Engineering Mechanics - Dynamics 16th edition Hibbeler Solutions Manual

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12–1.

A baseball is thrown downward from a 50-ft tower with an initial speed of 18 ft/s. Determine the speed at which it hits the ground and the time of travel.

SOLUTION

$(+\downarrow)\quad v_2^2 = v_1^2 + 2a_c(s_2 - s_1)$

$v_2^2 = (18)^2 + 2(32.2)(50 - 0)$

$v_2 = 59.532 = 59.5 \text{ ft/s} \downarrow$ **Ans.**

$(+\downarrow)\quad v_2 = v_1 + a_c t$

$59.532 = 18 + 32.2(t)$

$t = 1.29 \text{ s}$ **Ans.**

Ans:
$v_2 = 59.5 \text{ ft/s}$
$t = 1.29 \text{ s}$

12–2.

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 $t = 6$ s, and what is its position when $t = 11$ 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 $t = 6$ s,

$v = 0$ **Ans.**

When $t = 11$ s,

$s = 80.7$ m **Ans.**

Ans:
$v = 0$
$s = 80.7$ m

12–3.

From approximately what floor of a building must a car be dropped from an at-rest position so that it reaches a speed of 80.7 ft/s (55 mi/h) when it hits the ground? Each floor is 12 ft higher than the one below it. (*Note*: You may want to remember this when traveling 55 mi/h.)

SOLUTION

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

$$80.7^2 = 0 + 2(32.2)(s - 0)$$

$$s = 101.13 \text{ ft}$$

$$\# \text{ of floors} = \frac{101.13}{12} = 8.43$$

The car must be dropped from the 9th floor. **Ans.**

Ans:
$n = 9$

***12–4.**

A car is traveling at 15 m/s when the traffic light 50 m ahead turns yellow. Determine the required constant deceleration of the car and the time needed to stop the car at the light.

SOLUTION

Kinematics:

$v_0 = 0, s_0 = 0, s = 50$ m and $v_0 = 15$ m/s.

$(\overset{+}{\rightarrow})$ $\quad v^2 = v_0{}^2 + 2a_c(s - s_0)$

$0 = 15^2 + 2a_c(50 - 0)$

$a_c = -2.25\ \text{m/s}^2 = 2.25\ \text{m/s}^2 \leftarrow$ **Ans.**

$(\overset{+}{\rightarrow})$ $\quad v = v_0 + a_c t$

$0 = 15 + (-2.25)t$

$t = 6.67$ s **Ans.**

Ans:

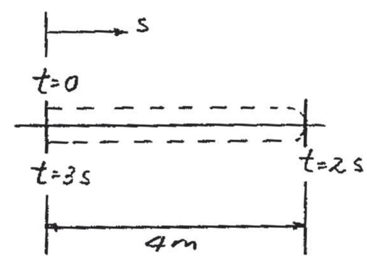
$a_c = -2.25\ \text{m/s}^2$

$t = 6.67$ s

12–5.

The velocity of a particle traveling in a straight line is given by $v = (6t - 3t^2)$ m/s, where t is in seconds. If $s = 0$ when $t = 0$, determine the particle's deceleration and position when $t = 3$ s. How far has the particle traveled during the 3-s time interval, and what is its average speed?

SOLUTION



$$\frac{ds}{dt} = v$$

$$ds = (6t - 3t^2)\,dt$$

$$\int_0^s ds = \int_0^t (6t - 3t^2)dt$$

$$s = 3t^2 - t^3$$

At $t = 3$ s, $\quad s = 3(3)^2 - 3^3 = 0 \quad$ **Ans.**

When $v = 0$; $\quad 0 = 6t - 3t^2 \quad t = 0$ and 2 s

At $t = 2$ s, $\quad s = 3(2)^2 - 2^3 = 4$ m

From the figure $\quad s_T = 2(4) = 8$ m $\quad$ **Ans.**

$$(v_{avg})_{sp} = \frac{s_T}{\Delta t} = \frac{8}{3} = 2.67 \text{ m/s} \quad \textbf{Ans.}$$

$$a = \frac{dv}{dt} = 6 - 6t$$

At $t = 3$ s, $\quad a = 6 - 6(3) = -12 \text{ m/s}^2 \quad$ **Ans.**

Ans:
$s = 0$
$s_T = 8$ m
$(v_{avg})_{sp} = 2.67$ m/s
$a = -12$ m/s^2

12–6.

A particle moves along a straight line with a velocity $v = (200s)$ mm/s, where s is in millimeters. Determine the acceleration of the particle at $s = 2000$ mm. How long does the particle take to reach this position if $s = 500$ mm when $t = 0$?

SOLUTION

Acceleration:

$$(\overset{+}{\rightarrow}) \qquad \frac{dv}{ds} = 200$$

Thus, $a = v\dfrac{dv}{ds} = (200s)(200) = \left\{40\left(10^3\right)s\right\}\ \text{mm/s}^2$

When $s = 2000$ mm,

$$a = 40\left(10^3\right)(2000) = 80\left(10^6\right)\ \text{mm/s}^2 = 80\ \text{km/s}^2 \rightarrow$$ **Ans.**

Position:

$$(\overset{+}{\rightarrow}) \qquad dt = \frac{ds}{v}$$

$$\int_0^t dt = \int_{500\ \text{mm}}^{s} \frac{ds}{200s}$$

$$t\Big|_0^t = \frac{1}{200}\ln s\Big|_{500\ \text{mm}}^{s}$$

$$t = \frac{1}{200}\ln\frac{s}{500}$$

At $s = 2000$ mm,

$$t = \frac{1}{200}\ln\frac{2000}{500} = 6.93\left(10^{-3}\right)\text{s} = 6.93\ \text{ms}$$ **Ans.**

Ans:
$a = 80\ \text{km/s}^2$
$t = 6.93$ ms

12–7.

A car has an initial speed of 25 m/s and a constant deceleration of 3 m/s^2. Determine the velocity of the car when $t = 4$ s. What is the displacement of the car during the 4-s time interval? How much time is needed to stop the car?

SOLUTION

$v = v_0 + a_c t$

$v = 25 + (-3)(4) = 13 \text{ m/s}$ **Ans.**

$\Delta s = s - s_0 = v_0 t + \dfrac{1}{2} a_c t^2$

$\Delta s = s - 0 = 25(4) + \dfrac{1}{2}(-3)(4)^2 = 76 \text{ m}$ **Ans.**

$v = v_0 + a_c t$

$0 = 25 + (-3)(t)$

$t = 8.33 \text{ s}$ **Ans.**

Ans:
$v = 13 \text{ m/s}$
$\Delta s = 76 \text{ m}$
$t = 8.33 \text{ s}$

***12–8.**

A particle is moving along a straight line such that its position is defined by $s = (10t^2 + 20)$ mm, where t is in seconds. Determine (a) the displacement of the particle during the time interval from $t = 1$ s to $t = 5$ s, (b) the average velocity of the particle during this time interval, and (c) the acceleration when $t = 1$ s.

SOLUTION

$s = 10t^2 + 20$

(a) $s|_{1\text{ s}} = 10(1)^2 + 20 = 30 \text{ mm}$

$s|_{5\text{ s}} = 10(5)^2 + 20 = 270 \text{ mm}$

$\Delta s = 270 - 30 = 240 \text{ mm}$ **Ans.**

(b) $\Delta t = 5 - 1 = 4 \text{ s}$

$v_{avg} = \dfrac{\Delta s}{\Delta t} = \dfrac{240}{4} = 60 \text{ mm/s}$ **Ans.**

(c) $a = \dfrac{d^2 s}{dt^2} = 20 \text{ mm/s}^2$ (for all t) **Ans.**

Ans:
(a) $\Delta s = 240$ mm
(b) $v_{avg} = 60$ mm/s
(c) $a = 20$ mm/s^2

12–9.

A particle moves along a straight path with an acceleration of $a = (5/s)\ \text{m/s}^2$, where s is in meters. Determine the particle's velocity when $s = 2$ m, if it is released from rest when $s = 1$ m.

SOLUTION

$$a\,ds = v\,dv$$

$$\frac{5}{s}\,ds = v\,dv$$

$$5\int_1^2 \frac{ds}{s} = \int_0^v v\,dv$$

$$5\,(\ln s)\Big|_1^2 = \frac{v^2}{2}$$

$$v = 2.63\ \text{m/s} \qquad \textbf{Ans.}$$

Ans:
$v = 2.63\ \text{m/s}$

12–10.

A particle moves along a straight line with an acceleration of $a = 5/(3s^{1/3} + s^{5/2})$ ft/s^2, where s is in feet. Determine the particle's velocity when $s = 2$ ft, if it starts from rest when $s = 1$ ft. Use a numerical method to evaluate the integral.

SOLUTION

$$a = \frac{5}{\left(3s^{\frac{1}{3}} + s^{\frac{5}{2}}\right)}$$

$$a\,ds = v\,dv$$

$$\int_1^2 \frac{5\,ds}{\left(3s^{\frac{1}{3}} + s^{\frac{5}{2}}\right)} = \int_0^v v\,dv$$

$$0.8351 = \frac{1}{2}v^2$$

$v = 1.29$ ft/s **Ans.**

Ans:
$v = 1.29$ ft/s

12–11.

A particle is moving along a straight line such that its velocity is defined as $v = (-4s^2)$ m/s, where s is in meters. If $s = 2$ m when $t = 0$, determine the velocity and acceleration as functions of time.

SOLUTION

$$v = -4s^2$$

$$\frac{ds}{dt} = -4s^2$$

$$\int_2^s s^{-2}\,ds = \int_0^t -4\,dt$$

$$-s^{-1}\big|_2^s = -4t\big|_0^t$$

$$t = \frac{1}{4}(s^{-1} - 0.5)$$

$$s = \frac{2}{8t + 1}$$

$$v = -4\left(\frac{2}{8t + 1}\right)^2 = -\frac{16}{(8t + 1)^2}\ \text{m/s}$$ **Ans.**

$$a = \frac{dv}{dt} = \frac{16(2)(8t + 1)(8)}{(8t + 1)^4} = \frac{256}{(8t + 1)^3}\ \text{m/s}^2$$ **Ans.**

Ans:

$$v = -\frac{16}{(8t + 1)^2}\ \text{m/s}$$

$$a = \frac{256}{(8t + 1)^3}\ \text{m/s}^2$$

***12–12.**

The speed of a particle traveling along a straight line within a liquid is measured as a function of its position as $v = (100 - s)$ mm/s, where s is in millimeters. Determine (a) the particle's deceleration when it is located at point A, where $s_A = 75$ mm, (b) the distance the particle travels before it stops, and (c) the time needed to stop the particle.

SOLUTION

(a) $a\,ds = v\,dv$

$$a = v\frac{dv}{ds} = (100 - s)(-1) = s - 100$$

When $s = s_A = 75$ mm, $a = 75 - 100 = -25 \text{ mm/s}^2$ **Ans.**

(b) $v = 100 - s$

$0 = 100 - s \qquad s = 100$ mm **Ans.**

(c) $v = \dfrac{ds}{dt}$

$$dt = \frac{ds}{v} = \frac{ds}{100 - s}$$

$$\int_0^t dt = \int_0^{100} \frac{ds}{100 - s}$$

$t = -\ln(100 - s)\big|_0^{100} \rightarrow \infty$ **Ans.**

Ans:
(a) $a_A = -25 \text{ mm/s}^2$
(b) $s = 100$ mm
(c) $t \rightarrow \infty$