Answers to Questions

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Exercise 4-14

The average velocity is the average rate of change of displacement with time, but the average speed is the average rate of change of distance with time.

If a runner runs a circular 400 m track in 60 s, her average velocity is zero (displacement is zero), but the average speed is

$$v = \frac{s}{t} = \frac{400\,\mathrm{m}}{60\,\mathrm{s}} \approx 6.7\,\mathrm{m\,s^{-1}}. \quad (1)$$

Average velocity is a vector quantity whereas the average speed is a scalar quantity.

Exercise 4-16

If the velocity changes, it is possible for the speed to stay constant. For example, if a bicycle rounds a curve at constant speed (say, $12\,\mathrm{m\,s^{-1}}$), the direction of the velocity is constantly changing. As a result, the speed is constant, but velocity changing.

If the velocity is constant, both the direction of motion and the speed are constants. As a result, the speed cannot change if the velocity stays constant.

Exercise 4-18

a) The average speed in 100 m is

$$v = \frac{s}{t} = \frac{100\,\mathrm{m}}{9.69\,\mathrm{s}} \approx 10\,\mathrm{m\,s^{-1}}. \tag{2}$$

b) The average speed in 10 000 m is

$$v = \frac{s}{t} = \frac{10\,000\,\mathrm{m}}{26 \times 60\,\mathrm{s} + 17\,\mathrm{s}} \approx 6.3\,\mathrm{m\,s^{-1}}. \tag{3}$$

c) The average speed in the marathon is

$$v = \frac{s}{t} = \frac{42\,195\,\mathrm{m}}{2 \times 60 \times 60\,\mathrm{s} + 3 \times 60\,\mathrm{s} + 59\,\mathrm{s}} \approx 5.7\,\mathrm{m\,s^{-1}}. \tag{4}$$

Exercise 4-21

The speed of light is so large that we see the lightning flash immediately.

Because the sound travels at constant speed, the lighning strike is

$$s = vt = 343\,\mathrm{m\,s^{-1}} \times 5\,\mathrm{s} \approx 2\,\mathrm{km} \tag{5}$$

away from the observer.

Exercise 4-22

From the equation of the average speed

$$v = \frac{s}{t} \tag{6}$$

it follows that the time taken is

$$t = \frac{s}{v} = \frac{149 \times 10^{9}\,\mathrm{m}}{3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}} \approx 497\,\mathrm{s} = 8\,\mathrm{min}\,18\,\mathrm{s}. \tag{7}$$

Exercise 4-22

Because the squirrel accelerates from rest, the initial velocity is $u = 0\,\mathrm{m\,s^{-1}}$. The final velocity is $v = 1.202\,\mathrm{m\,s^{-1}}$, and the time taken is $t = 0.891\,\mathrm{s}$.

The average acceleration is

$$a_{\mathrm{av}} = \frac{v-u}{t} = \frac{1.202\,\mathrm{m\,s^{-1}} - 0\,\mathrm{m\,s^{-1}}}{0.891\,\mathrm{s}} \approx 1.35\,\mathrm{m\,s^{-2}}. \tag{8}$$

We round the answer to three significant figures, because there are four significant figures in $1.202\,\mathrm{m\,s^{-1}}$, and three in $0.891\,\mathrm{s}$, which is the least precise value in the calculation.

The correct answer is a).

Exercise 4-27

Because the motorcycle accelerates from rest, the initial velocity is $u = 0\,\mathrm{m\,s^{-1}}$. The final velocity is $v = \frac{100\,\mathrm{km\,h^{-1}}}{3.6} = 27.8\,\mathrm{m\,s^{-1}}$, and the time taken is $t = 3.6\,\mathrm{s}$.

The average acceleration is

$$a_{\mathrm{av}} = \frac{v-u}{t} = \frac{27.8\,\mathrm{m\,s^{-1}} - 0\,\mathrm{m\,s^{-1}}}{3.6\,\mathrm{s}} \approx 7.7\,\mathrm{m\,s^{-2}}. \quad (9)$$

There are one, two, or three significant figures in $100\,\mathrm{km\,h^{-1}}$, and two in $0.891\,\mathrm{s}$. Assuming that there is least two significant figures in $100\,\mathrm{km\,h^{-1}}$, we round the answer to two significant figures.

Note that we have to use at least one significant figure more than the final result in $27.8\,\mathrm{m\,s^{-1}}$ to avoid the rounding error.

Exercise 5-1

The correct answer is a). When the net force is zero, there are no unbalanced forces. According to Newton's First Law of motion, the object is thus in uniform motion.

Item b) represents a common misconception. Being momentarily at rest does not imply zero acceleration. For example, a ball thrown vertically upwards is momentarily at rest at the highest point, but acceleration of the ball is the acceleration due to the gravity.

Exercise 5-3

The correct answer is c). In free fall the acceleration is the acceleration due to gravity which is independent of the mass.

We see this from the Newton's Second Law of Motion. The gravitational force that accelerates an object is $G = mg$. By the Newton's Second Law of Motion the acceleration is

$$a = \frac{F}{m} = \frac{mg}{m} = g = 9.81\,\mathrm{m\,s^{-2}} \tag{10}$$

which is independent of the mass. In free fall, the objects fall with the same acceleration independently of their mass.

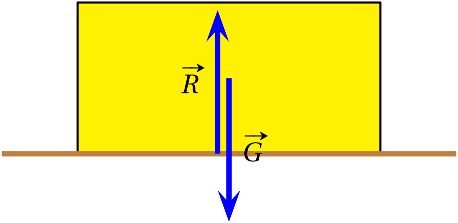
Exercise 5-4

a) Weight results from the gravitational interaction between the Earth and the apple. It is the gravitational force by the Earth on the apple. The reaction force to the weight of the apple is the gravitational force the apple exerts on the Earth.

b) As the chair pushes you up, you push the chair down. The reaction force to the normal reaction force is the force by which you push the chair down.

c) The reaction force to the force the ground exerts on the bicycle tyre is the frictional force the bicycle tyre exerts on the ground.

Exercise 5-5



a) A box lies on a table. Normal reaction force $\vec{R}$ is equal in magnitude to the weight $\vec{G}$, but points in opposite direction. The point of application for the weight is the center of mass. The normal reaction force starts from the middle of the bottom.

Exercise 5-5

b) No, they are not. Because the both forces act on the same object, they cannot be a force and the reaction force. See answers 5-4 a) and b) for the reaction forces.

b) The weight is

$$G = mg = 0.370\,\mathrm{kg} \times 9.81\,\mathrm{m\,s^{-2}} \approx 3.63\,\mathrm{N}. \tag{11}$$

Note that for the calculation of the weight, the mass has to be in kilograms.

Exercise 5-6

By the Newton's Third Law of Motion, the truck and the bug exert equal and opposite forces on one another.

Exercise 5-8

By Newton's Third Law go Motion, the teams exert equal and opposite forces on one another. Which team wins depends on various factors such as the total mass of a team, friction between the shoes and the ground, and the grip on the tug (image © CC Ekabhishek).

Exercise 5-9

$v_1 = 0\,\mathrm{m\,s^{-1}}, v_2 = 100\,\mathrm{km\,h^{-1}}, \Delta t = 5.7\,\mathrm{s}, m = 278\,\mathrm{kg}$

For the net force we need first solve the average acceleration of the motorcycle. Since the speed is expressed in $\mathrm{km\,h^{-1}}$, we convert to $\mathrm{m\,s^{-1}}$ by dividing the value by 3.6. The average acceleration is

$$a_{\mathrm{av}} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t} = \frac{\frac{100}{3.6}\,\mathrm{m\,s^{-1}} - 0\,\mathrm{m\,s^{-1}}}{5.7\,\mathrm{s}} \approx 4.873\,\mathrm{m\,s^{-2}}.$$

The magnitude of the (average) net force on the motorcycle system is

$$\Sigma F = ma = 278\,\mathrm{kg} \times 4.873\,\mathrm{m\,s^{-2}} \approx 1400\,\mathrm{N}. \quad (12)$$

The direction of the net force vector is in the direction of the motion of the motorcycle (i.e the direction of the acceleration vector).

Exercise 5-10

$F = 123\,\mathrm{N}, m = 0.450\,\mathrm{kg}$

By the Newton's Second Law of Motion, the magnitude of the acceleration of the ball is

$$a = \frac{F}{m} = \frac{123\,\mathrm{N}}{0.450\,\mathrm{kg}} \approx 270\,\mathrm{m\,s^{-2}}$$

which is approximately 27 times the acceleration due to the gravity!

The direction of the acceleration is the direction of the net force acting on the ball.

Exercise 5-11

$h = 60\,\mathrm{m}, \Delta t = 2.5\,\mathrm{s}, m = 278\,\mathrm{kg}, a_{\max} = 4g, g = 9.81\,\mathrm{m\,s^{-2}}, m = 50.2\,\mathrm{kg}$

a) The magnitude of Eetu's average velocity is

$$v_{\text{av}} = \frac{\Delta s}{\Delta t} = \frac{h}{\Delta t} = \frac{60\,\mathrm{m}}{2.5\,\mathrm{s}} \approx 24\,\mathrm{m\,s^{-1}}.$$

The direction of the average velocity vector is upwards.

b) The forces acting are the normal force from the chair $\vec{N}$, the weight $\vec{G}$, and air resistance $\vec{F}_{\text{air}}$.

c) From NII we see that the net force is proportional to acceleration ($F \propto a$). As a result, the net force is at maximum at maximum acceleration. The magnitude of the maximum net force is thus

$$F_{\max} = ma_{\max} = 50.2\,\mathrm{kg} \times 4 \times 9.81\,\mathrm{m\,s^{-2}} \approx 2000\,\mathrm{N} = 2.0 \times 10^3\,\mathrm{N} = 2.0\,\mathrm{kN}.$$