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DYNAMICS

**INSTRUCTOR
SOLUTIONS
MANUAL**

Fourteenth Edition



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12–1.

Starting from rest, a particle moving in a straight line has an acceleration of $a = (2t - 6) \text{ m/s}^2$, where t is in seconds. What is the particle's velocity when $t = 6 \text{ s}$, and what is its position when $t = 11 \text{ s}$?

SOLUTION

$$a = 2t - 6$$

$$dv = a \, dt$$

$$\int_0^v dv = \int_0^t (2t - 6) \, dt$$

$$v = t^2 - 6t$$

$$ds = v \, dt$$

$$\int_0^s ds = \int_0^t (t^2 - 6t) \, dt$$

$$s = \frac{t^3}{3} - 3t^2$$

When $t = 6 \text{ s}$,

$$v = 0$$

Ans.

When $t = 11 \text{ s}$,

$$s = 80.7 \text{ m}$$

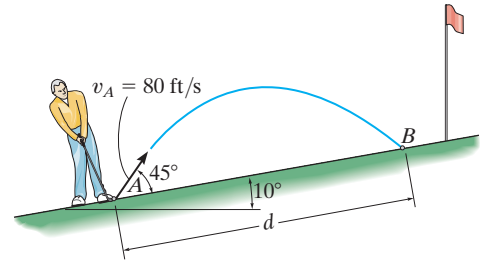
Ans.

Ans:

$$s = 80.7 \text{ m}$$

12–94.

A golf ball is struck with a velocity of 80 ft/s as shown. Determine the speed at which it strikes the ground at *B* and the time of flight from *A* to *B*.



SOLUTION

$$(v_A)_x = 80 \cos 55^\circ = 44.886$$

$$(v_A)_y = 80 \sin 55^\circ = 65.532$$

$$(\rightarrow) s = s_0 + v_0 t$$

$$d \cos 10^\circ = 0 + 45.886 t$$

$$(+\uparrow) s = s_0 + v_0 t + \frac{1}{2} a_c t^2$$

$$d \sin 10^\circ = 0 + 65.532 (t) + \frac{1}{2} (-32.2)(t^2)$$

$$d = 166 \text{ ft}$$

$$t = 3.568 = 3.57 \text{ s}$$

$$(v_B)_x = (v_A)_x = 45.886$$

$$(+\uparrow) v = v_0 + a_c t$$

$$(v_B)_y = 65.532 - 32.2(3.568)$$

$$(v_B)_y = -49.357$$

$$v_B = \sqrt{(45.886)^2 + (-49.357)^2}$$

$$v_B = 67.4 \text{ ft/s}$$

Ans.

Ans.

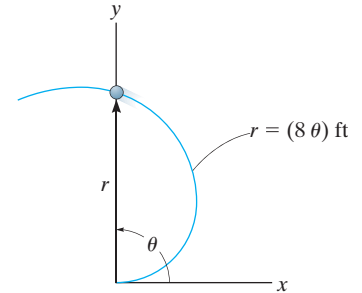
Ans:

$$t = 3.57 \text{ s}$$

$$v_B = 67.4 \text{ ft/s}$$

12–190.

Solve Prob. 12–189 if the particle has an angular acceleration $\ddot{\theta} = 5 \text{ rad/s}^2$ when $\dot{\theta} = 4 \text{ rad/s}$ at $\theta = \pi/2 \text{ rad}$.



SOLUTION

Time Derivatives: Here,

$$r = 8\theta = 8\left(\frac{\pi}{2}\right) = 4\pi \text{ ft} \quad \dot{r} = 8\dot{\theta} = 8(4) = 32.0 \text{ ft/s}$$

$$\ddot{r} = 8\ddot{\theta} = 8(5) = 40 \text{ ft/s}^2$$

Velocity: Applying Eq. 12–25, we have

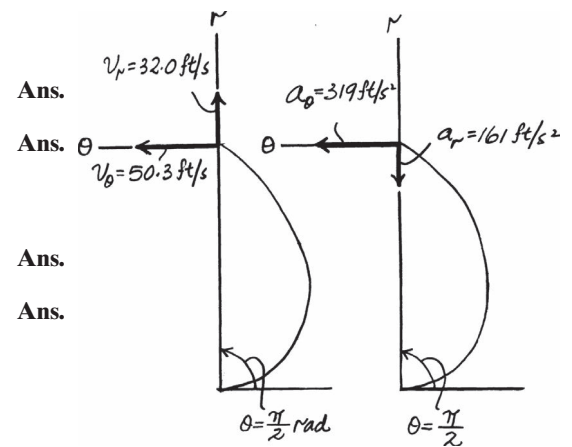
$$v_r = \dot{r} = 32.0 \text{ ft/s}$$

$$v_\theta = r\dot{\theta} = 4\pi(4) = 50.3 \text{ ft/s}$$

Acceleration: Applying Eq. 12–29, we have

$$a_r = \ddot{r} - r\dot{\theta}^2 = 40 - 4\pi(4^2) = -161 \text{ ft/s}^2$$

$$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta} = 4\pi(5) + 2(32.0)(4) = 319 \text{ ft/s}^2$$



Ans:

$$v_r = 32.0 \text{ ft/s}$$

$$v_\theta = 50.3 \text{ ft/s}$$

$$a_r = -161 \text{ ft/s}^2$$

$$a_\theta = 319 \text{ ft/s}^2$$

13–55.

Determine the maximum constant speed at which the pilot can travel around the vertical curve having a radius of curvature $\rho = 800$ m, so that he experiences a maximum acceleration $a_n = 8g = 78.5$ m/s². If he has a mass of 70 kg, determine the normal force he exerts on the seat of the airplane when the plane is traveling at this speed and is at its lowest point.

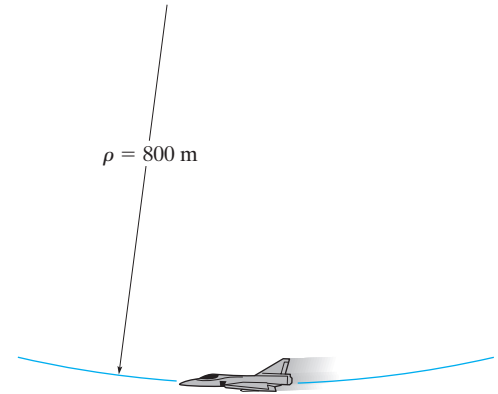
SOLUTION

$$a_n = \frac{v^2}{\rho}; \quad 78.5 = \frac{v^2}{800}$$

$$v = 251 \text{ m/s}$$

$$+\uparrow \Sigma F_n = ma_n; \quad N - 70(9.81) = 70(78.5)$$

$$N = 6.18 \text{ kN}$$



Ans.

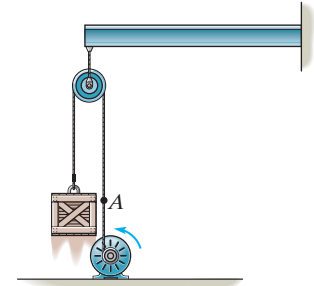
$$a_n \uparrow \quad 70(9.81) \text{ N}$$

Ans.

Ans:
 $N = 6.18 \text{ kN}$

***15–24.**

The motor pulls on the cable at A with a force $F = (e^{2t})$ lb, where t is in seconds. If the 34-lb crate is originally at rest on the ground at $t = 0$, determine the crate's velocity when $t = 2$ s. Neglect the mass of the cable and pulleys. *Hint:* First find the time needed to begin lifting the crate.



SOLUTION

$$F = e^{2t} = 34$$

$$t = 1.7632 \text{ s for crate to start moving}$$

$$(+\uparrow) \quad mv_1 + \Sigma \int F dt = mv_2$$

$$0 + \int_{1.7632}^2 e^{2t} dt - 34(2 - 1.7632) = \frac{34}{32.2} v_2$$

$$\frac{1}{2} e^{2t} \Big|_{1.7632}^2 - 8.0519 = 1.0559 v_2$$

$$v_2 = 2.13 \text{ m/s}$$

Ans.

Ans:
 $v_2 = 2.13 \text{ m/s}$

15-119.

The blade divides the jet of water having a diameter of 3 in. If one-fourth of the water flows downward while the other three-fourths flows upwards, and the total flow is $Q = 0.5 \text{ ft}^3/\text{s}$, determine the horizontal and vertical components of force exerted on the blade by the jet, $\gamma_w = 62.4 \text{ lb/ft}^3$.

SOLUTION

Equations of Steady Flow: Here, the flow rate $Q = 0.5 \text{ ft}^3/\text{s}$. Then,

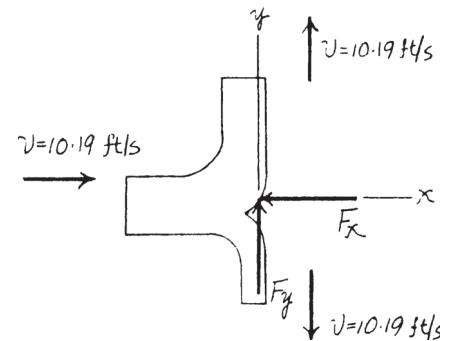
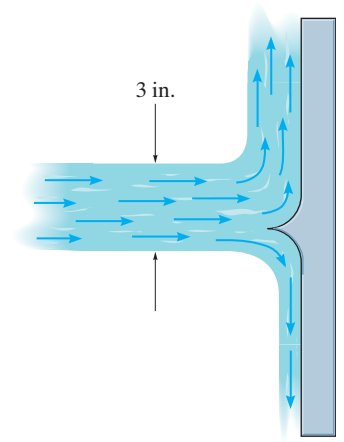
$$v = \frac{Q}{A} = \frac{0.5}{\frac{\pi}{4} \left(\frac{3}{12}\right)^2} = 10.19 \text{ ft/s. Also, } \frac{dm}{dt} = \rho_w Q = \frac{62.4}{32.2} (0.5) = 0.9689 \text{ slug/s.}$$

Applying Eq. 15-25 we have

$$\Sigma F_x = \Sigma \frac{dm}{dt} (v_{\text{out}_x} - v_{\text{in}_x}); -F_x = 0 - 0.9689 (10.19) \quad F_x = 9.87 \text{ lb} \quad \text{Ans.}$$

$$\Sigma F_y = \Sigma \frac{dm}{dt} (v_{\text{out}_y} - v_{\text{in}_y}); F_y = \frac{3}{4} (0.9689)(10.19) + \frac{1}{4} (0.9689)(-10.19)$$

$$F_y = 4.93 \text{ lb} \quad \text{Ans.}$$



Ans:
 $F_x = 9.87 \text{ lb}$
 $F_y = 4.93 \text{ lb}$

17-9.

Determine the moment of inertia of the homogeneous triangular prism with respect to the y axis. Express the result in terms of the mass m of the prism. *Hint:* For integration, use thin plate elements parallel to the x - y plane and having a thickness dz .

SOLUTION

$$dV = bx \, dz = b(a)(1 - \frac{z}{h}) \, dz$$

$$dI_y = dI_y + (dm)[(\frac{x}{2})^2 + z^2]$$

$$= \frac{1}{12} dm(x^2) + dm(\frac{x^2}{4}) + dmz^2$$

$$= dm(\frac{x^2}{3} + z^2)$$

$$= [b(a)(1 - \frac{z}{h})dz](\rho)[\frac{a^2}{3}(1 - \frac{z}{h})^2 + z^2]$$

$$I_y = ab\rho \int_0^h [\frac{a^2}{3}(\frac{h-z}{h})^3 + z^2(1 - \frac{z}{h})]dz$$

$$= ab\rho[\frac{a^2}{3h^3}(h^4 - \frac{3}{2}h^4 + h^4 - \frac{1}{4}h^4) + \frac{1}{h}(\frac{1}{3}h^4 - \frac{1}{4}h^4)]$$

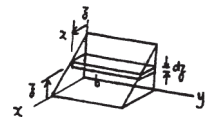
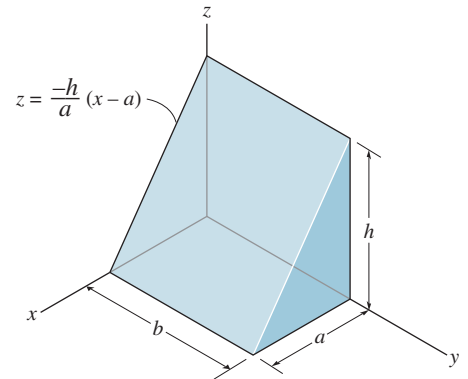
$$= \frac{1}{12} abh\rho(a^2 + h^2)$$

$$m = \rho V = \frac{1}{2} abh\rho$$

Thus,

$$I_y = \frac{m}{6}(a^2 + h^2)$$

Ans.

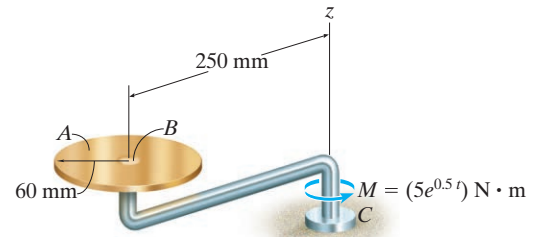


Ans:

$$I_y = \frac{m}{6}(a^2 + h^2)$$

19–15.

A 4-kg disk A is mounted on arm BC , which has a negligible mass. If a torque of $M = (5e^{0.5t}) \text{ N} \cdot \text{m}$, where t is in seconds, is applied to the arm at C , determine the angular velocity of BC in 2 s starting from rest. Solve the problem assuming that (a) the disk is set in a smooth bearing at B so that it rotates with curvilinear translation, (b) the disk is fixed to the shaft BC , and (c) the disk is given an initial freely spinning angular velocity of $\omega_D = \{-80\mathbf{k}\} \text{ rad/s}$ prior to application of the torque.



SOLUTION

a)

$$(H_z)_1 + \Sigma \int M_z dt = (H_z)_2$$

$$0 + \int_0^2 5e^{0.5t} dt = 4(v_B)(0.25)$$

$$\left. \frac{5}{0.5} e^{0.5t} \right|_0^2 = v_B$$

$$v_B = 17.18 \text{ m/s}$$

Thus,

$$\omega_{BC} = \frac{17.18}{0.25} = 68.7 \text{ rad/s}$$

Ans.

b)

$$(H_z)_1 + \Sigma \int M_z dt = (H_z)_2$$

$$0 + \int_0^2 5e^{0.5t} dt = 4(v_B)(0.25) + \left[\frac{1}{2}(4)(0.06)^2 \right] \omega_{BC}$$

Since $v_B = 0.25 \omega_{BC}$, then

$$\omega_{BC} = 66.8 \text{ rad/s}$$

Ans.

c)

$$(H_z)_1 + \Sigma \int M_z dt = (H_z)_2$$

$$-\left[\frac{1}{2}(4)(0.06)^2 \right](80) + \int_0^2 5e^{0.5t} dt = 4(v_B)(0.25) - \left[\frac{1}{2}(4)(0.06)^2 \right](80)$$

Since $v_B = 0.25 \omega_{BC}$,

$$\omega_{BC} = 68.7 \text{ rad/s}$$

Ans.

Ans:

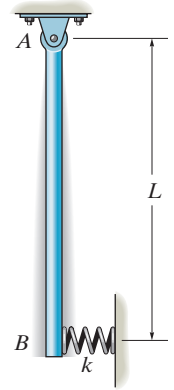
(a) $\omega_{BC} = 68.7 \text{ rad/s}$

(b) $\omega_{BC} = 66.8 \text{ rad/s}$

(c) $\omega_{BC} = 68.7 \text{ rad/s}$

22-10.

The uniform rod of mass m is supported by a pin at A and a spring at B . If B is given a small sideward displacement and released, determine the natural period of vibration.



SOLUTION

Equation of Motion. The mass moment of inertia of the rod about A is $I_A = \frac{1}{3}mL^2$. Referring to the FBD. of the rod, Fig. a ,

$$\zeta + \Sigma M_A = I_A \alpha; \quad -mg\left(\frac{L}{2} \sin \theta\right) - (kx \cos \theta)(L) = \left(\frac{1}{3}mL^2\right)\alpha$$

However; $x = L \sin \theta$. Then

$$\frac{-mgL}{2} \sin \theta - kL^2 \sin \theta \cos \theta = \frac{1}{3}mL^2 \alpha$$

Using the trigonometry identity $\sin 2\theta = 2 \sin \theta \cos \theta$,

$$\frac{-mgL}{2} \sin \theta - \frac{kL^2}{2} \sin 2\theta = \frac{1}{3}mL^2 \alpha$$

Here since θ is small $\sin \theta \approx \theta$ and $\sin 2\theta \approx 2\theta$. Also $\alpha = \ddot{\theta}$. Then the above equation becomes

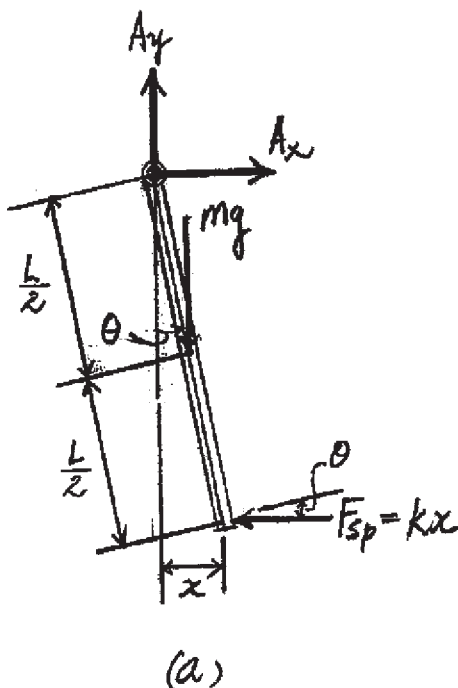
$$\frac{1}{3}mL^2 \ddot{\theta} + \left(\frac{mgL}{2} + kL^2\right)\theta = 0$$

$$\ddot{\theta} + \frac{3mg + 6kL}{2mL} \theta = 0$$

Comparing to that of the Standard form, $\omega_n = \sqrt{\frac{3mg + 6kL}{2mL}}$. Then

$$\tau = \frac{2\pi}{\omega_n} = 2\pi \sqrt{\frac{2mL}{3mg + 6kL}}$$

Ans.



$$kL^2 \sin \theta \cos \theta$$

$$\frac{kL^2}{2}$$

Ans:

$$\tau = 2\pi \sqrt{\frac{2mL}{3mg + 6kL}}$$