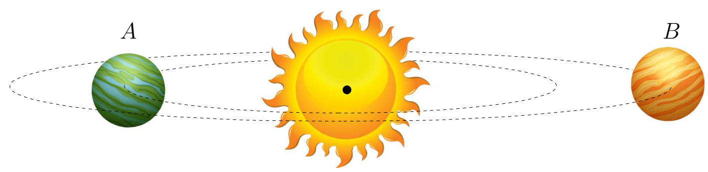
1. Two planets having equal masses are in circular orbit around a star. Planet A has a smaller orbital radius than planet B. Compare the kinetic energy, potential energy and the total mechanical energies of planet A with those of planet B. It clearly wasn't recognized that "smaller" potential meant "more negative"... not even to most of the proctors! So all answers were accepted.

   (A) A's kinetic energy is **larger**, its potential energy is **smaller**, and its total mechanical energy is **smaller** than B's

   (B) A's kinetic energy is **smaller**, its potential energy is **larger**, and its total mechanical energy is **smaller** than B's

   (C) A's kinetic energy is **larger**, its potential energy is **larger**, and its total mechanical energy is **larger** than B's

Answer LOs:
A: 34,40,60,61
B: 34,40,60,61
C: 34,40,60,61



Two equal-mass planets with different circular orbits around a star.

2. How would the gravitational potential energy of planets A and B in the previous problem change if the star they were orbiting suddenly collapsed to half its size without its mass changing?

   (A) The gravitational potential would be four times larger

   (B) The gravitational potential would be two times larger

   (C) The gravitational potential would not change

   (D) The gravitational potential would be half as large

   (E) The gravitational potential would be one fourth as large

Answer LOs:
A:
B:
C: 60,61
D:
E:

3. A 4.0-kg block is moving with a speed of 2.0 m/s in the $\hat{\imath}$ direction. Another block that has a mass of 1.0 kg is moving with a speed of 4.0 m/s, also in the $\hat{\imath}$ direction. Both blocks encounter the same constant braking force and are brought to rest. Compare the distance traveled by the two blocks before stopping.

   (A) The larger block would have travelled farther

   (B) The smaller block would have travelled farther

   (C) Both blocks would have travelled the same distance

   Answer LOs:
   A:
   B:
   C: 6,34,39

4. Continuing with the previous problem, if friction were the only braking force and both have the same coefficient of kinetic friction, compare the distance traveled by the two blocks before they come to rest.

   (A) The larger block would have travelled farther

   (B) The smaller block would have travelled farther

   (C) Both blocks would have travelled the same distance

   Answer LOs:
   A:
   B: 28,34,39
   C:

5. A bullet is shot into a block hanging from the ceiling by a light wire. The bullet is embedded in the block during the collision, and both swing upwards together after the collision. Which of the following statements is true?

   (A) The kinetic energy of the ball and block is conserved during the collision

   (B) The linear momentum and total mechanical energy of the ball and block are conserved during the collision

   (C) The linear momentum of the ball and block is not conserved during the collision, but the total mechanical energy is conserved after the collision

   (D) The linear momentum is conserved during the collision and the total mechanical energy is conserved after the collision.

   Answer LOs:
   A:
   B:
   C:
   D: 40,48

6. A firecracker of mass $2m$ is thrown with an initial velocity that is upward and to the right (positive $\hat{\imath}$ and $\hat{\jmath}$ directions), sending it in projectile motion. At the top of its trajectory the firecracker explodes breaking it into two equal parts each of mass m. After the explosion, one part is ejected downward with a velocity $-v_1\,\hat{\jmath}$ (no horizontal motion). What direction is the other half moving just after the explosion?

   (A) up and to the left ($-\hat{\imath}$ and $+\hat{\jmath}$)

   (B) straight up ($+\hat{\jmath}$ only)

   (C) up and to the right ($+\hat{\imath}$ and $+\hat{\jmath}$)

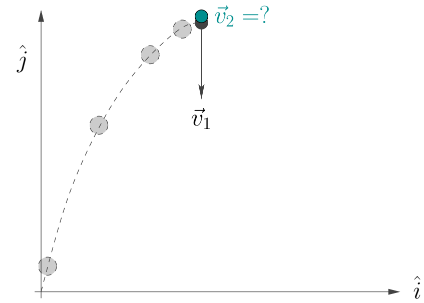
   (D) it stops moving ($\vec{v} = 0$)

   (E) down and to the right ($+\hat{\imath}$ and $-\hat{\jmath}$)

   (F) straight down ($-\hat{\jmath}$ only)

   (G) down and to the left ($-\hat{\imath}$ and $-\hat{\jmath}$)

   Answer LOs:
   A:
   B:
   C: 7,46,48
   D:
   E:
   F:
   G:



Firecracker exploding into two equal-mass pieces at the maximum height of it's trajectory.

7. Two objects of equal mass m are hung on strings of the same length. One mass is released from a height h above its free-hanging position and strikes the second mass; the two stick together and move off as shown in the figure. What is H, the height that the centre of mass of the combined object will reach?

   (A) $H = \frac{1}{4}h$

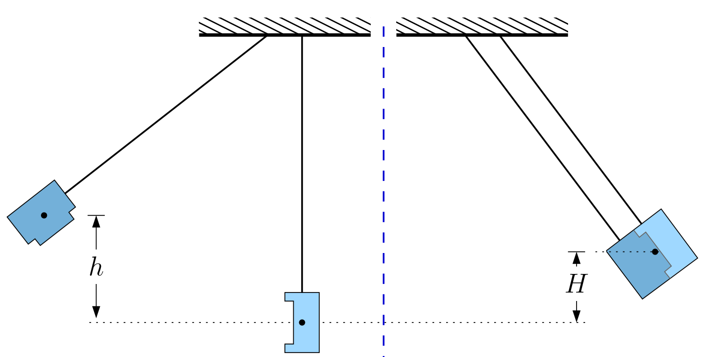
   (B) $H = \frac{1}{2}h$

   (C) $H = \frac{3}{4}h$

   (D) $H = h$

   (E) None of the above

   Answer LOs:
   A: 3,40,40,46,48
   B: 40,40
   C:
   D:
   E:



When released, the first mass swings down and then hits and sticks to the 2[nd] hanging mass. The black circles represent the center of mass of each body.

8. Large meteors can impact the earth with speeds of 80,000 km/h. If such a meteor were to impact Earth's surface tangentially and stick to it, the completely inelastic collision would result in a change of the Earth's angular momentum around its own axis of rotation of 80×10^{12} kg · m^2/s (an insignificant change, thankfully). Knowing that the radius of the Earth is 6.38×10^6 m, calculate the mass of such a meteor.

(A) 44 kg

(B) 109 kg

(C) 157 kg

(D) 392 kg

(E) 564 kg

(F) 1411 kg

Answer LOs:
A:
B:
C: 51,57,59
D:
E: 10,51,57,59
F: 10,57,59

A meteor crashing tangentially on the spinning earth.

9. Adam is sitting on a stool that can turn friction-free about its vertical axis. Initially, he has zero angular momentum as he is simply sitting in on the stool. He is handed a spinning bicycle wheel that has angular momentum $L_0\,\hat{j}$ (upwards). Adam decides to turn it upside down, *ie.* turn it vertically through $180°$. In doing this, Adam has acquired an angular momentum of:

(A) 0

(B) $-L_0\,\hat{j}$

(C) $L_0\,\hat{j}$

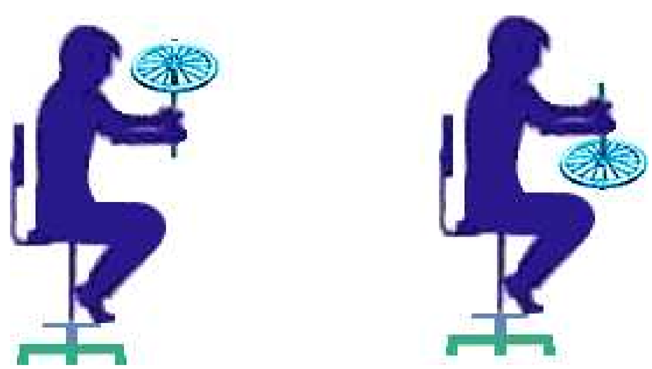
(D) $-2L_0\,\hat{j}$

(E) $2L_0\,\hat{j}$

(F) $-4L_0\,\hat{j}$

(G) $4L_0\,\hat{j}$

Answer LOs:
A:
B:
C:
D:
E: 57,59
F:
G:



Adam being handed a spinning wheel, then turning it upside down while sitting on a frictionless stool which is free to rotate.

10. A heavy block is supported by three wires as shown. The weights of the wires are negligibly small and may be ignored. Which of the following statements about the tensions in the wires is true?

(A) $T_1 > T_2$ and $T_2 > T_3$

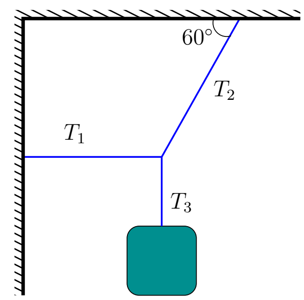
(B) $T_1 < T_2$ and $T_1 > T_3$

(C) $T_2 > T_3$ and $T_3 > T_1$

(D) $T_3 > T_1$ and $T_1 > T_2$

(E) $T_1 > T_3$ and $T_2 > T_3$

Answer LOs:
A:
B:
C: 21,24
D:
E:



Weight being held up by a wire and a bar.

11. A 10-m-long plank (of negligible mass) is supported at each end by vertical cables. A person sits on the plank between the cables. The tension in the left cable is 300 N, and in the right cable it is 200 N. How far is the person sitting from the left cable?

(A) $x = 2.0$ m

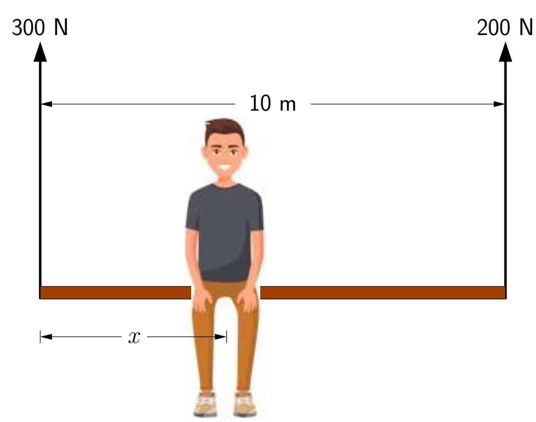
(B) $x = 3.0$ m

(C) $x = 4.0$ m

(D) $x = 5.0$ m

(E) $x = 6.0$ m

Answer LOs:
A:
B:
C: 54,54
D:
E:



Man sitting on a plank being held up by two cables.

12. A force $F = bx^3$ acts in the $\hat{x}$-direction, where the value of b is 3.70 N/m^3. How much work is done by this force in moving an object from $(x_0, y_0) = (0, 0)$ to $(x_f, y_f) = (2.60, 0)$ m?

    (A) 0 J

    (B) 11.4 J

    (C) 42.3 J

    (D) 56.4 J

    (E) 75.0 J

    (F) 169.1 J

    Answer LOs:
    A:
    B: 32
    C: 8,32
    D:
    E:
    F: 32

13. Al and Bert are kneeling in the middle of a large frozen lake (a horizontal, frictionless surface). Al has a mass of 110 kg and Bert has a mass of 90 kg. They argue until Al pushes on Bert with a force of 22 N for 0.75 s. Assume that both are at rest before Al pushes Bert. What is the speed that Al reaches after he pushes Bert?

    (A) 0.06 m/s

    (B) 0.15 m/s

    (C) 0.18 m/s

    (D) 0.20 m/s

    (E) 0.67 m/s

    (F) 5.00 m/s

    Answer LOs:
    A:
    B: 14,21,22
    C: 14,21
    D:
    E:
    F:

14. For a solid uniform disk of mass M and radius R that is rolling without slipping, which is larger: its translational kinetic energy or its rotational kinetic energy?

    (A) Its translational kinetic energy is larger

    (B) Its rotational kinetic energy is larger

    (C) Both energies have the same magnitude

    (D) The answer depends on the radius of the disk

    (E) The answer depends on the mass of the disk

    Answer LOs:
    A: 34,35
    B:
    C:
    D:
    E:

15. A 250-g model-train car traveling at 0.50 m/s collides with a 400-g car that is initially at rest. During the collision, the locking mechanism engages between the two cars and the move off together as one object. What is the speed of the cars immediately after they link up?

    (A) 0.10 m/s

    (B) 0.19 m/s

    (C) 0.31 m/s

    (D) 0.77 m/s

    (E) 1.00 m/s

    Answer LOs:
    A:
    B: 46,48,50
    C:
    D:
    E:

16. A truck is driving forward at a constant velocity in the $\hat{\imath}$ direction. The forward force of $2,500\,\hat{\imath}$ N is provided by the friction of the tires with the road. What is the force that the truck exerts on the road, F_{TR}, and what is the force that the truck exerts on the air molecules, f_{TA}, as it drives down the road? Assume that friction between the axle and truck is negligible, at least compared to the air friction experienced by the truck.

    (A) $F_{TR} = -250\,\hat{\imath}$ N and $F_{TA} = -250\,\hat{\imath}$ N

    (B) $F_{TR} = -250\,\hat{\imath}$ N and $F_{TA} = +250\,\hat{\imath}$ N

    (C) $F_{TR} = +250\,\hat{\imath}$ N and $F_{TA} = -250\,\hat{\imath}$ N

    (D) $F_{TR} = +250\,\hat{\imath}$ N and $F_{TA} = +250\,\hat{\imath}$ N

    (E) $F_{TR} = -2,500\,\hat{\imath}$ N and $F_{TA} = -2,500\,\hat{\imath}$ N

    (F) $F_{TR} = -2,500\,\hat{\imath}$ N and $F_{TA} = +2,500\,\hat{\imath}$ N

    (G) $F_{TR} = +2,500\,\hat{\imath}$ N and $F_{TA} = -2,500\,\hat{\imath}$ N

    (H) $F_{TR} = +2,500\,\hat{\imath}$ N and $F_{TA} = +2,500\,\hat{\imath}$ N

Answer LOs:

A:
B:
C:
D:
E: 22
F: 21,22,22
G: 21
H: 22

17. A shell at rest explodes into two fragments, one with a mass of $m_1 = 2.0$ kg and the other with a mass of $m_2 = 5.0$ kg. If the 2nd fragment gains $K_2 = 100$ J of kinetic energy from the explosion, how much kinetic energy does the lighter one gain, and what is the magnitude of the impulse it experiences from the explosion?

(A) $K_1 = 40$ J and $|\vec{J}| = 12.6$ kg m/s

(B) $K_1 = 40$ J and $|\vec{J}| = 22.4$ kg m/s

(C) $K_1 = 40$ J and $|\vec{J}| = 31.6$ kg m/s

(D) $K_1 = 100$ J and $|\vec{J}| = 12.6$ kg m/s

(E) $K_1 = 100$ J and $|\vec{J}| = 22.4$ kg m/s

(F) $K_1 = 100$ J and $|\vec{J}| = 31.6$ kg m/s

(G) $K_1 = 250$ J and $|\vec{J}| = 12.6$ kg m/s

(H) $K_1 = 250$ J and $|\vec{J}| = 22.4$ kg m/s

(I) $K_1 = 250$ J and $|\vec{J}| = 31.6$ kg m/s

Answer LOs:
A: 34,34,46,48,49
B:
C: 46,48,49
D:
E:
F: 46,48,49
G: 34,34
H: 34,34,46,48
I: 3,34,34,46,48,49

18. A ball of mass $M = 0.4$ kg is attached to a thin string of length $L = 0.6$ m. M is brought into uniform circular motion with the rope at an angle of $\theta = 30°$ to the vertical. Find its speed, v, and the tension, T, of the string.

(A) $v = 1.10$ m/s and $T = 4.00$ N

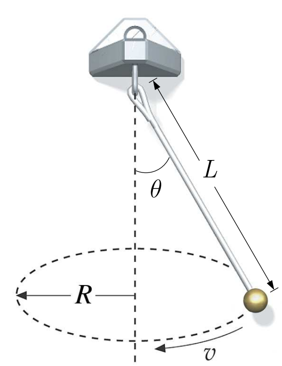
(B) $v = 1.10$ m/s and $T = 4.53$ N

(C) $v = 1.30$ m/s and $T = 4.00$ N

(D) $v = 1.30$ m/s and $T = 4.53$ N

(E) $v = 1.84$ m/s and $T = 9.00$ N

Answer LOs:
A:
B: 21,23,24
C: 19,21
D: 3,18,19,21,23,24
E:



Ball hanging from a thin string moving in horizontal circular motion.

19. A loaded elevator with very worn cables has a total mass of 2200 kg, and the cables can withstand a maximum tension of 3.00×10^4 N. Find the maximum upward acceleration for the elevator if the cables are not to break.

    (A) $a_{\text{max}} = 1.92$ m/s^2

    (B) $a_{\text{max}} = 3.84$ m/s^2

    (C) $a_{\text{max}} = 7.68$ m/s^2

    (D) $a_{\text{max}} = 13.6$ m/s^2

    (E) $a_{\text{max}} = 23.4$ m/s^2

    Answer LOs:
    A:
    B: 3,21,23,24
    C:
    D: 21,23
    E: 21,23,24

20. Firemen are shooting a stream of water at the front wall of a burning building using a high-pressure hose that shoots out the water with a speed of $v_i = 25.0$ m/s as it leaves the end of the hose. The firemen adjust the initial angle θ_i of the hose above the horizontal until the water takes 3.00 s to reach a building a distance $d = 45.0$ m away. You can ignore air resistance and assume that the end of the hose is at ground level. Find the angle θ_i.

    (A) $\theta_i = 19.0°$

    (B) $\theta_i = 31.0°$

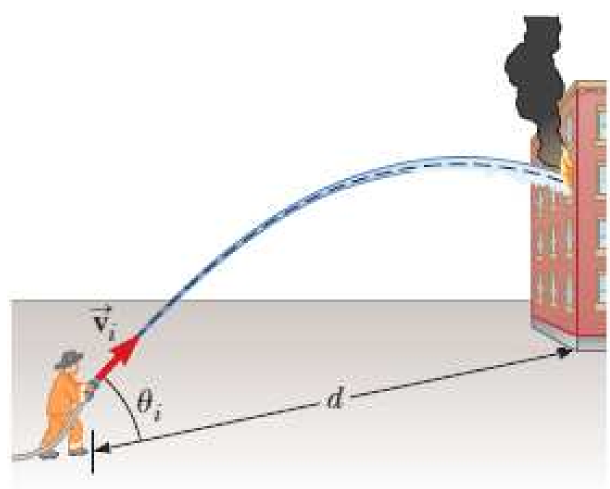
    (C) $\theta_i = 36.9°$

    (D) $\theta_i = 38.7°$

    (E) $\theta_i = 53.1°$

    (F) $\theta_i = 70.5°$

    Answer LOs:
    A:
    B:
    C: 14
    D:
    E: 1,14,15
    F:



Fireman shooting water on a burning building.

21. A light, flexible cable is wrapped around a drum, which may be considered a solid uniform cylinder of mass $M_{\text{drum}} = 12.0$ kg and radius $R_{\text{drum}} = 0.25$ m. The drum rotates with negligible friction about a stationary horizontal axis through its centre of mass. The free end of the cable is tied to a weight of mass $M = 7.90$ kg and released with no initial velocity. Find the tension in the cable and the acceleration of the weight as it descends.

(A) $T = 15.8$ N and $a = 10.3$ m/s^2

(B) $T = 15.8$ N and $a = 22.3$ m/s^2

(C) $T = 29.2$ N and $a = 7.4$ m/s^2

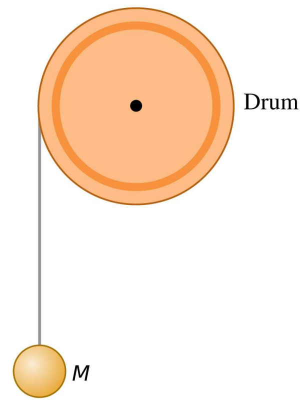
(D) $T = 29.2$ N and $a = 29.5$ m/s^2

(E) $T = 33.4$ N and $a = 5.57$ m/s^2

(F) $T = 33.4$ N and $a = 22.3$ m/s^2

(G) $T = 40.1$ N and $a = 7.4$ m/s^2

(H) $T = 40.1$ N and $a = 10.3$ m/s^2



Drum wound around by a light cable which is connected to a weight. The drum begins to rotate when the weight is released and starts to drop.

Answer LOs:
A:
B:
C: 4,24,54,55
D: 4,24,54,55
E: 4,21,23,24,54,55
F: 4,21,23,24,54
G:
H:

22. An airplane flies in a loop (a circular path in a vertical plane) of radius 170 m. The pilot's head always points toward the center of the loop. The speed of the airplane is not constant; the airplane goes slowest at the top of the loop and fastest at the bottom. At the top of the loop, the pilot feels weightless. What is the speed of the airplane at this point?

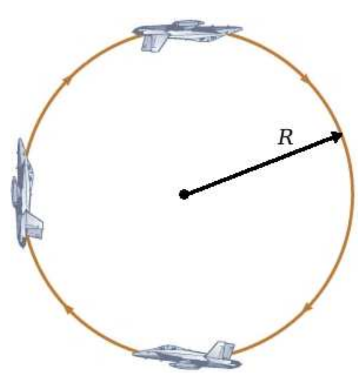
(A) 30.6 m/s

(B) 40.8 m/s

(C) 340 m/s

(D) 1310 m/s

(E) 1670 m/s



Stunt plane going through a vertical loop of radius $R = 170$ m.

Answer LOs:
A:
B: 3,18,23
C:
D:
E: 18

23. Continuing with the previous question, at the bottom of the loop, the speed of the airplane is 230 km/h. What is the apparent weight of the pilot at this point? Her true weight is 580 N.

   (A) 2.00 kN

   (B) 3.75 kN

   (C) 4.00 kN

   (D) 7.50 kN

   (E) 19.0 kN

   (F) 19.6 kN

   Answer LOs:
   A: 3,10,18,23,26
   B:
   C:
   D:
   E: 3,18,23,26
   F: 3,10,18,26

24. A river flows due south with a speed of 3.0 m/s. A man steers a motorboat across the river due east. The boat's speed in still water is 5.2 m/s, and the river is 1100 m wide. What is the man's velocity (magnitude and direction) as seen by someone standing on the bank of the river?

   (A) 4.1 m/s at 60° south of east

   (B) 5.2 m/s at 30° south of east

   (C) 6.0 m/s at 30° south of east

   (D) 8.2 m/s at 60° south of east

   (E) 11.0 m/s at 60° south of east

   Answer LOs:
   A:
   B: 2
   C: 2,20
   D:
   E:

25. On a very muddy football field, a 120 kg linebacker tackles an 80 kg halfback. Immediately before the collision, the linebacker is slipping with a velocity of 8.6 m/s north and the halfback is sliding with a velocity of 7.3 m/s east. What is the velocity (magnitude and direction) at which the two players move together immediately after the collision?

    (A) 5.93 m/s at $34.5°$ north of east

    (B) 5.93 m/s at $60.5°$ north of east

    (C) 7.90 m/s at $46.0°$ north of east

    (D) 7.90 m/s at $60.5°$ north of east

    (E) 11.3 m/s at $34.5°$ north of east

    (F) 11.3 m/s at $46.0°$ north of east

    (G) more information is needed to answer the question

    Answer LOs:
    A: 46,48
    B: 1,4,46,48
    C:
    D:
    E:
    F:
    G:

26. A vertical spring of spring constant 500 N/m is secured to the ground. A small point-like ball of mass 300 g is pushed down on the spring by a distance 25 cm from its natural length. When released, the ball shoots straight up. What is the speed of the ball when the spring uncompresses to its natural length, and what is the maximum height above its initial (spring-compressed) position that the ball reaches?

    (A) 5.92 m/s and 4.64 m

    (B) 7.80 m/s and 4.64 m

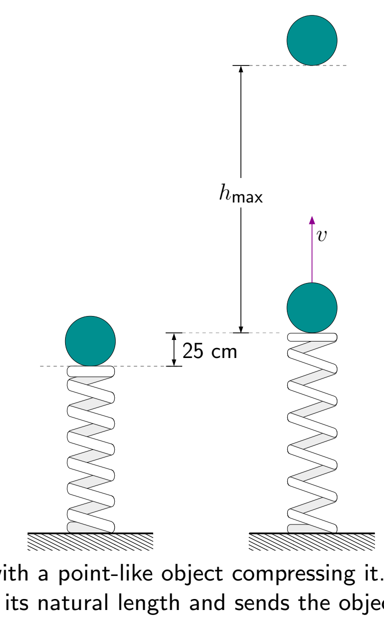
    (C) 9.96 m/s and 5.31 m

    (D) 10.21 m/s and 5.31 m

    (E) 12.13 m/s and 8.50 m

    (F) 12.91 m/s and 8.50 m

    Answer LOs:
    A:
    B:
    C: 10,34,38,38,40,40
    D: 10,34,38,40,40
    E: 34,38,38,40,40
    F: 34,38,40,40



A vertical spring with a point-like object compressing it. When released, the spring returns to its natural length and sends the object straight upward.

27. A satellite of mass 500 kg is in an approximately circular orbit around Earth with a period of 1.5 hours. What is its height h above the Earth's surface, and what is the gravitational potential energy? The mass of the Earth is $M_E = 5.97 \times 10^{24}$ kg, and its radius is $R_E = 6,380$ km. The universal constant of gravity is $G = 6.67 \times 10^{-11}$ N m^2/kg^2.

(A) $h = 0.22 \times 10^5$ m and $U = -703 \times 10^{10}$ J

(B) $h = 2.70 \times 10^5$ m and $U = -2.99 \times 10^{10}$ J

(C) $h = 2.70 \times 10^5$ m and $U = -73.6 \times 10^{10}$ J

(D) $h = 6.33 \times 10^5$ m and $U = -703 \times 10^{10}$ J

(E) $h = 6.99 \times 10^5$ m and $U = -28.5 \times 10^{10}$ J

(F) $h = 27.0 \times 10^5$ m and $U = -73.6 \times 10^{10}$ J

(G) $h = 63.8 \times 10^5$ m and $U = -28.5 \times 10^{10}$ J

(H) $h = 66.4 \times 10^5$ m and $U = -2.99 \times 10^{10}$ J

Answer LOs:
A: 19,60,61
B: 10,10,19,60,61
C: 10,10,19,60
D:
E:
F:
G:
H: 10,19,60,61

28. Two point-like beads which have the same mass are rotating at the ends of a $l_i = 50.0$-cm-long massless rod as shown. The rod is initially rotating at $\omega_i = 2.00$ rev/sec. An internal mechanism extends the length of the rod to be $l_f = 120$ cm. How fast is the rod rotating after its length was extended?

(A) $\omega_f = 0.174$ rev/s

(B) $\omega_f = 0.347$ rev/s

(C) $\omega_f = 0.417$ rev/s

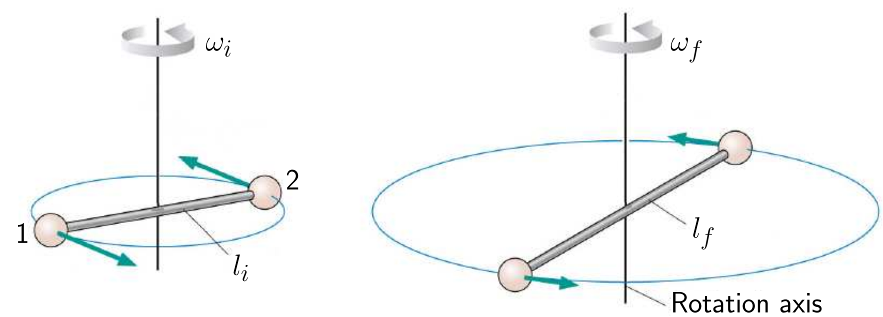
(D) $\omega_f = 0.833$ rev/s

(E) $\omega_f = 1.67$ rev/s

(F) $\omega_f = 2.00$ rev/s

(G) $\omega_f = 11.5$ rev/s

Answer LOs:
A:
B: 51,53,57,57,59
C:
D: 53,57,57,59
E:
F:
G: 57,59



A rotating massless rod with two beads on each end. The rod extends its length from l_i to l_f via an internal mechanism while rotating.

29. A thin rod of mass M and length L is pivoted on a frictionless hinge at one end, as shown. The rod is held at rest horizontally and then released. Gravity acts on the rod and accelerates it. What is the angular acceleration of the rod right after the release, α_0, and what is it when it passes the vertical position, $\alpha(\frac{\pi}{2})$?

(A) $\alpha_0 = \alpha(\frac{\pi}{2}) = 0$

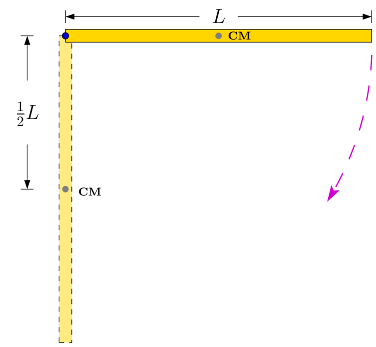
(B) $\alpha_0 = \frac{3g}{2L}$ and $\alpha(\frac{\pi}{2}) = 0$

(C) $\alpha_0 = \frac{3g}{2L}$ and $\alpha(\frac{\pi}{2}) = \frac{3g}{2L}$

(D) $\alpha_0 = \frac{3g}{L}$ and $\alpha(\frac{\pi}{2}) = 0$

(E) $\alpha_0 = \frac{6g}{L}$ and $\alpha(\frac{\pi}{2}) = \frac{3g}{2L}$

(F) $\alpha_0 = \frac{12g}{L}$ and $\alpha(\frac{\pi}{2}) = \frac{3g}{L}$



A thin rod with a hinge at one end released from rest from the horizontal position.

Answer LOs:

A:
B: 6,55,55
C: 55
D: 55
E:
F: