“Dynamics” Review Problems and Solutions Downloaded from the Beer and Johnston, Statics/Dynamics Website

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Up until the end of 2017, “Dynamics” review problems were available online on the website for the book: Beer and Johnston, *Vector Mechanics for Engineers, Statics and Dynamics*, Ninth Edition, 2010, at: http://highered.mcgraw-hill.com/sites/0073529400/information_center_view0/ . These review problems went “Out of Print” at the end of 2017. However, before the problems went out of print, I downloaded and collected them in this “problems.pdf” file.

This file contains, in Part 1 below, all the online review problems and online solutions that I downloaded from the Beer and Johnston, Statics/Dynamics Website, from Chapters 11 through 17, and Chapter 19. We don’t cover the topic of Chapter 18, “Kinetics of Rigid Bodies in 3D,” in the FE exam review class. In Part 1, I list all the problems identified by consecutive numbers in a manner similar to that used for problems in the textbook, namely, chapter number followed by a sequence number, or XX.X. The chapters and topics are listed below:

Chpt. 11: Kinematics of Particles
Chpt. 12: Kinetics of Particles: Newton's Second Law
Chpt. 13: Kinetics of Particles: Energy and Momentum Methods
Chpt. 14: Systems of Particles
Chpt. 15: Kinematics of Rigid Bodies
Chpt. 16: Plane Motion of Rigid Bodies: Forces and Accelerations
Chpt. 17: Plane Motion of Rigid Bodies: Energy and Momentum Methods
Chpt. 19: Mechanical Vibrations

As I mentioned in the FE exam review class, several of the review problems that I downloaded from the Beer and Johnston, Statics/Dynamics Website, have errors in their statements, solutions, and/or multiple-choice answers. Some of the mistakes in the solutions are quite serious because they involve the application of wrong physical principles. I list the errors and corrections in Part 2 of this file. The errors and corrections are listed according to the problem numbering scheme followed in Part 1.

Part 1

"FE Exam Review"
Online Problems and Solutions

Problem 11.1

The disk shown in the figure rotates, at the instant shown, with a counterclockwise angular velocity of 10 rad/s and with a clockwise angular acceleration of 5 rad/s^2. How long does it take before the disk comes to a temporary stop?

(a) 2 s
(b) 4 s
(c) 6 s
(d) 10 s

Answer a is correct. Integrating $\alpha = d\omega/dt = 5$ yields $\omega = 10 - 5t$. Setting $\omega = 0$ results in $t = 2$ seconds.

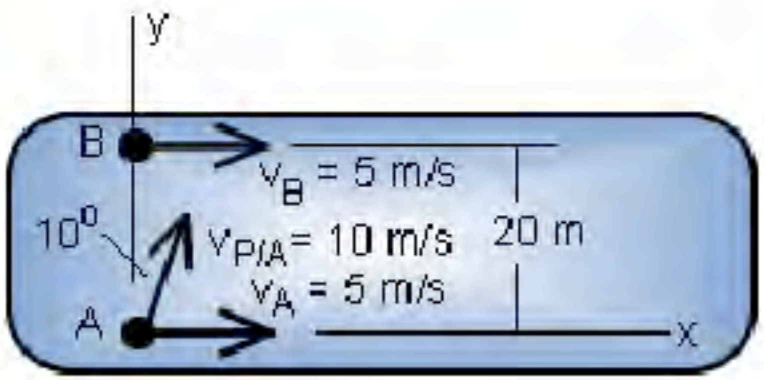
A projectile is shot at an inclination of 45° from the horizontal with a speed of 250 m/s. How far will it travel in the horizontal direction before it hits the ground again?

(a) 796 m
(b) 1592 m
(c) 3185 m
(d) 6371 m

Answer d is correct. Integrating $a_y = dv_y/dt = -g$ yields $v_y = (v_o)_y - gt$. Setting $v_y = 0$ yields one-half the time the projectile takes to hit the ground again, i.e., $t/2 = 18.02$ seconds. Twice integrating $a_x = dv_x/dt = 0$ yields $x = (v_o)_x\, t = 6371$ m.

Problem 11.3

Hockey player A passes the puck to player B with a 10 m/s relative velocity as shown here. If player B can reach forward 2 m with his stick and only 0.5 m behind, can he catch this pass?



(a) yes, the puck arrives 3.52 m in front of B
(b) yes, the puck arrives 5.32 m in front of B
(c) yes, the puck arrives 0.42 m behind B
(d) no, the puck arrives 5.32 m behind B

Answer a is correct. The puck's absolute *y*-velocity is $V_{P,y} = V_{A,y} + V_{P/A,y} = 0 + 10 \cos 10^o = 9.848$ m/s. It will then take $\Delta t = d / V_{P,y} = 2.031$ s for the puck to cross player B's path. In this time, the puck will have travelled in the *x*-direction a distance of $V_{P/A,x}\Delta t = 3.52$ m relative to player A as well as relative to player B. The puck is then in front of player B and well within player B's reach.

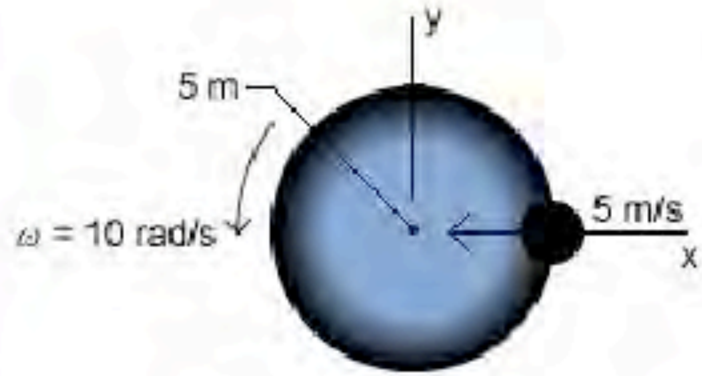
Problem 11.4

A projectile is shot vertically upward with a speed of 100 m/s. How long does it take to reach maximum altitude?

(a) 3.1 s
(b) 10.2 s
(c) 15.0 s
(d) 20.2 s

Answer b is correct. Integrating $a_y = dv_y/dt = -g$ yields $v_y = (v_o)_y - gt$. Setting $v_y = 0$ and solving for t = 10.2 s

Determine the acceleration of an object that starts moving inward, along the radial direction, with a constant speed of 5 m/s with respect to the rotating platform shown. The platform is rotating at a constant rate of 10 rad/s.

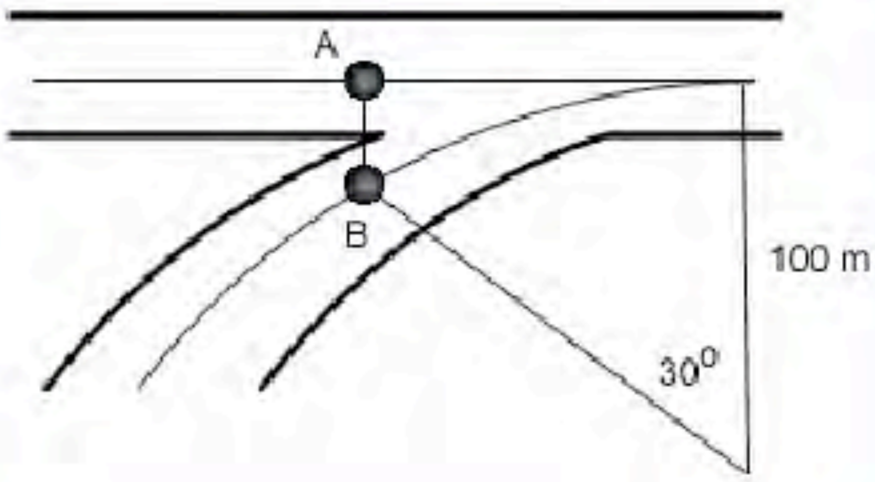


(a) 500 **i** + 100 **j** (m/s^2)
(b) 100 **i** - 500 **j** (m/s^2)
(c) 500 **i** - 100 **j** (m/s^2)
(d) -500 **i** + 100 **j** (m/s^2)

Answer d is correct. Realize the $a_A = d\Omega/dt = (d^2r_{P/A}/dt^2)_{Axyz} = 0$, therefore, $a_p = \Omega \times (\Omega \times r_{P/A}) + 2\,\Omega \times (dr_{P/A}/dt)_{Axyz}$. Since $\Omega = 10$ **k**, $r_{P/A} = 5$ **i**, $(dr_{P/A}/dt)_{Axyz} = -5$ **i**, therefore $a_p = -500$ **i** + 100 **j**.

Problem 11.6

Automobile A is travelling at 100 km/hr as it approaches an intersection. Automobile B is merging onto the road following a 100-m-radius entrance road. If the speed of automobile B is 90 km/hr at the instant shown here, will there be a collision?



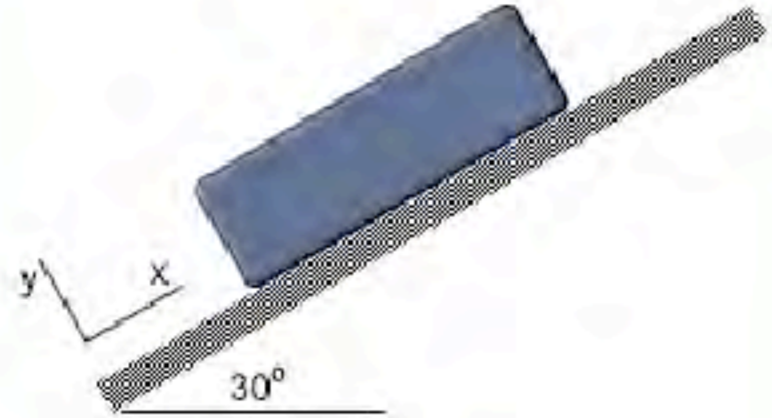
(a) yes
(b) no, B arrives 8.17 meters ahead of A
(c) no, B arrives 8.17 m behind A
(d) no, B arrives 10.0 m behind A

Answer c is correct. For a collision to occur, automobile B must be at the point at which the two paths intersect at the same time as automobile A. Automobile B must then travel a distance of $d_B = r\theta = 52.36$ m. Given automobile B's tangential velocity, it will take $\Delta t = d_B / V_{B,t} = 2.094$ s for B to reach the intersection of the two paths. In this time, automobile A will have travelled $d_A = V_A \Delta t = 58.17$ m from its current position. Hence, automobile B completes its entrance onto the road 8.17 m behind automobile A.

Problem 12.1

A 10-kg mass is initially moving up a smooth incline at 5 m/s. What distance up the incline will it travel before it stops?

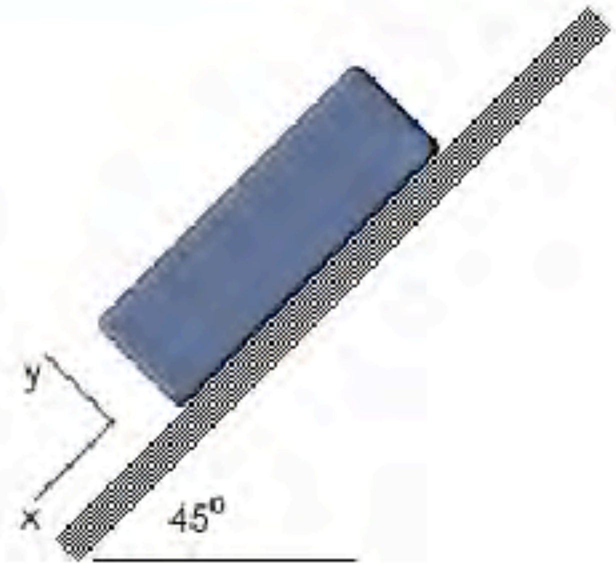
(a) 1.27 m
(b) 2.55 m
(c) 3.82 m
(d) 5.00 m



Answer b is correct. Newton's law as applied in the x-direction gives: $a = d^2x / dt^2 = - g \sin 30^\circ$. Integrating this once gives: $V = dx / dt = - g \sin 30^\circ\, t + V_o$ which for $V_o = 5$ m/s and $V = 0$ m/s gives the time at which the block stops as $t = 1.02$ s. Integrating the velocity equation produces: $x = - g \sin 30^\circ\, t^2/2 + V_o\, t + x_o$ which for $x_o = 0$ and $t = 1.02$ s gives $x = 2.55$ m.

A 15-kg mass is initially moving up a smooth incline at 10 m/s. What will be its acceleration after it stops moving up the incline, reverses direction, and starts moving down the incline?

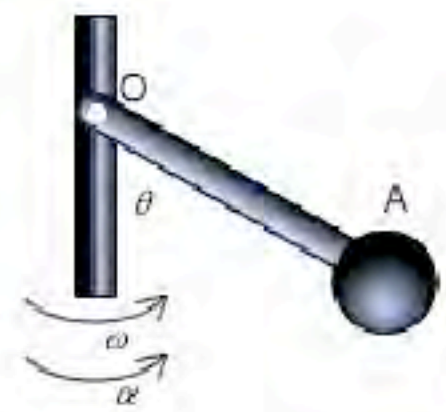
(a) 0.0 m/s^2
(b) 3.46 m/s^2
(c) 6.94 m/s^2
(d) 8.67 m/s^2



Answer c is correct. Summation of forces in the *x*-direction at the instant when the mass begins to move down the plane leads to $a_x = g \sin 45^o = 6.94$ m/s^2.

Problem 12.3

A 5-kg mass is attached to a vertical rotating shaft by a 2 m massless rod OA that is attached to the shaft by a hinge at O. What moment must be appplied about the axis perpendicular to the screen and passing through the hinge pin O to maintain a 20° angle when the shaft rotates at 50 RPM with an angular acceleration of 20 rad/s² in the shown directions?



(a) 143 N-m ccw
(b) 62 N-m ccw
(c) 62 N-m cw
(d) 143 N-m cw

Your answer is incorrect. Answer a is correct. The angular acceleration of the shaft generates no moments about the specified axis. The normal force in the rod also does not generate any moments about the specified axis. Only the weight and radial inertial force generate the requested moment. The radial inertial force is given by, $ma_r = mr\omega^2 = ml\omega^2 \sin\theta$. Assigning a ccw moment M_O at the hinge pin and summing moments about O yields $M_O = ml^2\omega^2 \sin\theta \cos\theta - mgl \sin\theta$ = 143 N-M ccw.

Problem 12.4

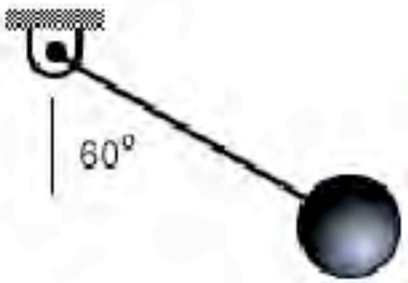
A 4-kg block rests on a smooth surface and is acted upon by force F, as shown in the figure. What is the value of the force F if the block accelerates at 15 m/s^2?

(a) 3.75 N
(b) 39.24 N
(c) 60.0 N
(d) 147.15 N

Answer c is correct. Summation of forces in the x-direction leads to $F = ma_x = 60.0$ N.

Problem 12.5

A 3-kg pendulum bob is released from rest at an angle of 60° from the vertical. What is the tension in the cord at the instant of release?

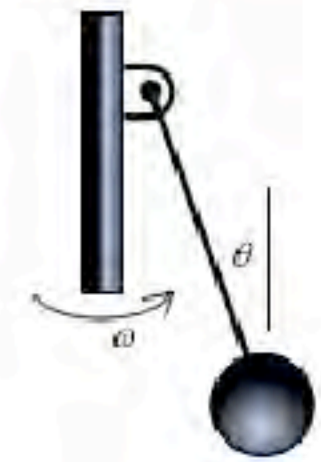


(a) 7.36 N
(b) 14.72 N
(c) 22.10 N
(d) 25.49 N

Answer b is correct. Summation of forces in the normal direction yields $T = mg \cos 60° = 14.72$ N.

Problem 12.6

A 3-kg pendulum bob is attached to a vertical rotating shaft by a 4 m cable. What angle is formed between the vertical and cable when the shaft rotates at a constant 20 RPM?



(a) 56°
(b) 63°
(c) 81°
(d) 90°

Answer a is correct. Summing the vertical forces acting on the pendulum bob gives $T \cos \theta = mg$. Similarly, summing the forces in the radial (i.e., horizontal) direction gives $T \sin \theta = ma_r$. In the radial direction, $a_r = r\omega^2 = l\omega^2 \sin \theta$. Combining these equations and solving for θ yields, $\theta = \cos\text{-}1[g / l\omega^2] = 56°$.

Problem 12.7

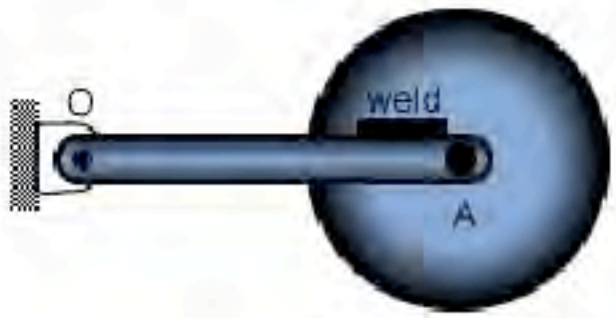
A stuntman crests the hill shown here. If the combined mass of the rider and motorcycle is 800 kg, what is the minimum velocity required for the rider and cycle to lose contact with the surface at the top of the hill?

(a) 9.81 m/s
(b) 17.1 m/s
(c) 34.7 m/s
(d) 42.9 m/s

Answer b is correct. At the top of the hill, the radial acceleration is V^2 / ρ. Summing forces in the vertical direction gives $mg = mV^2 / \rho$. Therefore, $V = (g\rho)^{0.5}$ = 17.1 m/s.

Problem 13.1

An assembly consists of a 1 m long slender rod which weighs 10 N and a 60 cm diameter disk whose mass is 10 kg. The assembly is welded together so as to prevent relative motion between the rod and the disk. If the assembly is released from rest in the position shown, what is the velocity of point A when the slender rod has achieved a vertical orientation?

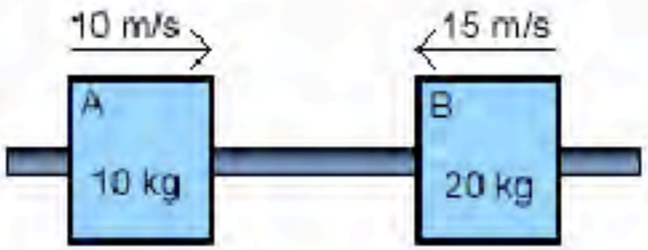


(a) 4.12 m/s
(b) 4.47 m/s
(c) 8.47 m/s
(d) 16.99 m/s

Your answer is incorrect. Answer a is correct. From the application of the principle of conservation of energy, i.e., $T_1 + V_1 = T_2 + V_2$, $T_1 = 0$, $V_1 = 103.1$, $T_2 = 6.07\ V_A^2$, $V_2 = 0$. Equating terms results in $V_A = 4.12$ m/s.

Problem 13.2

Determine the velocity of body A after an impact between the two bodies shown in the figure. The coefficient of restitution is 0.60.

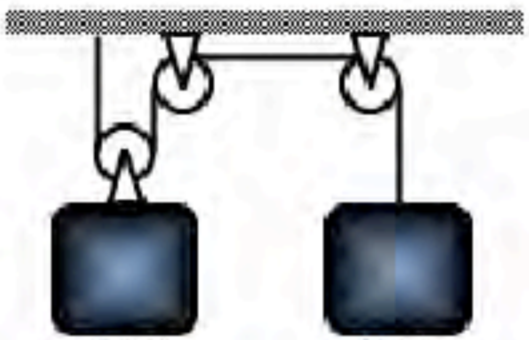


(a) -10.0 m/s
(b) 10.0 m/s
(c) -25.0 m/s
(d) 25.0 m/s

Your answer is incorrect. Answer c is correct. Application of the principle of conservation of linear momentum yields $-200 = 10\,v_A' + 20\,v_B'$. Using the equation for the coefficient of restitution results in $v_B' = 15 + v_A'$. Solving for v_A' gives $v_A' = -25$ m/s^2.

Problem 13.3

The system of two weights shown here is released from rest. What is the velocity of the 30 kg weight after the 40 kg weight has fallen 10 m?



(a) 2.41 m/s
(b) 3.92 m/s
(c) 5.08 m/s
(d) 8.73 m/s

Your answer is incorrect. Answer d is correct. According to the cable arrangement, $\Delta x_{30} = \Delta x_{40} / 2$ and $V_{30} = V_{40} / 2$. Application of the conservation of energy principle yields $m_{30} g \Delta x_{30} = m_{40} g \Delta x_{40} + m_{40} V_{40}^2 / 2 + m_{30} V_{30}^2 / 2$. The solution of these three equations gives V_{30} = 5.08 m/s.

Problem 13.4

A 15-g projectile is shot with a speed of 750 m/s at a 10-kg block of wood. The bullet becomes embedded in the block of wood. How fast are the bullet and block moving immediately after impact?

(a) 1.0 m/s
(b) 1.12 m/s
(c) 2.25 m/s
(d) 37.50 m/s

Answer b is correct. Applying conservation of linear momentum yields

$11.25 = 0.015\, v_A' + 10\, v_B'$.

Since $e = 0$ this implies that $v_A' = v_B' = v'$. Solving for v' yields $v' = 1.12$ m/s.

Problem 13.5

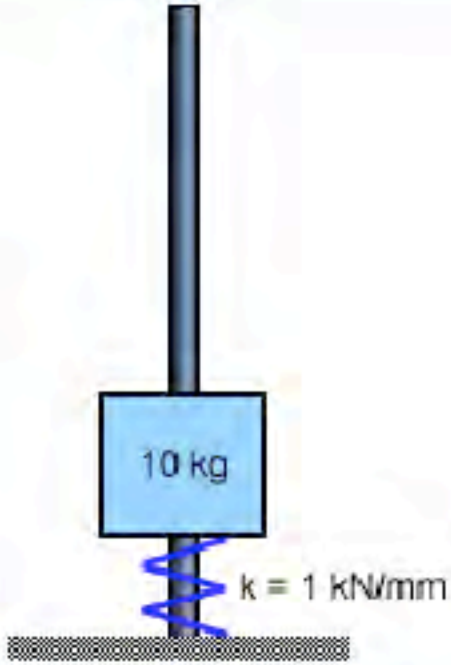
A 6000 kg SUV traveling at a speed of 10 m/s collides with a 4000 kg compact automobile which is stopped at a stop light. The coefficient of restitution is 0.7. The impact occurs over 0.3 s. What is the average impulse force applied to these vehicles?

(a) 6 kN
(b) 12 kN
(c) 18 kN
(d) 24 kN

Answer d is correct. The conservation of linear momentum principle gives $m_1u = m_1u' + m_2v'$ and the definition of the coefficient of restitution gives $v' - u' = 0.7u$. The solution of these two equations gives the velocity of the compact automobile following impact as $v' = 1.8$ m/s. Equating the impulse to the change in the compact autmobile linear momentum yields $F = m_2v' / \Delta t = 24$ kN.

Problem 13.6

The 10 kg mass shown here is free to slide along the vertical rod. Initially the mass sits on the shown spring and the spring has been compressed 2 cm from its free length. The mass is now released. What is the maximum velocity of the mass?

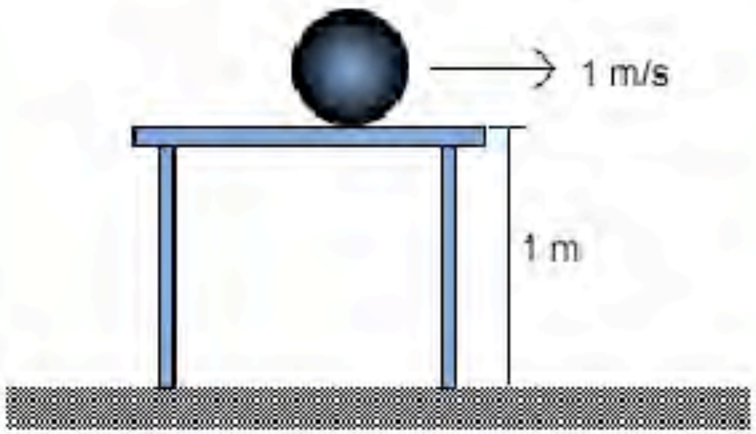


(a) 1 m/s
(b) 2 m/s
(c) 3 m/s
(d) 4 m/s

Answer b is correct. The energy initially stored in the spring is $T_s = k\Delta^2 / 2 = 200$ N-cm. Once released, the maximum velocity of the mass occurs just as the spring expands to its free length and all the energy stored in the spring has been converted to kinetic energy of the mass. Then, $V_{max} = [2T_s / m]^{1/2} = 2$ m/s.

Problem 13.7

A ball whose diameter is 100 mm falls off a table as shown, with a horizontal component of velocity of 1 m/s. The ball is seen to bounce back to a height of 0.80 m. Determine the coefficient of restitution.

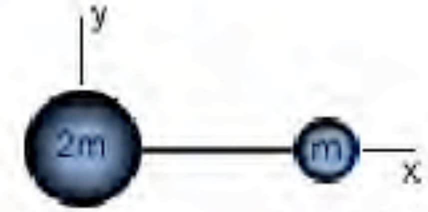


(a) 0.89
(b) 0.86
(c) 0.80
(d) 0.64

Answer a is correct. Conservation of energy before impact leads to $v_2 = (2gh_1)^{1/2}$. Conservation of energy after impact leads to $v_2' = (2gh_2)^{1/2}$. Finally, the coefficient of restitution equation leads to $e = v_2'/v_2 = (h_2/h_1)^{1/2} = 0.89$.

Problem 14.1

The shown assembly of two particles, connected by a massless rigid link 3-m long and where m = 1 kg, is rotating in the plane at a constant rate of 5 rad/s. Determine the angular momentum of the assembly with respect to the center of mass.

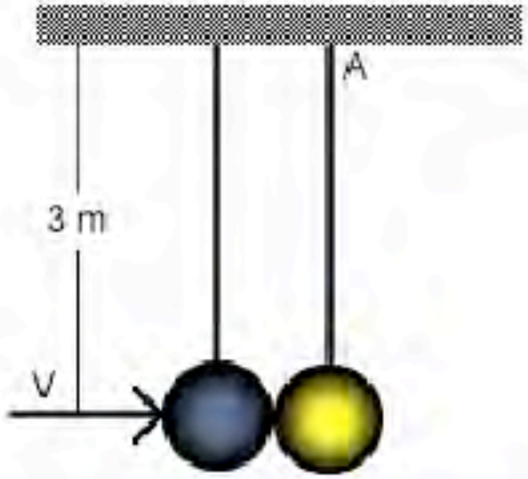


(a) 15 kg-m²/s
(b) 30 kg-m²/s
(c) 45 kg-m²/s
(d) 60 kg-m²/s

Answer b is correct. The location of the center of mass is at x_m = 1 m. Calculation of the angular momentum about the center of mass yields $H_G = 2m\varpi + 4m\varpi = 6m\varpi$ = 30 kg-m²/s.

Problem 14.2

In this system, the mass of the yellow ball is 1 kg and that of the blue ball is 0.5 kg. After being raised (while keeping the cable taut) and released, the blue ball strikes the at rest yellow ball with a velocity of 6 m/s. Assuming that the collision is perfectly elastic, What is the angular momentum of the yellow ball about A immediately after impact.



(a) 0 kg-m²/s
(b) 9 kg-m²/s
(c) 12 kg-m²/s
(d) 18 kg-m²/s

Answer c is correct. According to the linear momentum principle, the blue ball is at rest following the collision and the yellow ball's velocity is $2V/3$. The angular momentum of the yellow ball is then $H_A = 2mrV/3 = 12$ kg-m²/s.

Problem 14.3

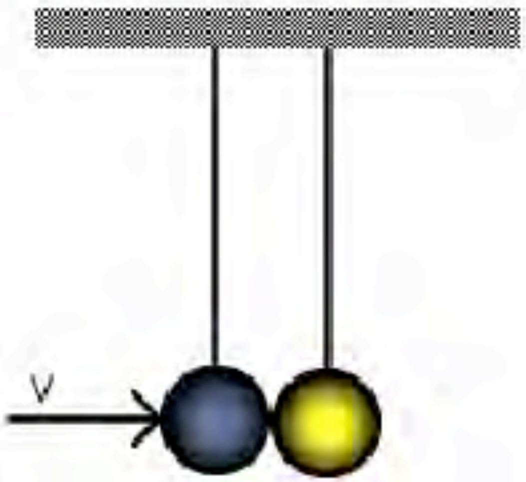
A 5 kg particle is moving with velocity **v** = 3**i** + 2**j** - 5**k** (m/s). Determine the angular momentum of the particle about the origin if the position vector of the particle is ***r*** = 10**i** - 2**j** + 5**k** (m).

(a) -20 **i** + 325 **j** + 130 **k** (kg - m^2/s)
(b) 20 **i** - 325 **j** + 130 **k** (kg - m^2/s)
(c) 325 **j** + 130 **k** (kg - m^2/s)
(d) -175 **i** + 130 **k** (kg - m^2/s)

Answer c is correct. Applying the definition of angular momentum, i.e., $\boldsymbol{H}_o = \boldsymbol{r} \times m\boldsymbol{v}$ yields $\boldsymbol{H}_0$ = 5 (10**i** - 2**j** + 5**k**) x (3**i** + 2**j** - 5**k**) = 325**j** + 130**k** (kg-m^2/s).

Problem 14.4

In this system, the mass of the yellow ball is twice that of the blue ball. After being raised (while keeping the cable taut) and released, the blue ball strikes the at rest yellow ball with a velocity of 6 m/s. Assuming that the collision is perfectly elastic, how high will the yellow ball swing?

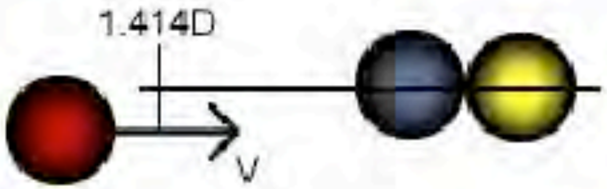


(a) 0 m
(b) 0.25 m
(c) 0.63 m
(d) 1.63 m

Your answer is incorrect. Answer d is correct. According to the linear momentum principle, the blue ball is at rest following the collision and the yellow ball's velocity is $V / 2$. Application of the conservaion of energy principle to the yellow ball gives $2mV^2 / 4 = 2mgh$. Solving for h yields $h = V^2 / 4g = 0.92$ m.

Problem 14.5

The red ball shown here has a velocity of 5 m/s. It strikes the two, at rest balls simultaneously. If all three balls have the same diameter, a mass of 1 kg, and this is a perfectly elastic collision, what is the final velocity of the yellow ball?



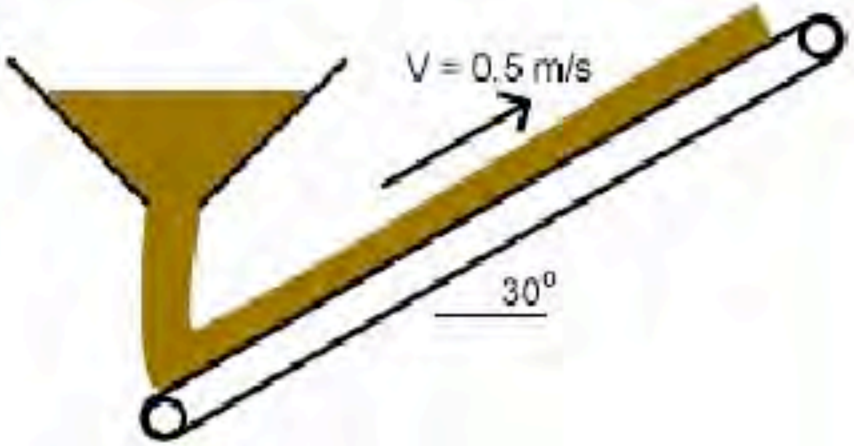
(a) 0 m/s
(b) 2.5 m/s
(c) 4.1 m/s
(d) 5 m/s

Answer b is correct. According to the geometry, the line of impact between the red and blue ball is 45° with respect to V. Conservation of linear momentum applied perpendicular to the line of impact reveals that the blue ball final velocity lies on the line of impact. Similarly, along the line of impact, $mV_{r,n} = mV'_{r,n} + mV'_b$ and the coefficient of restitution gives $V'_{r,n} - V'_b = -V_{r,n}$. The solution of these two equations gives $V'_b = V_{r,n} = V\cos\theta$. A similar analysis for the impact between the blue and yellow ball reveals that the yellow ball travels in the same direction as the intial red ball direction and $V'_y = V_{b,n} = V'_b\cos\theta = V\cos^2\theta = 2.5$ m/s.

Problem 14.6

Sand flows onto a conveyor belt as shown here. What force must be applied to this belt to transport sand at a rate of 20 kN/hr.

(a) 5.19 N
(b) 18.7 N
(c) 167 N
(d) 1.23 kN

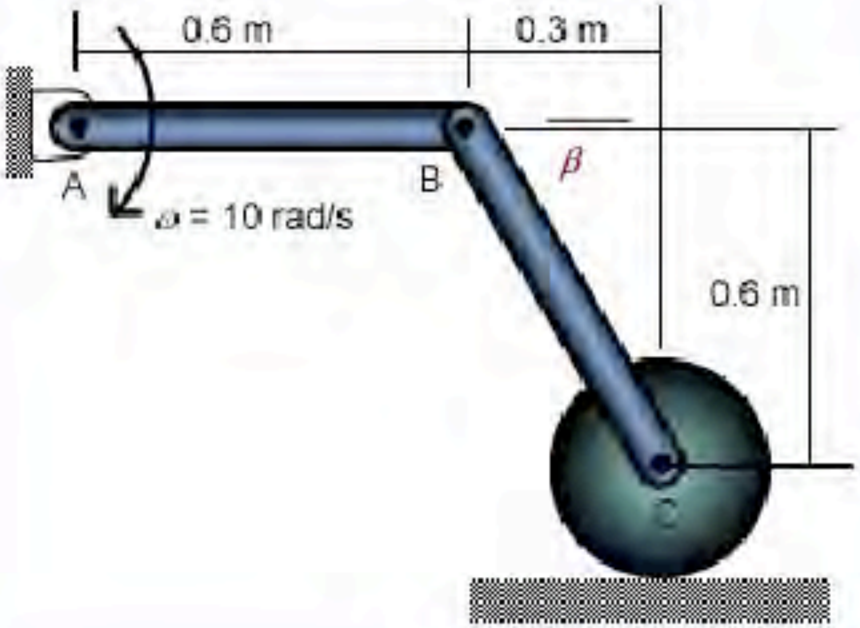


Answer a is correct. At the point where sand falls upon the belt, its velocity in the direction of the belt is 0.5 cos 30° = 0.433 m/s down the belt. It leaves the belt with a velocity of 0.5 m/s up the belt. The conservation of linear momentum principle applied along the belt gives $F = m_{rate}(V_2 - V_1)$ = 20(1000)[0.5 -(-0.433)] / 3600 = 5.18 N.

Problem 15.1

Bar AB rotates with constant angular velocity as shown. Determine the angular acceleration of member BC.

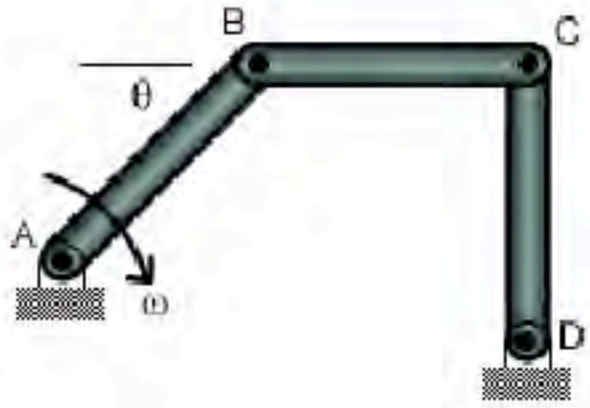
(a) 400 rad/s² CCW
(b) 400 rad/s² CW
(c) 800 rad/s² CCW
(d) 800 rad/s² CW



Your answer is incorrect. Answer c is correct. Relating the velocity of point B to that of point A we obtain $v_{B/A} = v_B - v_A = \omega_{AB} r_{B/A}$. Note that $v_A = 0$. Relating the velocity of point C to that of point B we obtain $v_{C/B} = v_C - v_B = \omega_{BC} r_{C/B}$. Combining the results, expanding and considering the scalar components in the *x*- and *y*-directions we obtain $v_C = 0.6\ \omega_{BC}$ and $0.3\ \omega_{BC} = 6$, respectively. From which we obtain that ω_{BC} = 20 rad/s CCW. Now we have to look at the acceleration equations. Relating the acceleration of point B to that of point A we obtain $a_{B/A} = a_B - a_A = \alpha_{AB} r_{B/A} + \omega_{AB} (\omega_{AB} r_{B/A})$. Note that $a_A = 0$. Relating the acceleration of point C to that of point B we obtain $a_{C/B} = a_C - a_B = \alpha_{BC} r_{C/B} + \omega_{BC}(\omega_{BC} r_{C/B})$. Combining the results, expanding and considering the scalar components in the *x*- and *y*-directions we obtain $a_C = -60 + 0.6\ \alpha_{BC} - 120$ and $240 = -0.3\ \alpha_{BC}$, respectively. From which we obtain that α_{BC} = 800 rad/s² (CW).

Link BC of this 4-bar linkage is 10 cm long and forms an angle of 45º with respect to link AB at the instant shown here. Where is the instantaneous center of link BC located?

(a) at point B
(b) at point C
(c) 10 cm directly above point B
(d) 10 cm directly above point C

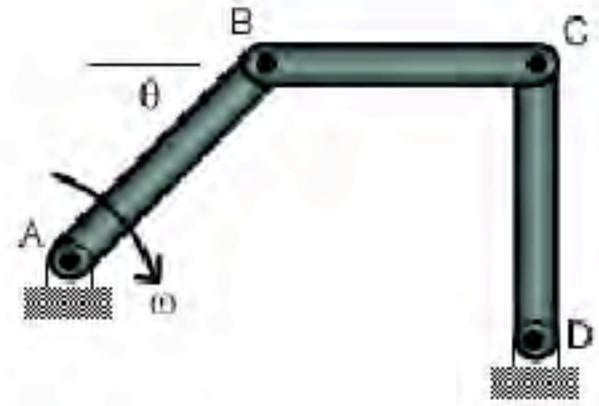


Answer d is correct. Links AB and CD rotate about their respective pivots. The velocity of point B is then 45º down from link BC and the velocity of point C is horizontal to the right. Constructing lines perpendicular to these two velocities locates their intersection at 10 cm directly above point C.

Problem 15.3

Link BC of this 4-bar linkage is 10 cm long and forms an angle of 45º with respect to link AB at the instant shown here. Link AB is 14 cm long, link CD is 20 cm long, and the angular velocity of link AB is 5 rad/s.

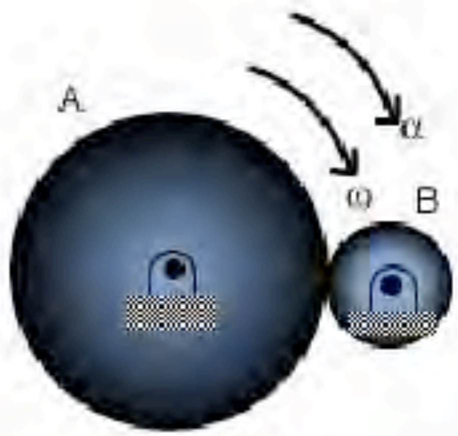
What is the angular velocity of link CD?



(a) 2.47 rad/s ccw
(b) 2.47 rad/s cw
(c) 5 rad/s ccw
(d) 5rad/s cw

Answer b is correct. The instantaneous center of link BC is located 10 cm directly above point C. The velocity of point B is $V_B = r_{AB}\omega_{AB}$ = 0.7 m/s and the rotational velocity of link BC is $\omega_{BC} = V_B / r_{icB}$ = 4.95 rad/s. The velocity at point C is then $V_C = r_{icC}\omega_{BC}$ = 0.5 m/s and the angular velocity of link CD is $\omega_{CD} = V_C / r_{cd}$ = 2.47 rad/s.

Gear A shown here has a pitch diameter of 20 cm and the pitch diameter of gear B is 5 cm. The angular velocity of gear A is 20 rad/s and its angular acceleration is 4 rad/s^2. What is the angular acceleration of gear B?



(a) 1 rad/s^2 CW
(b) 1 rad/s^2 CCW
(c) 16 rad/s^2 CW
(d) 16 rad/s^2 CCW

Answer d is correct. The tangential acceleration of the point of contact between the two gears is $a_t = r_B\alpha_B = r_A\alpha_A$ the solution of which gives $\alpha_B = r_A\alpha_A / r_B$ = 16 rad/s^2 which is counter-clockwise.

Problem 15.5

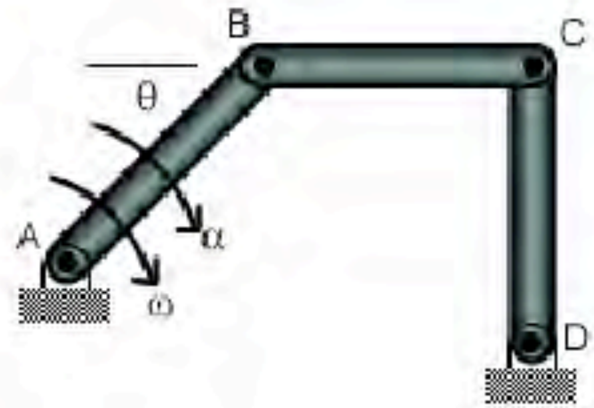
Consider the earth as a rotating frame of reference which rotates at constant rate Ω_E. If you are at the equator and are moving west with velocity v, determine the Coriolis component of acceleration that you are experiencing.

(a) $2\,\Omega_E v$ along an outwardly directed radial line
(b) $2\,\Omega_E v$ along an inwardly directed radial line
(c) $2\,\Omega_E/v$ along an outwardly directed radial line
(d) $2\,\Omega_E/v$ along an inwardly directed radial line

Answer a is correct. Assume that $\boldsymbol{\Omega}_E = \Omega_E\mathbf{j}$. Your velocity is given by $(d\mathbf{r}_{P/A}/dt)_{Axyz} = -v\,\mathbf{i}$. The Coriolis acceleration is therefore $\mathbf{a}_C = 2\boldsymbol{\Omega} \times (d\mathbf{r}_{P/A}/dt)_{Axyz} = 2\,\Omega_E v$, which is directed outward along a radial line.

Problem 15.6

Link BC of this 4-bar linkage is 10 cm long and forms an angle of 45° with respect to link AB at the instant shown here. Link AB is 14.14 cm long, link CD is 20 cm long, the angular velocity of link AB is 5 rad/s, and the angular acceleration of link AB is 10 rad/s^2. What is the acceleration of point C?

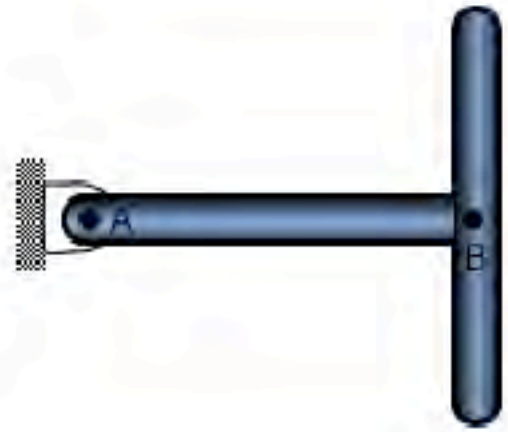


(a) 2.45**i** + 1**j** m/s^2
(b) 2.45**i** - 1**j** m/s^2
(c) 1**i** + 2.45**j** m/s^2
(d) 1**i** - 2.45**j** m/s^2

Your answer is incorrect. Answer c is correct. The instantaneous center of link BC is located 10 cm directly above point C. The velocity of point B is $V_B = r_{AB}\omega_{AB}$ = 0.7 m/s and the rotational velocity of link BC is $\omega_{BC} = V_B / r_{icB}$ = 4.95 rad/s. The tangential component of the aceleration of point B is $a_{t,B} = r_{AB}\alpha_{AB}$ = 14.14 m/s^2. The angular acceleration of link BC is then $\alpha_{BC} = a_{t,B} / r_{icB}$ = 10 rad/s^2. The *x*-component of the acceleration of point C is then $a_{t,C} = r_{icC}\alpha_{BC}$ = 1 m/s^2 to the right and the *y*-component is $a_{r,C} = r_{icC}\omega_{BC}^2$ = 2.45 m/s^2 upward. Thus, $\mathbf{a}_C$ = 1**i** + 2.45**j** m/s^2.

Problem 16.1

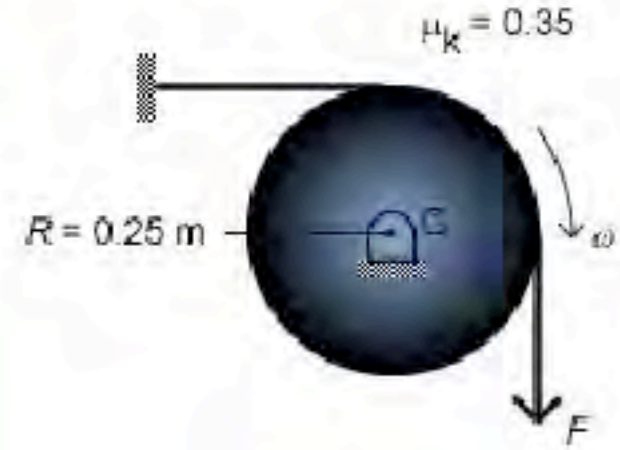
This T-shaped assembly is made up of two uniform slender rods, each of which is 1-m-long and weighs 20 N. If the assembly is released from rest, what is the vertical reaction force at point A?



(a) 8.24 N
(b) 15.6 N
(c) 20.0 N
(d) 23.9 N

Answer a is correct. Let A be the reaction force at point A. Applying Newton's law in the vertical direction gives: $A_v + 2W = 2ma_v = 2\ m^3l\alpha/4$. Taking moments about point A gives: $3l\ 2mg/4 = I_A\alpha = 17\ ml^2\alpha/12$. Solving these for A_v produces $A_v = 8.24$ N up.

A leather band is used to control the speed of a rotating flywheel whose radius is 0.25 m. For an applied force of 350 N, how long will it take to stop the rotating flywheel which has an initial rotating speed of 500 rpm?

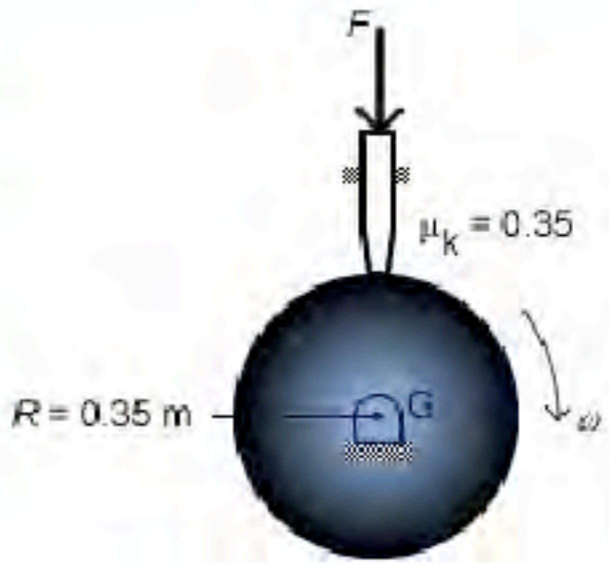


(a) 0.51 s
(b) 1.02 s
(c) 2.51 s
(d) 15.4 s

Answer a is correct. Taking moments about point G yields $\alpha = 2\,(T_2 - T_1)/mR$. Taking into account the effect of friction due to the leather band with the equation $T_2/T_1 = \exp(\mu_k\beta)$, where β is the included angle over which the leather belt acts, results in $T_2 = 1.7329\,T_1$, where $T_1 = F$. Substitution for T_2 leads to $\alpha = 102.6$ rad/s^2. Integrating $\alpha = d\varpi/dt = 102.6$ rad/s^2 results in $\varpi = \varpi_0 + \alpha t$. Substituting for $\varpi = 0$ and $\varpi_0 = 52.36$ rad/s results in $t = 0.51$ seconds.

Search

A simple braking device consists of a slender rod impinging on a 5-kg rotating wheel. If the wheel is rotating at 60 rpm, what is the force *F* required to make the wheel stop spinning in 1/4-turn?

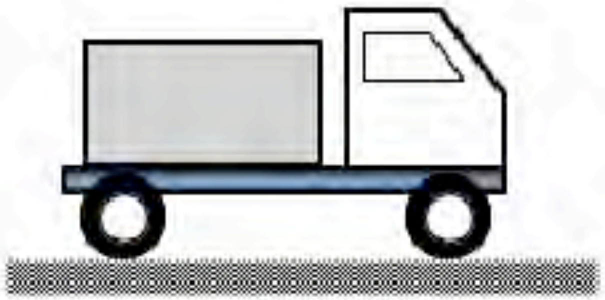


(a) 1.25 N
(b) 12.8 N
(c) 15.7 N
(d) 31.4 N

Answer d is correct. Taking moments about point G yields $\alpha = -0.4\,F$. Integrating $\alpha\, d\theta = \varpi\, d\varpi$ yields $\varpi^2 = \varpi_0^2 + 2\alpha\,(\Delta\theta)$. Setting $\varpi = 0$, $\Delta\theta = \pi/2$, and substituting α results in $F = 10\pi N = 31.4$ N.

Problem 16.4

How fast can this truck accelerate from a full stop so as not to drop the crate that is on the truck cargo platform? The static and dynamic friction coefficients are 0.40 and 0.30, respectively.



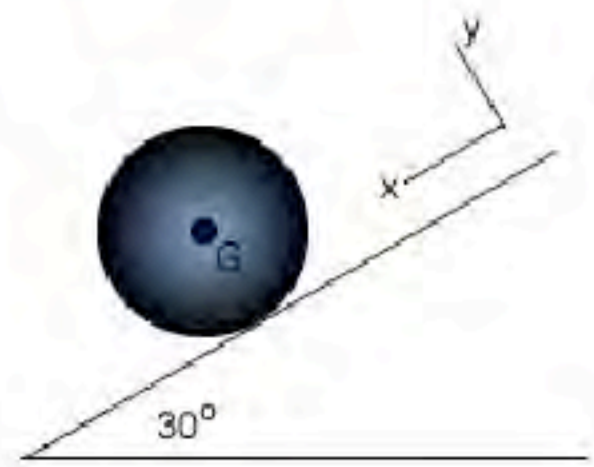
(a) 2.94 m/s^2
(b) 3.25 m/s^2
(c) 3.92 m/s^2
(d) 5.88 m/s^2

Answer c is correct. Summation of forces in the x-direction yields $a_x = \mu_s g = 3.92\ m/s^2$.

Problem 16.5

A 15-kg solid cylinder rolls without slipping down the incline shown in the figure. Determine the acceleration of point G, in the center of the cylinder.

(a) 3.27 m/s^2
(b) 5.66 m/s^2
(c) 6.32 m/s^2
(d) 7.83 m/s^2



Answer a is correct. Letting F be the force acting parallel to the inclined plane at the point of contact, Newton's law as applied to the rotating cylinder gives:

$F = mR\alpha/2$.

Applying Newton's law in the x-direction gives:

$mg \sin \theta - F = ma_x$.

Combining these results with $a_x = r\alpha$ gives a_x = 3.27 m/s^2.

Problem 16.6

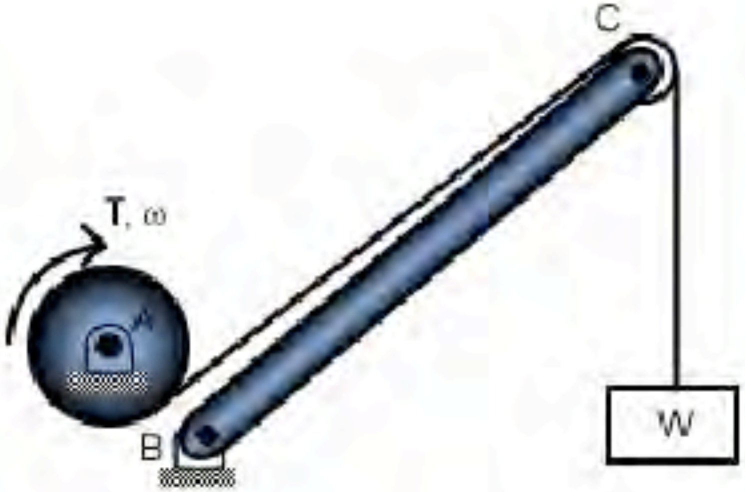
A 10-N slender rod is released from rest in the position shown. Determine the vertical component of the reaction at A.

(a) 2.5 N
(b) 10.0 N
(c) 24.5 N
(d) 54.5 N

Answer a is correct. The moment of inertia of the rod about A is $I_A = ml^2 / 3$. Then by taking moments about point A we obtain that $\alpha = (3/2)g / l$. Summation of forces in the tangential direction yields $A_t = ml\alpha / 2 - mg$. Substitution for α in the expression for A_t yields $A_t = 2.5$ N.

Problem 17.1

A construction crane uses winch A to lift the weight W using a cable and boom BC. The winch has a diameter of 1 m, mass of 600 kg, and a radius of gyration (about A) of 0.4 m. How much power is required to lift a weight of 10 kN at an instant when the upward velocity of the weight is 10 m/min and the upward acceleration is 1 m/s^2?

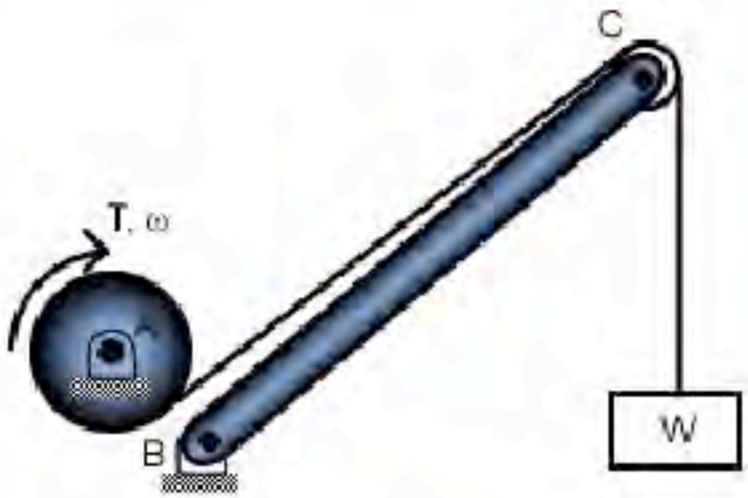


(a) 0.90 kW
(b) 1.35 kW
(c) 1.90 kW
(d) 2.35 kW

Answer c is correct. Using the tangential components, $\omega = V / r = 1/3$ rad/s and $\alpha = a / r = 2$ rad/s^2. According to the definition of the radius of gyration, $I_A = k^2 m = 96$ kg-m^2. Applying Newton's Law to the weight yields the tension in the cable as $T_c = mg + ma = 11$ kN. The torque that must be applied to the winch is then given by $T = T_c r + I\alpha = 5.69$ kN-m. The power required at this instant is then $P = T\omega = 1.90$ kW.

Problem 17.2

A construction crane uses winch A to lift the weight W using a cable and boom BC. The winch has a diameter of 1 m and a radius of gyration (about A) of 0.4 m. How much power is required to lift a weight of 10 kN at a constant speed of 10 m/min?

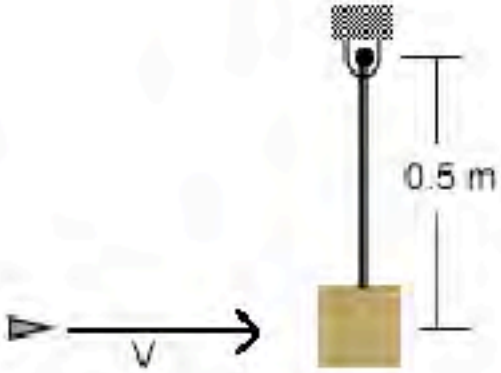


(a) 1.34 kW
(b) 1.67 kW
(c) 2 kW
(d) 2.34 kW

Answer b is correct. Nothing is accelerating in this problem. Then, $\omega = V / r$ = 1/3 rad/s, $T = Wr$ = 5 kN-m, and $P = T\omega$ = 1.67 kW.

Problem 17.3

The ballistics test apparatus shown here is used to measure the velocity of bullets. During one test, a 35 g bullet with a velocity of 300 m/s strikes and becomes embedded in the 500 kg block. What is the angular velocity of the block-bullet immediately after impact?

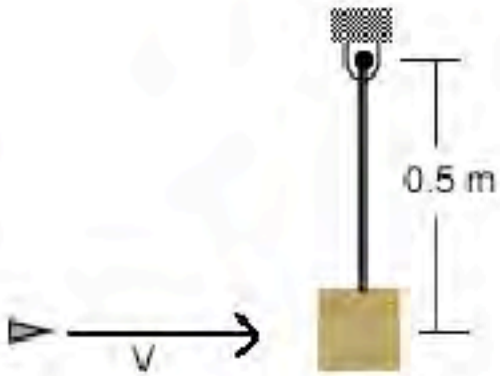


(a) 5.02 rad/s
(b) 7.43 rad/s
(c) 11.7 rad/s
(d) 15.3 rad/s

Answer a is correct. Since no energy is lost from this system, the kinetic energy of the bullet prior to impact equals the kinetic energy of the bullet-block immediately after impact. Thus, $\omega = [m / (m + M)]^{1/2}(V / r) = 5.02$ rad/s.

Problem 17.4

The ballistics test apparatus shown here is used to measure the velocity of bullets. During one test, a 35 g bullet causes the 500 kg block of wood in which the bullet becomes embedded to swing 30º from its intitial position. What is the velocity of the bullet just as it strikes the wood block?

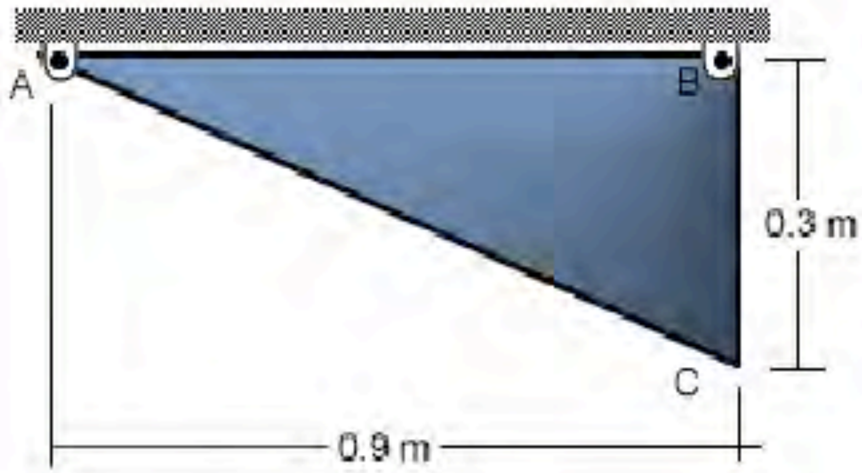


(a) 982 m/s
(b) 624 m/s
(c) 273 m/s
(d) 137 m/s

Your answer is incorrect. Answer d is correct. The impact of the bullet causes the block-bullet combination to rise a distance $\Delta h = 0.5(1 - \cos 30^\circ) = 0.067$ m. Now, the kinetic energy of the bullet must equal the change in the potential energy of the bullet-block. Then, $V = [2(m + M)g\Delta h / m]^{1/2} = 137$ m/s.

Problem 17.5

Uniform thickness plate ABC shown here is initially pinned at corners A and B. Pin B is now released and the plate is free to rotate about pin A. What is the angular velocity of the plate at the instant when its center of gravity is directly below pin A?



(a) 0.90 kW
(b) 1.35 kW
(c) 1.90 kW
(d) 2.35 kW

Your answer is incorrect. Answer c is correct. The centroid is initially located 0.6 m to the right of A and 0.1 m below A. At the instant of interest, the centroid is 0.6083 m below A for an elevation change of Δh = 0.5085 m and the potential energy of the plate has decreased by $\Delta PE = mg\Delta h$. The mass moment of inertia of the plate about the centroid is $I_o = m(b^2 + h^2) / 18$ = 0.05 m and about point A, $I_A = I_o + md^2$ = 0.420 m. Conservation of energy yields $\omega = (\Delta PE / I_A)^{1/2}$ = 3.44 rad/s.

Problem 17.6

The 1 kg sphere shown here has a velocity of 10 m/s just before it strikes the 1-m-long, 10 kg rod. If the coefficient of restitution is 0.7, what is the velocity of the ball following impact?

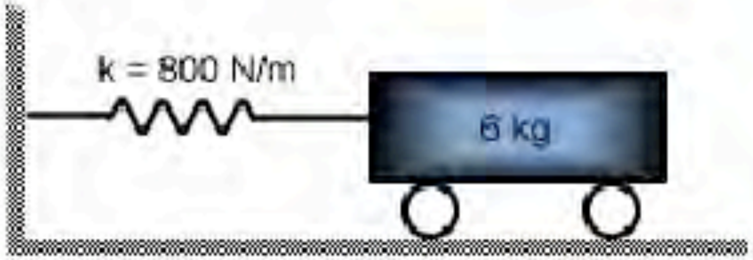
(a) 3.08 m/s to the right
(b) 6.00 m/s to the right
(c) 3.08 m/s to the left
(d) 6.00 m/s to the left

Answer c is correct. The angular moment about point A prior to impact equals that following impact. Then, $Lm_sV = Lm_sV' + (m_r\omega'_rL^2 / 4) + I_A\omega'_r$, which upon substituting the given values becomes $10 = V' + 3.333\omega'_r$. Using the relative velocities, $r\omega'_r - V' = eV$, which upon substituting the given values becomes $\omega'_r = 7 + V'$. The solution of these two equations gives $V' = 3.08$ m/s to the left.

Problem 19.1

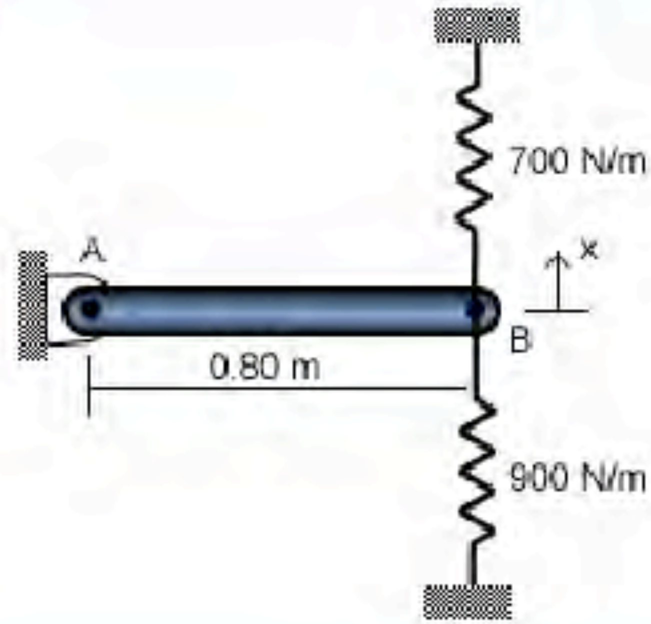
Determine the natural frequency of the system shown.

(a) 0.086 rad/s
(b) 11.55 rad/s
(c) 34.64 rad/s
(d) 133.3 rad/s



Answer b is correct. Substituting values into the equation for natural frequency $p = (k/m)^{1/2}$ = 11.55 rad/s.

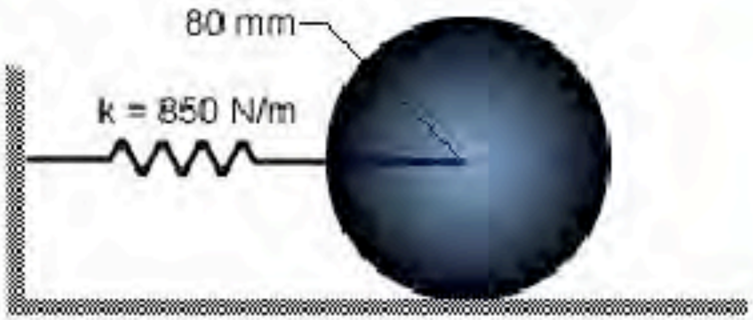
A uniform 10 kg slender rod is attached to two springs as shown. Rod end B is given a small displacement and released. Determine the period of oscillation of the rod.



(a) 0.09 s
(b) 0.14 s
(c) 0.21 s
(d) 0.29 s

Answer d is correct. Obtain $T = I_A\omega^2/2$, where $I_A = ml^2/3$, and $V = 350\,x^2 + 450\,x^2$. From conservation of energy $d(T + V)/dt = (1/3)m(d^2x/dt^2) + 1600x = 0$, which yields $\tau = 2\pi/p = 0.29$ seconds.

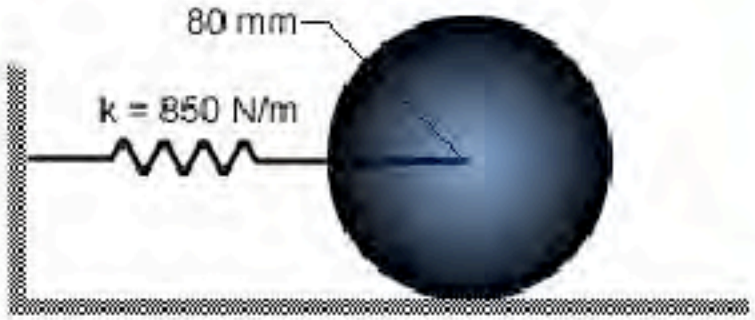
A 10 kg uniform cylinder rolls without slipping. If the cylinder is released 20 mm from its equilibrium position, determine the maximum velocity of the center of the cylinder.



(a) 0.15 m/s
(b) 0.20 m/s
(c) 0.30 m/s
(d) 0.45 m/s

Answer a is correct. Obtain $T = (3/4)m(dx/dt)$ and $V = kx^2/2$. From conservation of energy $d(T + V)/dt = (3/2)m(d^2x/dt^2) + kx = 0$, which yields $p = [(2/3)(k/m)]^{1/2} = 7.53$ rad/s. The maximum velocity is therefore $v_m = x_m p = 0.15$ m/s.

A 10 kg uniform cylinder rolls without slipping. If the cylinder is released 20 mm from its equilibrium position, determine the period of vibration.

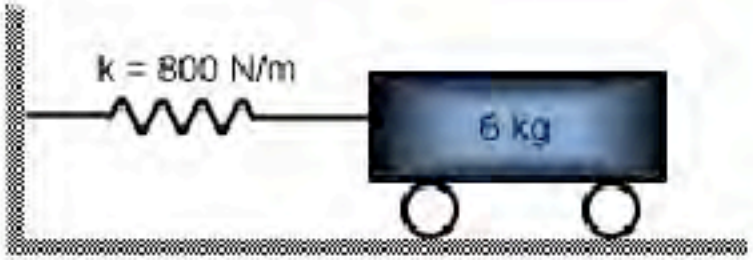


(a) 0.56 s
(b) 0.84 s
(c) 1.20 s
(d) 2.40 s

Answer b is correct. Obtain $T = (3/4)m(dx/dt)$ and $V = kx^2/2$. From conservation of energy $d(T + V)/dt = (3/2)m(d^2x/dt^2) + kx = 0$, which yields $t = 2\pi/p = 0.84$ seconds.

Problem 19.5

The block in the spring-mass system shown is displaced 30 mm from equilibrium and then released. Determine the maximum velocity of the block.



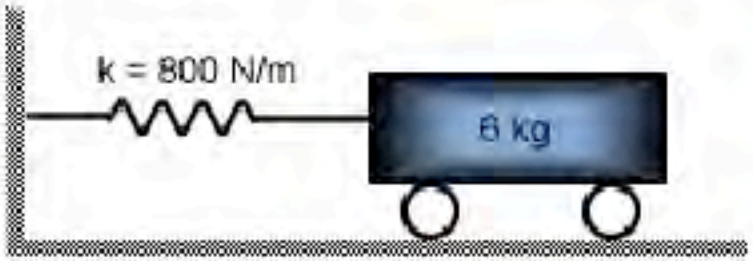
(a) 0.15 m/s
(b) 0.30 m/s
(c) 0.32 m/s
(d) 1.00 m/s

Your answer is incorrect. Answer b is correct. The maximum velocity is $v_m = x_m p = 0.30$ m/s.

Problem 19.6

The block in the spring-mass system shown is displaced 30 mm from equilibrium and then released.

Determine the maximum acceleration of the block.



(a) 0.30 m/s²
(b) 3.0 m/s²
(c) 6.0 m/s²
(d) 10.0 m/s²

Answer b is correct. The maximum acceleration is $a_m = x_m p^2 = 3.0 \text{ m/s}^2$.

Part 2

Errors and Corrections

Problem 11.1

"counterclockwise" should read "clockwise"

"clockwise" should read "counterclockwise"

Problem 11.5

The correct solution gives the answer, $-500\mathbf{i} - 100\mathbf{j}$, m/s^2. This answer is not shown among the multiple choices.

Problem 12.3

The correct solution gives the answer of (d), not (a).

Problem 13.1

This problem should be moved to Chapter 17! The correct solution gives the answer, 4.37 m/s. This answer is not shown among the multiple choices.

Problem 13.2

The correct solution gives the answer, -16.67 m/s. This answer is not shown among the multiple choices.

Problem 13.3

The correct answer is (c), not (d). The solution is correct!

Problem 13.5

The correct solution gives the answer, 136 kN. This answer is not shown among the multiple choices.

Problem 13.6

The value for k in the figure should read "0.1 kN/mm", instead of "1 kN/mm". If the effect of gravity is included, then the solution gives the answer, 1.902 m/s.

Problem 14.2

The blue ball is **not** at rest following the collision!

Problem 14.4

The correct solution gives the answer, 0.815 m. This answer is not shown among the multiple choices. Also, the blue ball is **not** at rest following the collision!

Problem 14.5

The dimension "1.414D" in the figure should read "0.707D".

Problem 14.6

The correct solution gives the answer, 0.425 N. This answer is not shown among the multiple choices.

Problem 15.1

Answer (d) is correct as calculated, not (c).

Problem 15.6

The correct solution gives the answer, $-4\mathbf{i}-1.25\mathbf{j}$, m/s^2. This answer is not shown among the multiple choices.

Problem 16.2

The mass of the flywheel is not given. The flywheel has a 20-kg mass, and has the shape of a uniform disk.

Problem 17.3

The correct solution gives the answer, 0.0420 rad/s. This answer is not shown among the multiple choices.

Problem 17.4

The correct solution gives the answer, 16,379 m/s. This answer is not shown among the multiple choices. However, the answer is physically unrealistic, implying that the specified angle of 30° is much too large!

Problem 17.5

All the numbers and units of the multiple-choice answers are wrong! The correct solution gives the answer, 4.87 rad/s.

Problem 19.5

The solution gives the answer, 0.346 m/s. This answer is not shown among the multiple choices.

Problem 19.6

The solution, continued from Problem19.5 above, gives the answer, 4 m/s^2. This answer is not shown among the multiple choices.