PHYSICS 1020

Homework set 3

15 January 1997

[3.4] If you ride on a smooth fast train at an unchanging speed and throw a baseball upward inside the train, will the baseball then get left behind, and will it come down toward the rear of the car? Explain.
Answer:
The ball will move straight up and come back down into your hand. Before being tossed up into the air, the ball is moving at the same velocity as the train, and keeps doing it (law of inertia). The up- and then downward motion due to being thrown straight up does not have any influence on the horizontal motion, since no force is exerted in the direction of the train's (and therefore the ball's horizontal) velocity.

[3.11] You wish to travel from downtown New York City (NYC) to downtown Washington, DC (DC), a distance of 330 km. You consider two options: train and plane. The high-speed train takes 1.5 hr plus 30 min. in stations. The airplane flies the 330 km (airport to airport) in just 30 min., but the drive to the NYC airport takes 30 min., you must arrive 30 min. before departure time; the plane waits 15 min. before take-off; and it takes 45 min. to get your luggage and drive into DC. Find the train's track speed, the plane's flying speed, the total travel time for each option, and the overall average speed for each option.
Answer:
The train's track speed = distance/time = 330 km /1.5 hr = 220 km/hr;
plane's flying speed = 330 km / 0.5 hr = 660 km/hr;
total time for train = (1.5 + 0.5) hr = 2.0 hr;
total time for plane = (0.5 + 0.5 + 0.25 + 0.5 + 0.75) hr = 2.5 hr;
average speed for train = 330 km / 2.0 hr = 165 km/hr;
average speeed for plane = 330 km / 2.5 hr = 132 km/hr.

[3.12] You drive from New York City to Washington, DC, by car. You drive in traffic for the first hour at an average 50km/hr. You cover the next 250 km in 3.0 hr and then drive the remaining 30 km into Washington in 30 min. Find your total time and average speed.
Answer:
Distance covered during first hour = speed • time = (50 km/hr) • 1 hr = 50 km;
total distance driven = 50 km + 250 km + 30 km = 330 km;
total duration of trip = 1.0 hr + 3.0 hr + 0.5 hr = 4.5 hr;
average speed = (total distance)/(total duration) = 330 km / 4.5 hr = 73.3 km/hr.

[3.13] A French TGV (*"train à grande vitesse"*) train cruises on straight tracks at a steady 290 km/hr (180 mi/hr). What is its acceleration?
Answer:
Since the train's velocity does not change, its acceleration is zero.

[**3.19**] Can a slow-moving object have a large acceleration? Can a fast-moving object have a small acceleration?
Answer:
Since acceleration is the rate of *change of velocity*, the answer to both questions is "yes"; a racing car at the beginning of the race has a very small speed, but very high acceleration; an airplane at cruising altitude and speed has a high speed, but very small (possibly even zero) acceleration.

[**3.27**] An astronaut on another planet drops a rock off a cliff. How much faster is the rock moving at the end of 3 s, as compared with 1 s? How much farther (measured from the release point) does the rock fall in 3 s, as compared with 1 s?
Answer:
Free fall is motion with constant acceleration; for such a motion, the speed is proportional to the time elapsed since the beginning of the motion, and the distance travelled is proportional to the square of that time. Therefore, the speed after 3 s is 3 times the speed after 1 s, and the distance travelled after 3 s is 9 times that after 1 s.

[**3.20**] How many devices in a car are designed to cause acceleration?
Answer:
Accleration being the rate of change of velocity, anything that causes the speed or the direction of motion to change causes acceleration; thus, there are three devices in a car that cause acceleration: the accelerator, the brake, and the steering wheel.

[**3.28**] Neglecting air resistance, would the answers to exercise [3.27] be different if the rock were dropped on Earth? Neglecting air resistance, would the distance fallen in 3s on Earth be likely to be the same as the distance fallen in 3 s on the other planet?
Answer:
The answers to exercise [3.27] are independent of the value of the constant acceleration. But the value of the distance travelled after a given time *does* depend on the value of the acceleration, which is very likely to be different on the two planets.

[**3.30**] 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 the object be moving after 2s? After 3 seconds? How far would the object fall in 2s? In 3s?
Answer:
For motion with constant acceleration, the speed at time t is given by

$$v(t) = v_0 + at$$

For an object released at rest, $v_0 = 0$, and therefore $a = v(t)/t = (8\text{m/s}/1\text{s}) = 8\text{m/s}^2$. After 2 seconds the speed of the object would be $v(2) = 8\text{m/s}^2 \times 2\text{s} = 16\text{m/s}$, and after 3 seconds it would be 24 m/s.
The distance travelled in motion with constant acceleration,

$$D(t) = x(t) - x_0 = v_0 t + \frac{a}{2}t^2$$

For motion starting from rest, this gives $D(t) = \frac{a}{2}t^2$, corresponding to 4m, 16m, 36m in 1, 2, 3 seconds.