General Physics I
Homework Chapter 2

Jonathan Henrique Maia de Moraes (ID: 1620855)

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Problem (1)

A car travels up a hill at a constant speed of 41 mi/h and returns down the hill at a constant speed of 65 mi/h. Calculate the average speed (in mi/h) for the round trip.

R:

$$\begin{aligned}
\text{average speed} &= \frac{1}{2}\left(41\ mi/h + 65\ mi/h\right) \\
&= 53\ mi/h
\end{aligned} \tag{1}$$

Problem (2)

A particle's position is given by $x = 24.0 - 6.0t + 3.0t^2$, in which x is in meters and t is in seconds. Where is the particle when it momentarily stops?

R:

$$\begin{aligned}
x(t) &= 24.0 - 6.0t + 3.0t^2 \\
\frac{dx}{dt} &= v = \frac{d}{dt}\left[24.0 - 6.0t + 3.0t^2\right] \\
v(t) &= -6.0 + 6.0t = 0 \\
t &= 1.0\ s \\
x(1\ s) &= 24.0\ m - (6.0\ m/s)(1\ s) + \left(3.0\ m/s^2\right)(1\ s)^2 \\
&= 24.0\ m - 6.0\ m + 3.0\ m \\
&= 21.0\ m
\end{aligned} \tag{2}$$

Problem (3)

At a certain time a particle had a speed of 42 ft/s in the positive x direction, and 5.2 s later its speed was 77 ft/s in the opposite direction. What was the average acceleration of the particle during this 5.2 s interval?

R:

$$
\begin{aligned}
\bar{a} &= \frac{\Delta v}{\Delta t} \\
\Delta v &= v_f - v_i = (-77\ ft/s) - (42\ ft/s) = -119\ ft/s \\
\Delta t &= t_f - t_i = (5.2\ s) - (0\ s) = 5.2 \\
\bar{a} &= \frac{-119\ ft/s}{5.2\ s} = -22.9\ ft/s^2
\end{aligned} \tag{3}
$$

Problem (4)

On a dry road, a car with good tires may be able to brake with a constant deceleration of 5.6 m/s^2.

Question (a)

How long does such a car, initially travelling at 29 m/s, take to stop?

R:

$$
\begin{aligned}
v_0 &= 29\ m/s \\
v &= 0\ m/s \\
a &= \ -5.6\ m/s^2 \\
v &= v_0 + at \\
0\ m/s &= (29\ m/s) + \left(-5.6\ m/s^2\right) t \\
t &= \frac{29\ m/s}{5.6\ m/s^2} = 5.2\ s
\end{aligned} \tag{4}
$$

Question (b)

How far does it travel in this time?

R:

$$
\begin{aligned}
x_0 &= 0\ m \\
x &= x_0 + v_0 t + \frac{1}{2} a t^2 \\
&= (0\ m) + (29\ m/s)(5.2\ s) + \frac{1}{2}\left(-5.6\ m/s^2\right)(5.2\ s)^2 \\
&= (150.8\ m) - (-75.7\ m) = 75.1\ m
\end{aligned} \tag{5}
$$

Problem (5)

The brakes on your automobile are capable of creating a deceleration of $23\ ft/s^2$. If you are going $93\ mi/h$ and suddenly see a state trooper, what is the minimum time in which you can get your car under the $65\ mi/h$ speed limit? (The answer reveals the futility of braking to keep your high speed from being detected with a radar or laser gun.)

R:

$$
\begin{aligned}
v_0 &= 93\ mi/h\ \times \left(\frac{5280\ ft}{1\ mi}\right) \times \left(\frac{1\ h}{60\ min}\right) \times \left(\frac{1\ min}{60\ s}\right) \\
&= (93 \times 1.467)\ ft/s = 136.431\ ft/s \\
v &= 65\ mi/h \\
&= (65 \times 1.467)\ ft/s = 95.355\ ft/s \\
a &= (-23\ ft/s^2) \\
v &= v_0 + at \\
(95.355\ ft/s) &= (136.431\ ft/s) + \left(-23\ ft/s^2\right) t \\
t &= \frac{(95.355\ ft/s) - (136.431\ ft/s)}{-23\ ft/s^2} \\
&= \frac{-41.076\ ft/s}{-23\ ft/s^2} = 1.786\ s
\end{aligned} \tag{6}
$$

Problem (6)

The speed of a bullet is measured to be 630 m/s as the bullet emerges from a barrel of length 1.1 m. Assuming constant acceleration, find the time that the bullet spends in the barrel after it is fired.

R:

$$\begin{aligned}
v_0 &= 0\ m/s \\
v &= 630\ m/s \\
x_0 &= 0\ m \\
x &= 1.1\ m \\
x &= x_0 + \frac{1}{2}\left(v_0 + v\right)t \\
1.1\ m &= (0\ m) + \frac{1}{2}\left[(0\ m/s) + (630\ m/s)\right]t \\
t &= \frac{1.1\ m}{315\ m/s} = 0.0035\ s
\end{aligned} \tag{7}$$

Problem (7)

At a construction site a pipe wrench struck the ground with a speed of 25 m/s.

Question (a)

From what height was it inadvertently dropped?

R:

$$\begin{aligned}
v_0 &= 0\ m/s \\
v &= -25\ m/s \\
a &= -9.8\ m/s^2 \\
x &= 0\ m
\end{aligned}$$

$$\begin{aligned} 2a(x - x_0) &= v^2 - v_0^2 \\ 2\left(-9.8\ m/s^2\right)(0 - x_0) &= (-25\ m/s)^2 - (0\ m/s)^2 \\ x_0 &= \frac{625\ m^2/s^2}{19.6\ m/s^2} = 31.9\ m \end{aligned} \tag{8}$$

Question (b)

How long was it falling?
R:

$$\begin{aligned} v &= v_0 + at \\ (-25\ m/s) &= (0\ m/s) + \left(-9.8\ m/s^2\right) t \\ t &= \frac{-25\ m/s}{-9.8\ m/s^2} = 2.6\ s \end{aligned} \tag{9}$$

Problem (8)

A hot-air balloon is ascending at the rate of 35 ft/s and is 150 ft above the ground when a package is dropped over the side.

Question (a)

How long does the package take to reach the ground?
R:

$$\begin{aligned} x_0 &= 150\ ft \\ x &= 0\ ft \\ v_0 &= 35\ ft/s \\ a &= -32.2\ ft/s^2 \end{aligned}$$

$$
\begin{aligned}
x &= x_0 + v_0 t + \frac{1}{2} a t^2 \\
0\ ft &= (150\ ft) + (35\ ft/s)t + \frac{1}{2}\left(-32.2\ ft/s^2\right) t^2 \\
a &= \ -16.1 \\
b &= 35 \\
c &= 150 \\
t &= \ \left(\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\right)\ s \\
&= \left(\frac{-(35) \pm \sqrt{(35)^2 - 4(-16.1)(150)}}{2(-16.1)}\right)\ s \\
&= \left(\frac{35 \pm \sqrt{10\ 885}}{32.2}\right)\ s \\
&= \left(\frac{35 \pm 104.33}{32.2}\right)\ s \\
&= \left(\frac{139.33}{32.2}\right)\ s = 4.33\ s
\end{aligned}
\tag{10}
$$

Question (b)

With what speed does it hit the ground?
R:

$$
\begin{aligned}
v &= v_0 + at \\
v &= (35\ ft/s) + \left(-32.2\ ft/s^2\right)(4.33\ s) \\
&= (35\ ft/s) - (139.43\ ft/s) = -104.43\ ft/s \\
\text{speed} &= |v| = 104.43\ ft/s
\end{aligned}
\tag{11}
$$

Problem (9)

A ball is shot vertically upward from the surface of another planet. A plot of y versus t for the ball is shown in fig. 1,

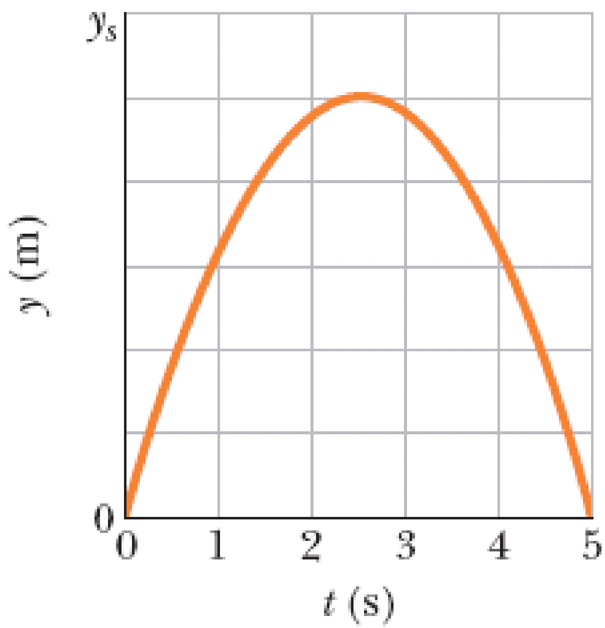

Figure 1: Plot of y versus t

where y is the height of the ball above its starting point and $t = 0$ at the instant the ball is shot. The point marked as y_s has a value of 48.0 m.

Question (a)

What is the magnitude of the free-fall acceleration on the planet?

R:

$$
\begin{aligned}
y_s &= 48.0\ m \\
y_i &= \frac{48.0\ m}{6} = 8\ m \\
y(0\ s) &= 0\ m \\
y(1\ s) &\approx 25\ m \\
y(2\ s) &\approx 38\ m \\
y(2.5\ s) &= 40\ m \\
y(3\ s) &\approx 38\ m \\
y(4\ s) &\approx 25\ m \\
y(5\ s) &\approx 0\ m
\end{aligned}
$$

$$
\begin{aligned}
\bar{v} = \frac{\Delta x}{\Delta t} &= \frac{\text{rise}}{\text{run}} \\
\bar{v}(0\ s \rightarrow 1\ s) &\approx 25\ m/s \\
\bar{v}(1\ s \rightarrow 2\ s) &\approx 13\ m/s \\
\bar{v}(2\ s \rightarrow 3\ s) &\approx 0\ m/s \\
\bar{v}(3\ s \rightarrow 4\ s) &\approx\ -13\ m/s \\
\bar{v}(4\ s \rightarrow 5\ s) &\approx\ -25\ m/s
\end{aligned}
$$

$$
\begin{aligned}
\bar{a} &= \frac{\Delta v}{\Delta t} \\
\bar{a}(1\ s \rightarrow 2\ s) &\approx\ -12\ m/s^2 \\
\bar{a}(2\ s \rightarrow 3\ s) &\approx\ -13\ m/s^2 \\
\bar{a}(3\ s \rightarrow 4\ s) &\approx\ -13\ m/s^2 \\
\bar{a}(4\ s \rightarrow 5\ s) &\approx\ -12\ m/s^2 \\
\text{free-fall acceleration} &\approx -12.5\ m/s^2
\end{aligned} \tag{12}
$$

Question (b)

What is the magnitude of the initial velocity of the ball?

R:

$$\begin{aligned} y &= y_0 + v_0 t + \frac{1}{2}at^2 \\ 25\ m &= (0\ m) + v_0(1\ s) + \frac{1}{2}\left(-12.5\ m/s^2\right)(1\ s)^2 \\ v_0 &= \frac{(25\ m) + (6.25\ m)}{1\ s} = 31.25\ m/s \end{aligned} \tag{13}$$

The function of the fig. 1 can be approximated:

$$y(t) = 31.25t - 6.25t^2 \tag{14}$$

Problem (10)

At the instant the traffic light turns green, an automobile starts with a constant acceleration of 6.7 ft/s^2. At the same instant a truck, traveling with a constant speed of 32 ft/s, overtakes and passes the automobile.

Question (a)

How far beyond the traffic signal will the automobile overtake the truck?

R:

Automobile	Truck
$x_{A_0} = 0\ ft$	$x_{T_0} = 0\ ft$
$x_A = x_T$	$x_T = x_A$
$v_{A_0} = 0\ ft/s$	$v_{T_0} = 32\ ft/s$
$v_A = ?\ ft/s$	$v_T = v_{T_0} = 32\ ft/s$
$a_A = 6.7\ ft/s^2$	$a_T = 0\ ft/s^2$

$$\begin{aligned}
x &= x_0 + v_0 t + \frac{1}{2} a t^2 \\
x_A &= (0\ ft) + (0\ ft/s)t + \frac{1}{2}\left(6.7\ ft/s^2\right)t^2 \\
&= \left(3.35\ ft/s^2\right)t^2 \\
x_T &= (0\ ft) + (32\ ft/s)t + \frac{1}{2}\left(0\ ft/s^2\right)t^2 \\
x_T &= (32\ ft/s)t
\end{aligned}$$

$$\begin{aligned}
\left(3.35\ ft/s^2\right)t^2 &= (32\ ft/s)t \\
t &= \frac{32\ ft/s}{3.35\ ft/s^2} = 9.552\ s \\
x_T &= (32\ ft/s)(9.552\ s) = 305.7\ ft \qquad (15) \\
x_A &= \left(3.35\ ft/s^2\right)(9.552\ s)^2 \\
&= \left(3.35\ ft/s^2\right)\left(91.241\ s^2\right) = 305.7\ ft \qquad (16)
\end{aligned}$$

Question (b)

How fast will the car be traveling at that instant?

R:

$$\begin{aligned}
v &= v_0 + at \\
v_A &= (0\ ft/s) + (6.7\ ft/s^2)(9.552\ s) = 64\ ft/s
\end{aligned} \qquad (17)$$

Problem (11)

A proton moves along the x axis according to the equation $x = 47t + 12t^2$, where x is in meters and t in seconds. Calculate:

Question (a)

The average velocity of the proton during the first 3.0 s of its motion.
R:

$$\begin{aligned}
x(0.0\ s) &= (47\ m/s)(0.0\ s) + (12\ m/s^2)(0.0\ s)^2 = 0\ m \\
x(3.0\ s) &= (47\ m/s)(3.0\ s) + (12\ m/s^2)(3.0\ s)^2 \\
&= (141\ m) + (108\ m) = 249\ m \\
\bar{v} &= \frac{\Delta x}{\Delta t} = \frac{249\ m}{3\ s} = 93\ m/s
\end{aligned} \tag{18}$$

Question (b)

The instantaneous velocity of the proton at $t = 3.0\ s$.
R:

$$\begin{aligned}
v &= \frac{dx}{dt} = \frac{d}{dt}\left[47t + 12t^2\right] \\
&= 47 + 24t \\
v(3.0\ s) &= (47\ m/s) + \left(24\ m/s^2\right)(3.0\ s) \\
&= 119\ m/s
\end{aligned} \tag{19}$$

Question (c)

The instantaneous acceleration of the proton at $t = 3.0\ s$.
R:

$$\begin{aligned}
a &= \frac{dv}{dt} = \frac{d}{dt}[47 + 24t] \\
&= 24 \\
a(3.0\ s) &= 24\ m/s^2
\end{aligned} \tag{20}$$