107 Answer Key - Chapter 3 assignments

Conceptual: 8, 30, 34
Problems: 2, 6, 10, 16

September 18

1 Conceptual Exercises

8) "In order to experimentally verify the law of inertia, would you need to be able to measure time? Weight? Distance?"

First we need to decide what definition of the law of inertia we will be using. The book provides 3 different definitions:

i) A body that is subject to no external forces will stay at rest if it was at rest to begin with, and will keep moving if it was moving to begin with; in the latter case, its motion will be in a straight line at an unchanging speed.

To show an object stays at rest, you need to show its $\boxed{\text{position}}$ does not change for a long period of $\boxed{\text{time}}$. Likewise, if you are to show an object keeps moving, you need to show its position keeps changing for a long period of time. Notice that the definition of the law of inertia $\boxed{\text{does not mention weight}}$, so we will not need to measure it to verify the law.

ii) A body that is subject to no external forces must maintain an unchanging velocity.

Since $velocity = \frac{change\ in\ position}{change\ in\ time}$ with a direction, to show that velocity is not changing requires measuring $\boxed{\text{distance}}$ and $\boxed{\text{time}}$. Note once again that weight is not in the definition of the law of inertia.

iii) A body that is subject to no external forces must be unaccelerated.

An acceleration is a change in velocity, so to show that an object's acceleration is zero requires showing the velocity is constant; this was done in (ii).

30) "A car accelerates from 0 to 100 km/hr in 10 s. Find its acceleration. Drag racers can get to 400 km/hr from rest in 5 s. How big is this acceleration?"

$$\begin{aligned}
Acceleration &= \tfrac{change\ in\ velocity}{time\ elapsed} \\
A_{car} &= \tfrac{100\ km/hr - 0\ km/hr}{10\ s} = \tfrac{10\ \frac{km}{hr}}{s} = \boxed{.00278\ \tfrac{km}{s^2}} = 2.78\ \tfrac{m}{s^2} \simeq .28\ g's \\
A_{drag} &= \tfrac{400\ km/hr - 0\ km/hr}{5\ s} = \tfrac{80\ \frac{km}{hr}}{s} = \boxed{.0222\ \tfrac{km}{s^2}} = 22.2\ \tfrac{m}{s^2} \simeq 2.2\ g's
\end{aligned}$$

$A_{drag}/A_{car} = 7.98$, so the acceleration of the drag-racer is about 8 times that of the car. Note that the drag-racer is accelerating at about 2 g's - two times the acceleration of gravity!

34) "Figure 3.16 represents a multiple-flash photo of a falling ball. Neglect air resistance. At which point, A or B, is the ball's acceleration larger? At which point is its velocity larger?"

Since the ball is falling in gravity, we know that the $\boxed{\text{acceleration must be constant}}$, so A and B have the same acceleration. However, the $\boxed{\text{velocity at B is larger}}$ $\boxed{\text{than A because}}$ (either justification is correct):

i) the points nearby B are spaced further apart than at A, so the ball is traveling a larger distance for the same amount of time, meaning the velocity is larger.

ii) the velocity of an object increases the longer it is falling in gravity; since B is later than A, its velocity should be larger.

2 Problems

2) "It takes light about 8 minutes to travel here from the sun. Given that the speed of light is 300,000 km/s, how far is it to the sun?"

Let's first invert our formula for speed to find the distance traveled by the light:

$$\begin{aligned}
speed &= \tfrac{distance\ traveled}{time\ elapsed} \\
\Rightarrow dist.\ traveled &= (speed)(time\ elapsed) = 300,000\ km/s * 8\ min.
\end{aligned}$$

But we can't cancel the seconds and minutes - they're not the same units! So, we need to convert the minutes:

$$8\ min * \frac{60\ s}{1\ min} = 480\ s. \tag{1}$$

Now we can complete the problem:

$$dist.\ to\ sun = 300,000\ km/s * 480\ s = \boxed{\text{144,000,000 km}} = 1.44 * 10^8\ km. \tag{2}$$

6) "A car starts from rest and maintains an acceleration of 4.5 (km/hr)/s for 5 s. How fast is it going at the end of the 5 s?"

Even though the acceleration looks odd, it is still a valid to use it in this form.

$$\begin{aligned} acceleration &= \tfrac{change\ in\ velocity}{time\ elapsed} \\ \Rightarrow change\ in\ velocity &= (acceleration) * (time\ elapsed) = \end{aligned}$$

$$4.5\ \tfrac{kmhr}{s} * 5\ s = \boxed{22.5\ \tfrac{km}{hr}.}$$

10) "You drop a rock down a well and hear a splash 3 s later. As Charlie Brown would say, the well is 'three seconds deep.' But how many meters deep is it, assuming that air resistance is negligible, and that the time for sound to travel back up the well is also negligible?"

One way to do this problem is to look at Figure 3.12 page 81, and read off how far an object would fall in 3 seconds - $\boxed{\text{45 meters}}$.

However, let's do it using the equations we now know about falling in gravity. If acceleration is constant, we have the following equation:

$$\begin{aligned} distance &= \tfrac{1}{2}(acceleration) * (time)^2 \\ acceleration\ on\ Earth &= 9.8\ m/s^2 \\ distance &= \tfrac{1}{2}(9.8\ m/s^2) * (3\ s)^2 \qquad = \boxed{\text{44.1 m}}. \end{aligned}$$

Note that we used the more exact 9.8 m/s^2 in the above equation; if you use $10m/s^2$, the answer will be 45 meters, in agreement with Figure 3.12.

16) "On the planet Mars, a free-falling object released from rest falls 4 m in 1 s and is moving at 8 m/s at that time. How fast would such an object be moving after 2 s? 3 s?"

There are two ways of solving this problem: using concepts and using equations.

<u>Conceptual Solution</u>

Looking once again at Figure 3.12 on page 81, we see that the speed of a ball falling in gravity increases by the same amount each second - namely 10 m/s for Earth. All we need to do is find the change in speed per second for Mars. But this is given to us: in 1 second, the change is 8 m/s! So, after 2 s the speed is 8 m/s more: $\boxed{\text{16 m/s.}}$ After 3 s the speed is another 8 m/s more: $\boxed{\text{24 m/s.}}$

<u>Equation-based Solution</u>

We proceed in two steps: 1) find the acceleration due to gravity on Mars, then 2) use this in the equation speed = (acceleration)*(time elapse) to find the speed after 2 s and 3 s.

1) By the definition of the acceleration on Mars:

$$Acceleration_{Mars} = \frac{change\ in\ velocity}{time\ elapsed} = \frac{8\ m/s}{1\ s} = 8\ m/s^2. \qquad (3)$$

2) Using the acceleration:

$$speed(t = 2\ s) = (8\ m/s^2) * 2\ s = \boxed{16 \text{ m/s}}$$
$$speed(t = 3\ s) = (8\ m/s^2) * 3\ s = \boxed{24 \text{ m/s.}}$$