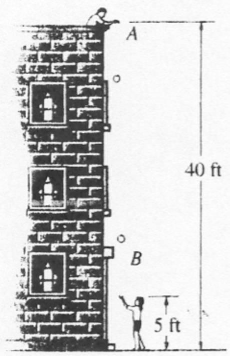
12-26. Ball A is released from rest at a height of 40 ft at the same time that a second ball B is thrown upward 5 ft from the ground. If the balls pass one another at a height of 20 ft, determine the speed at which ball B was thrown upward.



For ball # 1 :

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

$$20 = 0 + 0 + \tfrac{1}{2}(32.2)t^2$$

$$t = 1.1146 \text{ s}$$

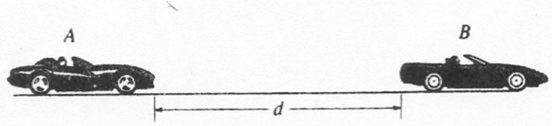
For ball # 2 :

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

$$15 = 0 + v_B(1.1146) + \tfrac{1}{2}(-32.2)(1.1146)^2$$

$$v_B = 31.4 \text{ ft/s} \qquad \text{Ans}$$

***12-32.** When two cars A and B are next to one another, they are traveling in the same direction with speeds v_A and v_B, respectively. If B maintains its constant speed, while A begins to decelerate at a_A, determine the distance d between the cars at the instant A stops.



Motion of car A :

$$v = v_0 + a_c t$$

$$0 = v v_A - a_A t \qquad t = \frac{v_A}{a_A}$$

$$v^2 = v_0^2 + 2a_c(s - s_0)$$

$$0 = v_A^2 + 2(-a_A)(s_A - 0)$$

$$s_A = \frac{v_A^2}{2a_A}$$

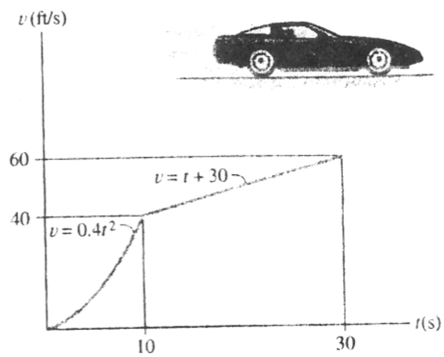
Motion of car B :

$$s_B = v_B t = v_B\left(\frac{v_A}{a_A}\right) = \frac{v_A v_B}{a_A}$$

The distance between cars A and B is

$$s_{BA} = |s_B - s_A| = \left|\frac{v_A v_B}{a_A} - \frac{v_A^2}{2a_A}\right| = \left|\frac{2v_A v_B - v_A^2}{2a_A}\right| \qquad \text{Ans}$$

✓ **12-50.** The v–t graph for the motion of a car as it moves along a straight road is shown. Draw the s–t graph and determine the average speed and the distance traveled for the 30-s time interval. The car starts from rest at $s = 0$.



For $t < 10$ s,

$$v = 0.4t^2$$

$$ds = v\,dt$$

$$\int_0^s ds = \int_0^t 0.4t^2\,dt$$

$$s = 0.1333t^3$$

At $t = 10$ s,

$$s = 133.3 \text{ ft}$$

For $10 < t < 30$ s,

$$v = t + 30$$

$$ds = v\,dt$$

$$\int_{133.3}^s ds = \int_{10}^t (t + 30)\,dt$$

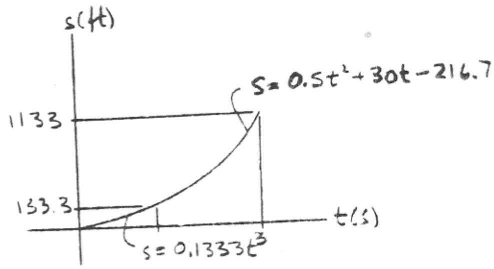
$$s = 0.5t^2 + 30t - 216.7$$

At $t = 30$ s,

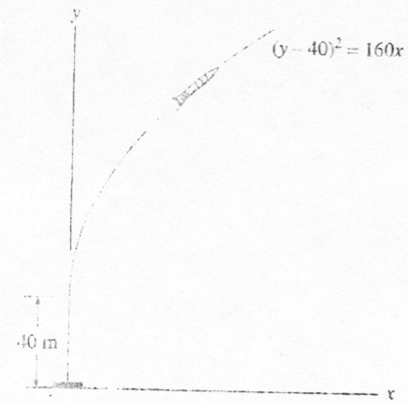
$$s = 1133 \text{ ft}$$

$$(v_{sp})_{Avg} = \frac{\Delta s}{\Delta t} = \frac{1133}{30} = 37.8 \text{ ft/s} \quad \textbf{Ans}$$

$$s_T = 1133 \text{ ft} = 1.13(10^3) \text{ ft} \quad \textbf{Ans}$$



12-79. When a rocket reaches an altitude of 40 m it begins to travel along the parabolic path $(y-40)^2 = 160x$, where the coordinates are measured in meters. If the component of velocity in the vertical direction is constant at $v_y = 180$ m/s, determine the magnitudes of the rocket's velocity and acceleration when it reaches an altitude of 80 m.



$v_y = 180$ m/s

$(y-40)^2 = 160x$

$2(y-40)v_y = 160v_x \qquad (1)$

$2(80-40)(180) = 160v_x$

$v_x = 90$ m/s

$v = \sqrt{90^2 + 180^2} = 201$ m/s **Ans**

$a_y = \frac{dv_y}{dt} = 0$

From Eq. 1,

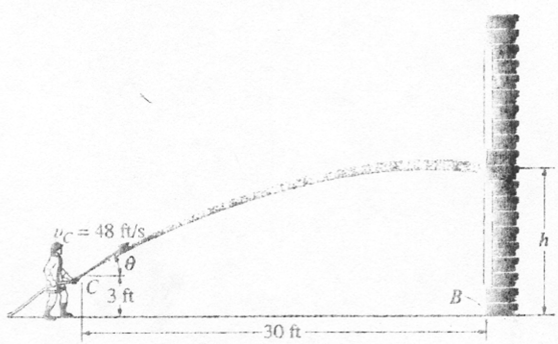
$2v_y^2 + 2(y-40)a_y = 160a_x$

$2(180)^2 + 0 = 160a_x$

$a_x = 405$ m/s^2

$a = 405$ m/s^2 **Ans**

***12-84.** Determine the smallest angle θ, measured above the horizontal, that the hose should be directed so that the water stream strikes the bottom of the wall at B. The speed of the water at the nozzle is $v_C = 48$ ft/s.



$(\xrightarrow{+})\; s = s_0 + v_0 t$

$30 = 0 + 48\cos\theta\, t$

$t = \frac{30}{48\cos\theta}$

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

$0 = 3 + 48\sin\theta\, t + \frac{1}{2}(-32.2)t^2$

$0 = 3 + \frac{48\sin\theta\,(30)}{48\cos\theta} - 16.1\left(\frac{30}{48\cos\theta}\right)^2$

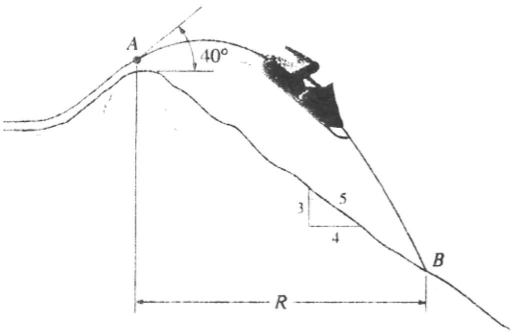
$0 = 3\cos^2\theta + 30\sin\theta\cos\theta - 6.2891$

$3\cos^2\theta + 15\sin 2\theta = 6.2891$

Solving

$\theta = 6.41°$ **Ans**

*12-88. The snowmobile is traveling at 10 m/s when it leaves the embankment at A. Determine the time of flight from A to B and the range R of the trajectory.



$(\overset{+}{\rightarrow})\quad s_B = s_A + v_A t$

$R = 0 + 10\cos 40°\, t$

$(+\uparrow)\quad s_B = s_A + v_A t + \frac{1}{2}a_c t^2$

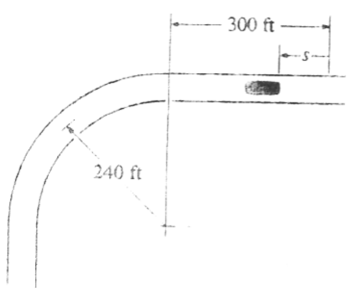
$-R(\frac{3}{4}) = 0 + 10\sin 40°\, t - \frac{1}{2}(9.81)t^2$

Solving :

$R = 19.0$ m   Ans

$t = 2.48$ s   Ans

12-113. The automobile is originally at rest at $s = 0$. If its speed is increased by $\dot{v} = (0.05t^2)$ ft/s², where t is in seconds, determine the magnitudes of its velocity and acceleration when $t = 18$ s.



$a_t = 0.05\, t^2$

$\int_0^v dv = \int_0^t 0.05\, t^2\, dt$

$v = 0.0167\, t^3$

$\int_0^s ds = \int_0^t 0.0167\, t^3\, dt$

$s = 4.167(10^{-3})\, t^4$

When $t = 18$ s, $s = 437.4$ ft

Therefore the car is on a curved path.

$v = 0.0167(18)^3 = 97.2$ ft/s   Ans

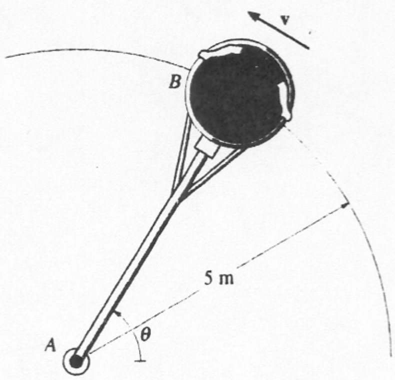
$a_n = \frac{(97.2)^2}{240} = 39.37$ ft/s²

$a_t = 0.05(18)^2 = 16.2$ ft/s²

$a = \sqrt{(39.37)^2 + (16.2)^2}$

$a = 42.6$ ft/s²   Ans

■12-119. The car B turns such that its speed is increased by $\dot{v}_B = (0.5e^t)$ m/s^2, where t is in seconds. If the car starts from rest when $\theta = 0°$, determine the magnitudes of its velocity and acceleration when the arm AB rotates $\theta = 30°$. Neglect the size of the car.



$$\frac{dv_B}{dt} = 0.5\,e^t$$

$$\int_0^{v_B} dv_B = \int_0^t 0.5\,e^t\,dt$$

$$v_B = 0.5(e^t - 1)$$

$$\int_0^{s_B} ds_B = \int_0^t 0.5(e^t - 1)\,dt$$

$$s_B = 0.5\,(e^t - t)|_0^t = 0.5(e^t - t - 1)$$

At $\theta = 30°$,

$$s_B = (\frac{30°}{180°}\pi)(5) = 2.618 \text{ m}$$

Thus,

$$6.236 = (e^t - t)$$

Solving by trial and error,

$$t = 2.123 \text{ s}$$

Thus,

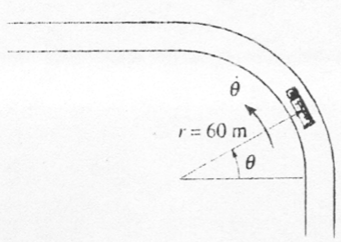
$$v_B = 0.5(e^{2.123} - 1) = 3.678 = 3.68 \text{ m/s}$$ Ans

$$(a_B)_t = \dot{v}_B = 0.5(e^{2.123}) = 4.178 \text{ m/s}^2$$

$$(a_B)_n = \frac{v_B^2}{5} = \frac{(3.678)^2}{5} = 2.706 \text{ m/s}^2$$

$$a_B = \sqrt{(4.178)^2 + (2.706)^2} = 4.98 \text{ m/s}^2$$ Ans

12-145. A truck is traveling along the horizontal circular curve of radius $r = 60$ m with a speed of 20 m/s which is increasing at 3 m/s^2. Determine the truck's radial and transverse components of acceleration.



$$r = 60$$

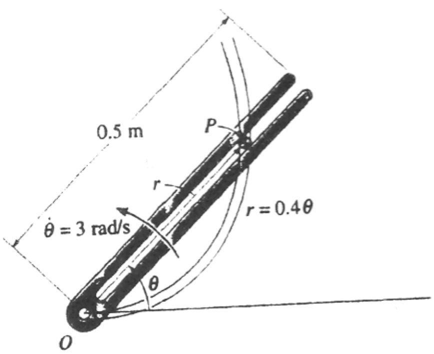
$$a_t = 3 \text{ m/s}^2$$

$$a_n = \frac{v^2}{r} = \frac{(20)^2}{60} = 6.67 \text{ m/s}^2$$

$$a_r = -a_n = -6.67 \text{ m/s}^2$$ Ans

$$a_\theta = a_t = 3 \text{ m/s}^2$$ Ans

***12-148.** Solve Prob. 12-147 if the slotted link has an angular acceleration $\ddot{\theta} = 8\ \text{rad/s}^2$ when $\dot{\theta} = 3$ rad/s at $\theta = \pi/3$ rad.



$\dot{\theta} = 3$ rad/s $\quad r = 0.4\,\theta$

$\dot{r} = 0.4\,\dot{\theta}$

$\ddot{r} = 0.4\,\ddot{\theta}$

$\theta = \frac{\pi}{3}$

$\dot{\theta} = 3$

$\ddot{\theta} = 8$

$r = 0.4189$

$\dot{r} = 1.20$

$\ddot{r} = 0.4(8) = 3.20$

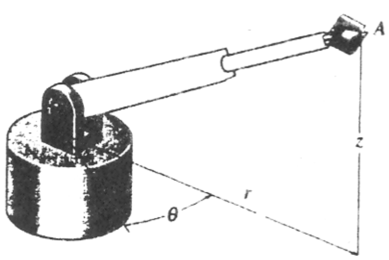
$v_r = \dot{r} = 1.20$ m/s **Ans**

$v_\theta = r\dot{\theta} = 0.4189(3) = 1.26$ m/s **Ans**

$a_r = \ddot{r} - r\dot{\theta}^2 = 3.20 - 0.4189(3)^2 = -0.570\ \text{m/s}^2$ **Ans**

$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta} = 0.4189(8) + 2(1.20)(3) = 10.6\ \text{m/s}^2$ **Ans**

12-157. The arm of the robot has a fixed length so that $r = 3$ ft and its grip A moves along the path $z = (3\sin 4\theta)$ ft, where θ is in radians. If $\theta = (0.5t)$ rad, where t is in seconds, determine the magnitudes of the grip's velocity and acceleration when $t = 3$ s.



$\theta = 0.5\,t \quad r = 3 \quad z = 3\sin 2t$

$\dot{\theta} = 0.5 \quad \dot{r} = 0 \quad \dot{z} = 6\cos 2t$

$\ddot{\theta} = 0 \quad \ddot{r} = 0 \quad \ddot{z} = -12\sin 2t$

At $t = 3$ s,

$z = -0.8382$

$\dot{z} = 5.761$

$\ddot{z} = 3.353$

$v_r = 0$

$v_\theta = 3(0.5) = 1.5$

$v_z = 5.761$

$v = \sqrt{(0)^2 + (1.5)^2 + (5.761)^2} = 5.95$ ft/s **Ans**

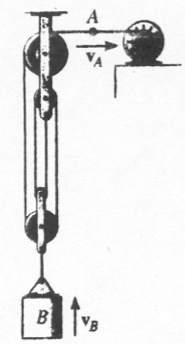
$a_r = 0 - 3(0.5)^2 = -0.75$

$a_\theta = 0 + 0 = 0$

$a_z = 3.353$

$a = \sqrt{(-0.75)^2 + (0)^2 + (3.353)^2} = 3.44\ \text{ft/s}^2$ **Ans**

12-174. Determine the constant speed at which the cable at A must be drawn in by the motor in order to hoist the load at B 15 ft in 5 s.



$$v_B = \frac{-15}{5} = -3 \text{ ft/s} = 3 \text{ ft/s} \uparrow$$

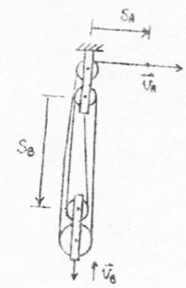
$$4s_B + s_A = l$$

$$4\Delta s_B = -\Delta s_A$$

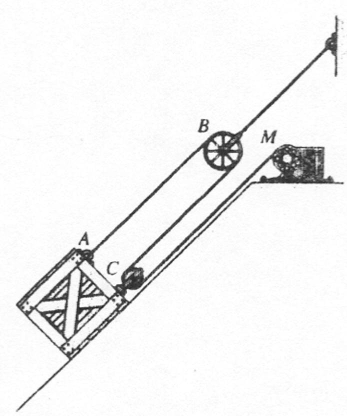
$$4v_B = -v_A$$

$$4(-3) = -v_A$$

$$v_A = 12 \text{ ft/s} \rightarrow \qquad \text{Ans}$$



12-177. The crate is being lifted up the inclined plane using the motor M and the rope and pulley arrangement shown. Determine the speed at which the cable must be taken up by the motor in order to move the crate up the plane with a constant speed of 4 ft/s.



Position - Coordinate Equation : Datum is established at fixed pulley B. The position of point P and crate A with respect to datum are s_P and s_A, respectively.

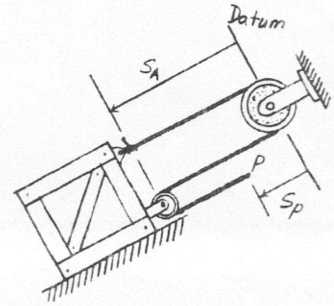
$$2s_A + (s_A - s_P) = l$$
$$3s_A - s_P = 0$$

Time Derivative : Taking the time derivative of the above equation yields

$$3v_A - v_P = 0 \qquad [1]$$

Since $v_A = 4$ ft/s, from Eq. [1]

$$(+\ ) \qquad 3(4) - v_P = 0$$
$$v_P = 12 \text{ ft/s} \qquad \text{Ans}$$



12-191. The man pulls the boy up to the tree limb C by walking backward. If he starts from rest when $x_A = 0$ and moves backward with a constant acceleration $a_A = 0.2\ \mathrm{m/s^2}$, determine the speed of the boy at the instant $y_B = 4$ m. Neglect the size of the limb. When $x_A = 0$, $y_B = 8$ m, so that A and B are coincident, i.e., the rope is 16 m long.

Position - Coordinate Equation : Using the Pythagorean theorem to determine l_{AC}, we have $l_{AC} = \sqrt{x_A^2 + 8^2}$. Thus,

$$l = l_{AC} + y_B$$
$$16 = \sqrt{x_A^2 + 8^2} + y_B$$
$$y_B = 16 - \sqrt{x_A^2 + 64} \qquad [1]$$

Time Derivative : Taking the time derivative of Eq. [1] where $\upsilon_A = \dfrac{dx_A}{dt}$ and $\upsilon_B = \dfrac{dy_B}{dt}$, we have

$$\upsilon_B = \frac{dy_B}{dt} = -\frac{x_A}{\sqrt{x_A^2 + 64}}\frac{dx_A}{dt}$$
$$\upsilon_B = -\frac{x_A}{\sqrt{x_A^2 + 64}}\upsilon_A \qquad [2]$$

At the instant $y_B = 4$ m, from Eq. [1], $4 = 16 - \sqrt{x_A^2 + 64}$, $x_A = 8.944$ m. The velocity of the man at that instant can be obtained.

$$\upsilon_A^2 = (\upsilon_0)_A^2 + 2(a_c)_A\left[s_A - (s_0)_A\right]$$
$$\upsilon_A^2 = 0 + 2(0.2)(8.944 - 0)$$
$$\upsilon_A = 1.891\ \mathrm{m/s}$$

Substitute the above results into Eq. [2] yields

$$\upsilon_B = -\frac{8.944}{\sqrt{8.944^2 + 64}}(1.891) = -1.41\ \mathrm{m/s} = 1.41\ \mathrm{m/s}\ \uparrow \qquad \textbf{Ans}$$

Note : The negative sign indicates that velocity υ_B is in the opposite direction to that of