 9.6 m/s^2, 4.2 m/s^2
D) 7.6 m/s^2, 5.2 m/s^2
E) 7.6 m/s^2, 6.2 m/s^2

Ans:

$$a_g = \frac{GM}{R^2} = 7.6\frac{m}{s^2};\ a_g = \frac{G(5M)}{(3R)^2} = 4.2\ m/s^2$$

Q20.

The Martial satellite Phobos travels in an approximately circular orbit of radius 9.4×10^{6} m with a period of 7 h 39 min. Calculate the mass of Mars from this information.

A) 6.5×10^{23} kg
B) 7.5×10^{23} kg
C) 8.5×10^{23} kg
D) 9.5×10^{23} kg
E) 5.5×10^{23} kg

Ans:

$$M = \frac{4\pi^2 r^3}{GT^2} = 6.5\times10^{23}\ kg$$

Q21.

A rock is suspended by a light string. When the rock is in air, the tension in the string is 39.2 N. When the rock is totally immersed in water, the tension is 28.4 N. When the rock is totally immersed in an unknown liquid, the tension is 18.6 N. The density of the unknown liquid is:

A) 1.91×10^{3} kg/m^3
B) 2.82×10^{3} kg/m^3
C) 3.73×10^{3} kg/m^3
D) 4.64×10^{3} kg/m^3
E) 5.55×10^{3} kg/m^3

Ans:

$$\rho_W Vg = 39.2\ N - 28.4\ N = 10.8\ N$$

$$\rho_x Vg = 39.2\ N - 18.6\ N = 20.8\ N$$

$$\rightarrow \rho_x = 1.91\times10^{3} kg/m^3$$

Q22.

An open water tank has a small hole of cross sectional area 0.5 mm^2 in its wall at a depth of 0.6 m below the open water surface in the tank. The volume of water per second leaving the tank is:

A) 1.71×10^{-6} m^3/s
B) 2.68×10^{-6} m^3/s
C) 3.79×10^{-6} m^3/s
D) 4.80×10^{-6} m^3/s
E) 5.91×10^{-6} m^3/s

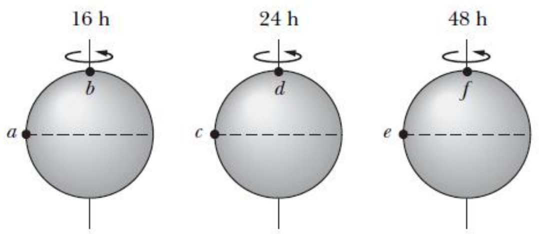
Ans:

$$\frac{1}{2}\rho v^2 = \rho g h \rightarrow v = \sqrt{2gh} = 3.44\frac{m}{s}$$
$$R = A \times v = 1.71 \times 10^{-6} m^3/s$$

Q23.

Figure 8 shows three uniform spherical planets that are identical in size and mass. The periods of rotation T for the planets are given, and six lettered points are indicated, three points on the equators of the planets and three points are on the north poles. Rank the points according to the value of the free-fall acceleration g, greated first.

Figure 8



A) *b and d and f tie, e, c, a*
B) *b and d and f tie, c, e, a*
C) *b and d and f tie, e, a, c*
D) *e, c, a, b and d and f tie*
E) *a, c, e, b and d and f tie*

Ans:

$$g = \frac{GM}{R^2} - \frac{2\pi}{T}R^2 \rightarrow (A)\ \ b\ and\ d\ and\ f\ tie, e, c, a$$

Q24.

If the part of the iceberg that extends above the water were suddenly removed

A) the buoyant force on the iceberg would decrease
B) the iceberg would sink
C) the density of the iceberg would change
D) the pressure on the bottom of the iceberg would increase
E) none of the others

Ans:

A

Q25.

Air flows over the upper surface of an aircraft's wing at a speed of 135 m/s and under the lower surface at a speed of 120 m/s. The total wing area is 28 m^2. What is the lift on the wing? (Density of air = 1.20 kg/m^3)

A) 64.3 kN
B) 75.4 kN
C) 86.5 kN
D) 97.6 kN
E) 98.7 kN

Ans:

$$p_A + \frac{1}{2}\rho v_u^2 = p_l + \frac{1}{2}\rho v_d^2 \rightarrow F = (p_l - p_u) \times A = \frac{\rho}{2}(v_u^2 - v_l^2)A = 64.3\ kN$$

Q26.

Which of the following relationships between the acceleration a and the displacement x of a particle involve SHM? (a) $a = 0.5x$, (b) $a = 400x^2$, (c) $a = -20x$, (d) $a = -3x^2$

A) c
B) a
C) b
D) d
E) None of the others

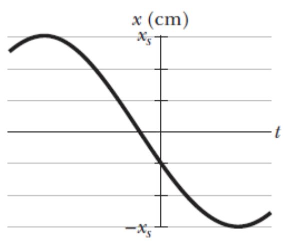
Ans:

A (c) a = -20 x

Q27.

What is the phase constant for the harmonic oscillator with the position function $x(t)$ given in **Figure 9** if the position function has the form $x(t) = x_m \cos(\omega t + \varphi)$? The vertical axis scale is set by $x_s = 6.0$ cm.

Figure 9



A) + 1.91 rad
B) + 2.02 rad
C) + 3.13 rad
D) + 4.24 rad
E) + 5.35 rad

Ans:

$x(0) = 6 \times cos(\varphi) = -2$

$\dot{x}(0) = -6 \times \omega \times sin(\varphi) < 0$

$\rightarrow \varphi = +1.91\ rad$

Q28.

Two particles execute simple harmonic motion of the same amplitude and frequency along close parallel lines. They pass each other moving in opposite directions each time their displacement is half their amplitude. What is their phase difference?

A) $2\pi/3$
B) $3\pi/4$
C) $5\pi/6$
D) $\pi/3$
E) $4\pi/3$

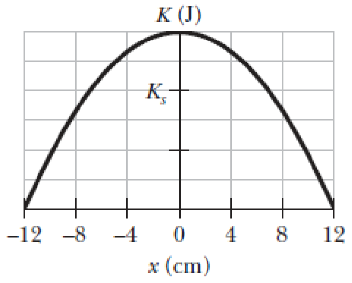
Ans:

$x_1(t) = x_m \times cos(\omega t_1 + \varphi_1)$
$x_1(t_1) = \frac{x_m}{2}$
$\dot{x}_1(t_1) > 0$
$\omega t_1 + \varphi_1 = \pi/3$
$x_2(t) = x_m \times cos(\omega t_1 + \varphi_2)$
$\dot{x}_2(t_1) < 0$
$\omega t_1 + \varphi_2 = -\pi/3$
$\rightarrow \varphi_1 - \varphi_2 = 2\pi/3$

Q29.

Figure 10 shows the kinetic energy K of a simple harmonic oscillator versus its position x. The vertical axis scale is set by $K_s = 4.0$ J. What is the spring constant?

Figure 10



A) 8.3×10^2 N/m
B) 9.4×10^2 N/m
C) 7.2×10^2 N/m
D) 6.1×10^2 N/m
E) 5.0×10^2 N/m

Ans:

$\frac{1}{2}kx^2 + \frac{1}{2}mv^2 = 6\,J$

$At\ x = 0.12\,m, v = 0 \rightarrow \frac{1}{2}k(0.12\,m)^2 = 6\,J \rightarrow k = 8.3 \times 10^2\,N/m$

Q30.

A thin uniform rod (mass = 0.50 kg) swings about an axis that passes through one end of the rod and is perpendicular to the plane of the swing. The rod swings with a period of 1.5 s and an angular amplitude of 10^{o}. What is the length of the rod?

A) 0.84 m
B) 0.95 m
C) 0.73 m
D) 0.62 m
E) 0.51 m

Ans:

$$\omega = \sqrt{\frac{mgL}{2I}};\ T = \frac{2\pi}{\omega}$$

$$I = \frac{M}{3}L^2$$

$$T = 1.5\ s \rightarrow L = 0.84\ m$$
