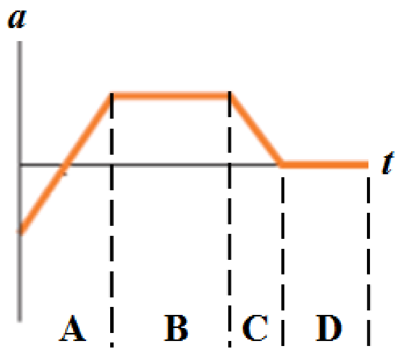
Q1.
Figure 1 is a graph of the acceleration versus time for a car moving along a horizontal axis. In which of the time intervals (A, B, C, D) indicated in the Figure does the car move at constant speed?



Solution:
Constant speed implies zero acceleration

A) D only
B) A and C
C) B and D
D) A only
E) B only

Q2.
A ball thrown vertically upward is caught by the thrower after 2.10 s at the same height of the initial point of release. Find the maximum height the ball reaches from the point of release.

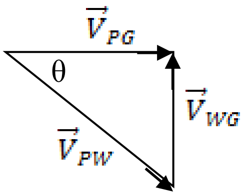
A) 5.40 m
B) 7.10 m
C) 9.20 m
D) 2.80 m
E) 4.20 m

Solution:
The time from maximum height to the point of release is 1.05 s

$$h = -y = -\frac{1}{2}gt^2 = 5.4\ m$$

Q3.
A plane moves due east relative to the ground in a steady wind whose velocity relative to the ground is 65.0 km/h due north. The plane's velocity relative to the wind has a magnitude of 215 km/h, directed at angle θ south of east. Find the angle θ.

A) 17.6°
B) 14.2°
C) 10.4°
D) 12.7°
E) 19.1°



Solution:

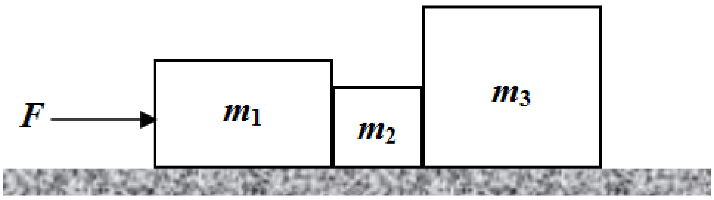
$$\sin\theta = \frac{V_{WG}}{V_{PW}} = \frac{65}{215} \Rightarrow \theta = 17.6°$$

Q4.
A particle in uniform circular motion about the origin of an *xy* coordinate system is moving clockwise with a period of 5.0 s. At one instant, its position vector (measured from the origin) is $\vec{r} = (5.0\hat{i} + 5.0\hat{j})\,\text{m}$. Which one of the following choices gives the velocity (in m/s) of the particle?

A) $6.3\hat{i} - 6.3\hat{j}$
B) $6.3\hat{i} + 6.3\hat{j}$
C) $4.5\hat{i} - 4.5\hat{j}$
D) $-4.5\hat{i} - 4.5\hat{j}$
E) $-4.5\hat{i} + 4.5\hat{j}$

Solution:
$r = \sqrt{5^2 + 5^2} = 7.07\ m$
$v = \dfrac{2\pi r}{T} = 8.9\ m/s$
Since the motion is clockwise:
$\vec{v} = 8.9\ \cos 45°\,\hat{\imath} - 8.9\ \sin 45°\hat{\jmath} = 6.3\hat{\imath} - 6.3\hat{\jmath}$

Q5.
The three blocks in **Figure 2**, with masses m_1 = 5.0 kg, m_2 = 2.0 kg and m_3 = 7.0 kg are pushed along a horizontal frictionless surface by a horizontal applied force *F* = 28 N, acting on m_1. What is the magnitude of the force from m_1 on m_2?



A) 18 N
B) 7.0 N
C) 24 N
D) 10 N
E) 14 N

Solution:
$a = \dfrac{F}{m_1 + m_2 + m_2} = 2\dfrac{m}{s^2}$
$F - F_{12} = m_1 a \ \Rightarrow\ F_{12} = 18\ N$

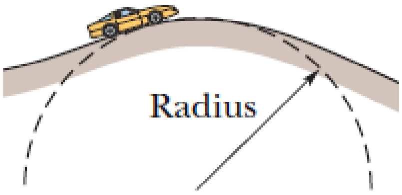
Q6.
A 30-kg box is sliding down a rough incline angled at 15° above the horizontal. The box is accelerating at 1.5 m/s^2 down the incline. What is the force of friction between the box and the incline?

A) 31 N
B) 60 N
C) 16 N
D) 39 N
E) 26 N

Solution:
$mg \sin 15° - f_k = ma \ \Rightarrow\ f_k = 31\ N$

Q7.

A car traveling at a speed of 20 m/s goes over a hill of radius 50 m as shown in **Figure 3**. What is the magnitude of the net force on the 50 kg driver at the top of the hill?



Solution:

$$F_{net} = \frac{mv^2}{r} = 400\ N$$

A) 400 N
B) 490 N
C) 890 N
D) 560 N
E) 660 N

Q8.

A force acts on a 3.0 kg particle-like object whose position is given by $x = 9.0t - 6.0\,t^2$, with x is in meters and t is in seconds. Find the work done by the force on the object in the time interval from $t = 0.0$ to $t = 4.0$ s.

A) 2.2 kJ
B) 1.4 kJ
C) 1.9 kJ
D) 0.98 kJ
E) 2.7 kJ

Solution:

$$v(t) = \frac{dx}{dt} = 9.0 - 12\,t$$

$$v(t = 0) = 9\frac{m}{s}; v(t = 4) = -39\frac{m}{s}$$

$$W = \Delta K = 2160\ J$$

Q9.

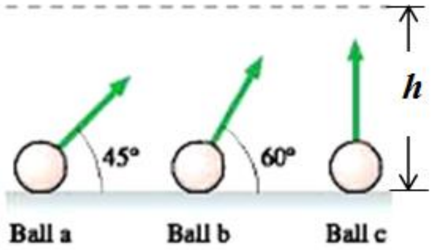
A crate (mass = 14 kg) initially moving with speed of 0.60 m/s is pushed into a horizontal rough floor with a constant force F = 40 N. After a straight-line displacement of magnitude d = 0.50 m, the speed of the crate decreases to 0.20 m/s. Find the increase in the thermal energy of the crate and the floor.

A) 22 J
B) 16 J
C) 28 J
D) 36 J
E) 40 J

Solution:

$$\Delta K = W_F + W_{th} \quad \Rightarrow \quad \Delta E_{th} = -W_{th} = W_F - \Delta K = 22.2\ J$$

Q10.
The three balls (a, b, and c) in **Figure 4**, have equal masses. They are fired from the same initial height with the same speeds but with different launching angles. Rank in order, from **largest to smallest**, the speeds of the balls v_a, v_b, and v_c, as they cross the dashed horizontal line at height h.



Solution:
Use conservation of energy

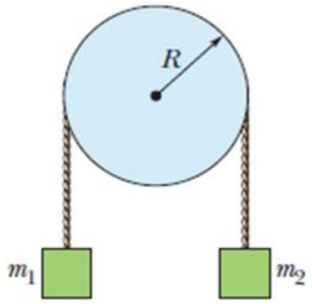
A) All the balls will have the same speed
B) v_a, v_b, v_c
C) v_a, v_c, v_b
D) v_b, v_a, v_c
E) v_c, v_a, v_b

Q11.
Two 2.0 kg objects, A and B collide with each other. Their velocities before the collision are $\vec{v}_A = (15\hat{i} + 30\hat{j})$ m/s and $\vec{v}_B = (-10\hat{i} + 5.0\hat{j})$ m/s. After the collision, the velocity of object A is $\vec{v}'_A = (-5.0\hat{i} + 20\hat{j})$ m/s. Calculate the change in the total kinetic energy of the objects due to the collision.

A) − 500 J
B) − 600 J
C) − 700 J
D) − 800 J
E) − 900 J

Solution:
From conservation of momentum, find the final velocity of particle B:
$\overrightarrow{v_B} = 10\hat{i} + 15\hat{j}$
The change in kinetic energy is $\Delta K = K_f - K_i = -500\ J$

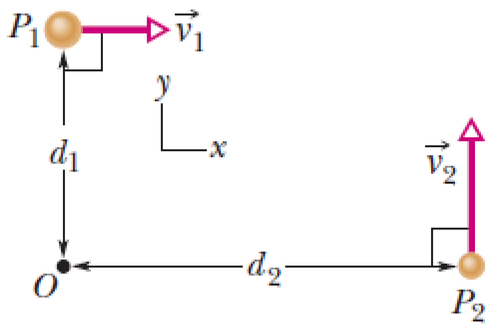
Q12.
In **Figure 5**, the two masses m_1 and m_2 are connected by a cord that goes over a pulley which is mounted on a horizontal axle with negligible friction. The pulley has a shape of a disk with mass 200 g and radius 5.0 cm. When released from rest, m_2 descends with a constant acceleration, a distance of 75 cm in 5.0 s. What is the magnitude of the net torque on the pulley?



Solution:
The magnitude of the linear acceleration of the masses is $a = -\frac{2y}{t^2} = 0.06\ m/s^2$
The net torque:
$\tau = I\alpha = \frac{1}{2}MR^2\frac{a}{R} = 3.0 \times 10^{-4}$ N.m

A) 3.0×10^{-4} N.m
B) 2.0×10^{-4} N.m
C) 4.0×10^{-4} N.m
D) 5.0×10^{-4} N.m
E) 6.0×10^{-4} N.m

Q13.
In **Figure 6**, particle P_1 has mass 6.5 kg and speed 2.2 m/s and particle P_2 has mass 3.1 kg and speed 3.6 m/s. The distance d_1 = 1.5 m and d_2 = 2.8 m. Find the magnitude of the net angular momentum of the two particles about the point O.



A) 9.8 kg.m^2/s
B) 26 kg.m^2/s
C) 21 kg.m^2/s
D) 13 kg.m^2/s
E) 6.1 kg.m^2/s

Solution:

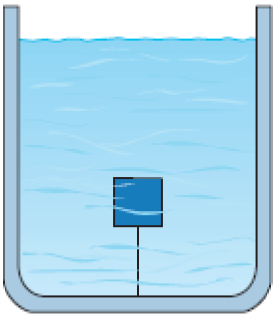
$L = m_1 r_1 v_1 - m_2 r_2 v_2 = 9.8\ kg \cdot m^2/s$

Q14.
A uniform solid sphere, of mass M = 6.00 kg and radius R, rolls smoothly from rest down a ramp at angle θ = 30.0°. What is the magnitude of the frictional force on the ball as it rolls down the ramp?

A) 8.40 N
B) 7.75 N
C) 9.22 N
D) 12.0 N
E) 15.5 N

Solution:
$f = mg\sin\theta - ma_{cm}$
Or
$\tau = I\alpha \Rightarrow f = \frac{I\alpha}{R}$

Q15.
Figure 7 shows an object completely submerged in a fluid with density ρ, and is tied with a string to the bottom of a tank. The tension in the string is one-third the weight of the object. What is the density of the object?



Solution:
$F_b = \rho V g = mg + T = \frac{4}{3}mg = \frac{4}{3}\rho_{object}Vg \Rightarrow \frac{3}{4}\rho$

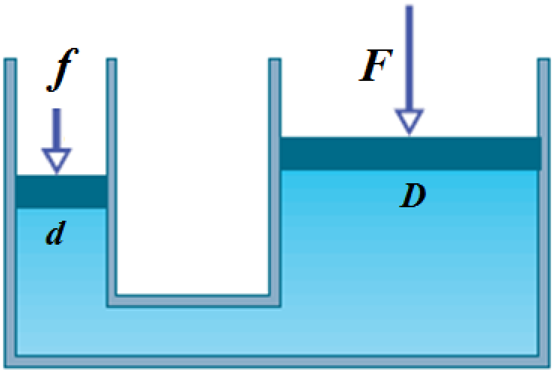
A) 3ρ/4
B) ρ/3
C) 2ρ/3
D) ρ/2
E) ρ/4

Q16.
A solid copper sphere has a radius of 85.5 cm. How much stress should be applied to the sphere to reduce the radius to 85.0 cm? The bulk modulus of copper is 1.4x10^{11} N/m^2.

A) 2.4×10^9 N/m^2
B) 4.7×10^9 N/m^2
C) 3.6×10^9 N/m^2
D) 5.8×10^9 N/m^2
E) 6.6×10^9 N/m^2

Solution:
$\frac{F}{A} = B\frac{\Delta V}{V} = 1.4\times10^{11}\frac{85.5^3 - 85^3}{85.5^3} = 2.44\times10^9 N/m^2$

Q17.
A piston of diameter d = 3.80 cm is used in a hydraulic press to exert a small force f on the enclosed liquid. A conecting pipe leads to a larger piston of diameter D = 53.0 cm. See **Figure 8**. What is the magnitude of the force f on the small piston that is needed to balance a force F = 15 kN on the large piston?

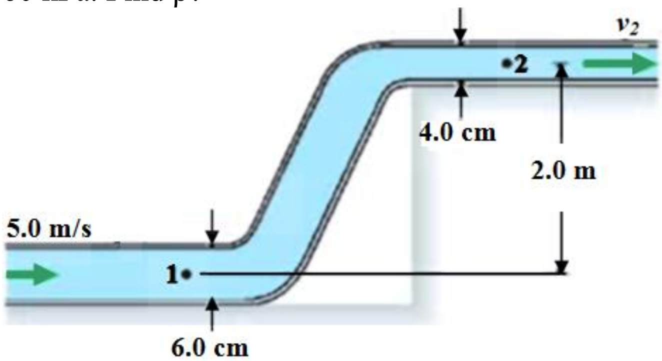


Solution:

$$\frac{f}{a} = \frac{F}{A} \Rightarrow f = 77.1\ N$$

A) 77.1 N
B) 43.5 N
C) 61.7 N
D) 59.0 N
E) 83.3 N

Q18.
A fluid of density ρ flows through the pipe shown in **Figure 9**. The fluid's speed through the lower section of the pipe is 5.0 m/s. The diameters of the lower and the upper sections of the pipe are 6.0 cm and 4.0 cm, respectively. The upper section is 2.0 m higher than the lower section, and the pressure difference between the lower and upper sections of the pipe is 60 kPa. Find ρ?



Solution:

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) + \rho g(y_2 - y_1) =$$

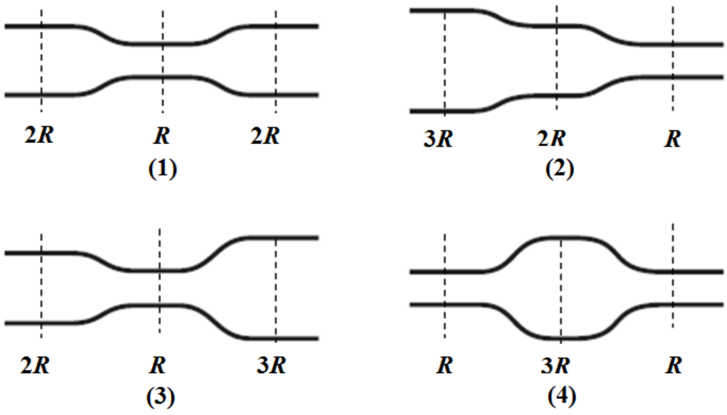
$$\rho\left[\frac{1}{2}(v_2^2 - v_1^2) + g(y_2 - y_1)\right]$$

$$\rho = \frac{P_1 - P_2}{\frac{v_1^2}{2}\left(\frac{v_2^2}{v_1^2} - 1\right) + g(y_2 - y_1)} = 853\ kg/m3$$

$$A_1v_1 = A_2v_2 \Rightarrow \frac{v_2^2}{v_1^2} = \frac{A_1^2}{A_2^2} = \frac{d_1^4}{d_2^4} = \frac{6^4}{4^4} = 5.06$$

A) 850 kg/m^3
B) 920 kg/m^3
C) 940 kg/m^3
D) 980 kg/m^3
E) 820 kg/m^3

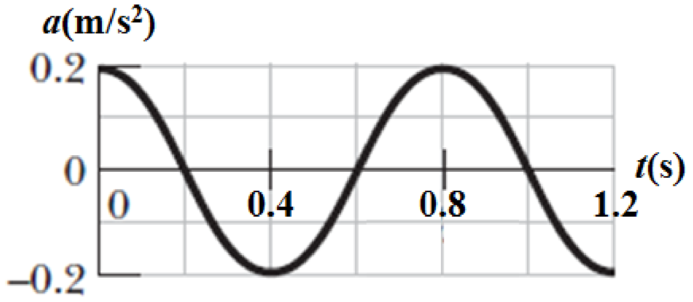
Q19.
Figure 10 shows four arrangements of pipes through which water flows smoothly toward the right. The radii of the pipe sections are indicated in the Figure. In which arrangements is the net work done on a unit volume of water moving from the leftmost to the rightmost section is **greatest**.



A) (2)
B) (1)
C) (3)
D) (4)
E) The net work is the same in all pipes

Solution:
$$W = \Delta K = \frac{1}{2}m\left(v_f^2 - v_i^2\right)$$

Q20.
Figure 11 shows a graph of the acceleration vs. time for a spring-block system that oscillates in simple harmonic motion. Find the amplitude of oscillation?



A) 3.2×10^{-3} m
B) 5.7×10^{-3} m
C) 9.8×10^{-3} m
D) 1.2×10^{-2} m
E) 1.9×10^{-2} m

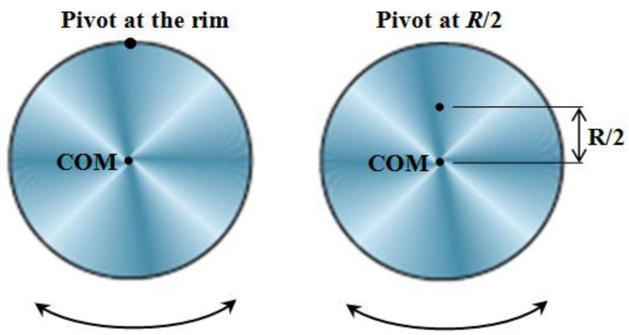
Solution:
$$T = 0.8\ s \Rightarrow \omega = \frac{2\pi}{T};\ a_{max} = \omega^2 x_m$$
$$\Rightarrow x_m = \frac{a_{max}}{\omega^2} = 3.2\times10^{-3}\ m$$

Q21.
The motion of a particle in a mass-spring system performing a simple harmonic motion is given by:
$x(t) = (25\text{cm})\sin(10t)$, where t is in seconds. Starting from t = 0.0, find the time when the kinetic energy is twice the potential energy

A) 0.06 s
B) 0.13 s
C) 0.30 s
D) 0.22 s
E) 0.44 s

Solution:
$$x(t) = 25\sin(10t);\ v(t) = 250\cos(10t)$$
$$K = 2U \Rightarrow \frac{1}{2}mv^2 = 2\frac{1}{2}kx^2$$
$$\Rightarrow \frac{1}{2}m[250\cos(10t)]^2 = k[25\sin(10t)]^2$$
$$\Rightarrow (\tan(10t))^2 = 0.5 \Rightarrow t = 0.06\ s$$

Q22.
Figure 12 shows a uniform solid disk performing a simple harmonic motion in a vertical plane. When the disk is pivoted about a frictionless pin through a point $R/2$ from its center of mass, the period of oscillation is T. What is the period if the disk is pivoted at the rim (edge)?



A) T
B) $2T$
C) $T/2$
D) $\sqrt{2}\ T$
E) $T/\sqrt{2}$

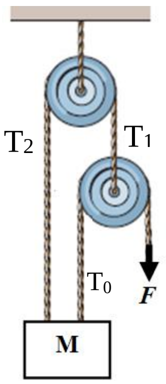
Solution:
When the pivot is at R/2:
$$I = \frac{1}{2}mR^2 + m\frac{R^2}{4} = \frac{3}{4}mR^2$$
$$\Rightarrow T = 2\pi\sqrt{\frac{3}{4}\frac{mR^2}{mg(R/2)}} = 2\pi\sqrt{\frac{3}{2}\frac{R}{g}}$$
When the pivot is at R:
$$I = \frac{1}{2}mR^2 + mR^2 = \frac{3}{2}mR^2$$
$$\Rightarrow T' = 2\pi\sqrt{\frac{3}{2}\frac{mR^2}{mgR}} = 2\pi\sqrt{\frac{3}{2}\frac{R}{g}} = T$$

Q23.
A block of mass 2.0 kg is attached to a spring (k = 200 N/m) and is performing a simple harmonic motion on a horizontal frictionless surface. When the displacement from the equilibrium is 3.0 m, the speed of the block is 40 m/s. What is the amplitude of the oscillation?

A) 5.0 m
B) 7.0 m
C) 9.0 m
D) 11 m
E) 13 m

Solution:
$$E = \frac{1}{2}kx_m^2 = K + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = 2500\ J$$
$$x_m = \sqrt{\frac{2E}{k}} = 5.0\ m$$

Q24.
A force F of magnitude 15 N, shown in the **Figure 13**, keeps the hanging block of mass M and massless pulleys in equilibrium. What is the mass M?



Solution:

$T_0 = F$

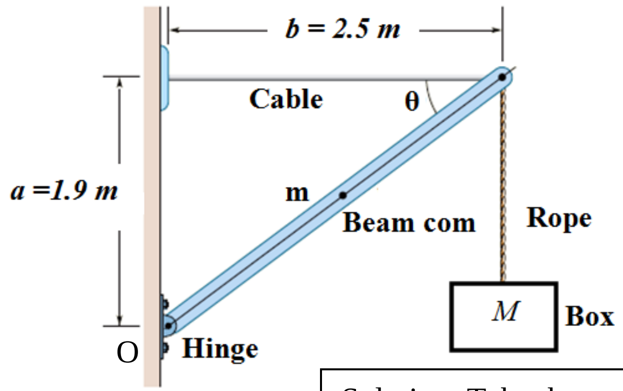
$T_0 + F = T_1 = 2F$

$T_2 = T_1 = 2F$

$T_0 + T_2 = Mg \Rightarrow F + 2F = Mg \Rightarrow M = \frac{3F}{g} = 4.6\ kg$

A) 4.6 kg
B) 2.2 kg
C) 5.2 kg
D) 5.8 kg
E) 6.2 kg

Q25.
Figure 14 shows a box (M = 430 kg) hanging by a rope from a boom that consists of a uniform hinged beam (m = 85 kg) and a horizontal cable of negligible mass. The system is in equilibrium. What is the tension in the cable?



Solution: Take the torque about the point O

$\tau = 0 = Ta - mg\left(\frac{b}{2}\right) - Mgb$

$T = \frac{mg\left(\frac{b}{2}\right) + Mgb}{a} = 6093\ N$

A) 6100 N
B) 6700 N
C) 7600 N
D) 8000 N
E) 8400 N

Q26.

An asteroid whose mass is 2.0×10^{-4} times the mass of earth, revolves in a circular orbit around the Sun at a distance that is twice the Earth's distance from the Sun. What is the ratio of the kinetic energy of the asteroid to the kinetic energy of the Earth?

A) 1.0×10^{-4}
B) 2.0×10^{-4}
C) 1.5×10^{-4}
D) 3.0×10^{-4}
E) 4.0×10^{-4}

Solution:

$$\frac{K_A}{K_E} = \frac{m_A}{r_A}\frac{r_E}{m_E} = 1.0 \times 10^{-4}$$

Q27.

A projectile is fired straight upward from Earth's surface with a speed *v*. The projectile reaches an altitude *R*/3 above the surface of Earth, where *R* is the radius of the Earth. Find the ratio v/v_{esc}.

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

Solution:

$$= \frac{1}{2}mv^2 - \frac{GMm}{R} = -\frac{3}{4}\frac{GMm}{R} \Rightarrow v = \sqrt{\frac{GM}{2R}} \Rightarrow \frac{v}{v_{esc}} = \frac{1}{2}$$

Q28.

A spherical planet has a uniformly distributed mass *M* and radius *R*. The gravitational force of the planet on a mass *m* located at an altitude 2*R* above the surface of the planet, is *F* = 4 *m*g, where g is the Earth's free fall acceleration. What will be the force on the mass *m* if it is located at a distance *R*/4 below the surface of the planet?

A) 27 *mg*
B) 36 *mg*
C) 12 *mg*
D) 21 *mg*
E) 16 *mg*

Solution:

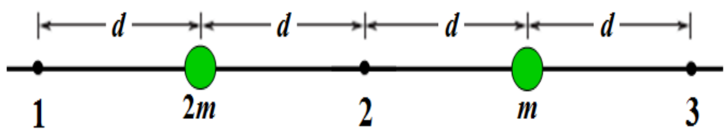
At altitude 2R

$$F = \frac{GMm}{9R^2} = 4\,mg \Rightarrow \frac{GMm}{R^2} = 36\,mg$$

At depth R/4, r=3R/4

$$F = \frac{GMm}{R^3}\frac{3R}{4} = \frac{3}{4}\frac{GMm}{R^2} = \frac{3}{4}\,36\,mg = 27\,mg$$

Q29.
Figure 15 shows two particles of masses *m* and 2*m* fixed in place on the axis. We want to move a third particle of mass *m* from an infinite distance to one of the three possible locations **1**, **2** and **3**. Rank these three locations, according to the magnitude of the net gravitational force on the third particle due to the fixed particles, **greatest to least**.



A) 1, 3, 2
B) 3, 1, 2
C) 2, 3, 1
D) 2, 1, 3
E) 3, 2, 1

Solution:

$$F_1 = -\frac{Gm(2m)}{d^2} - \frac{Gm(m)}{9d^2} = -\frac{19}{9}\frac{Gm^2}{d^2}$$

$$F_2 = -\frac{Gm(2m)}{d^2} + \frac{Gm(m)}{d^2} = -\frac{Gm^2}{d^2}$$

$$F_3 = -\frac{Gm(2m)}{9d^2} - \frac{Gm(m)}{d^2} = -\frac{11}{9}\frac{Gm^2}{d^2}$$

Q30.
Earth has a circular orbit about the Sun of radius 1.5×10^8 km and with orbital period of 365 days. Pluto's circular orbit about the Sun has a radius of 5.9×10^9 km. Calculate Pluto's orbital period in earth days.

A) 9.0×10^4 days
B) 7.0×10^4 days
C) 5.0×10^4 days
D) 3.0×10^4 days
E) 1.0×10^4 days

Solution:

$$T_P^2 = \frac{r_P^3}{r_E^3} T_E^2 = \left(\frac{59}{1.5}\right)^3 (365)^2 \Rightarrow T_P = 9\times10^4\ days$$