Physics 2002 , Spring 2018

Problem Set 2

8 problems; 46 points; estimated time: 1 hr.

1.(5) A block with a mass of 5 kilograms is pulled across a tabletop by a force of 10 newtons applied by a string tied to the end of the block. The table exerts a frictional force of 2 newtons on the block opposite to the direction of motion. What is the acceleration of the block?

1. (Answer, 5 points)

$$F = m \times a$$
$$F_{net} = F_{pull} - F_{friction} = m \times a$$
$$(10\ N) - (2\ N) = (5\ kg) \times a$$
$$a = \frac{8\ N}{5\ kg} = \frac{8\ kg \times m/s^2}{5\ kg}$$
$$a = 1.6\ m/s^2$$

2. (2) What is the difference between mass and weight?

2. (Answer, 2 points) Weight is the measure of the gravitational force acting on an object, while mass is an inherent property relating to the amount of matter comprising an object.

3. (3) If only two forces of equal magnitude act on an object in opposite directions, does the object accelerate? Could the object be moving?

3. (Answer, 3 points) The object cannot be accelerate given only two equal forces applied in opposite direction; however, the object could be moving with a constant velocity (or be stationary, with a constant velocity of zero). This principle is called Newtonian relativity.

4. (5) A silk tablecloth, when being pulled, exerts a frictional force of 0.6 newtons on a ceramic plate with a mass of 0.4 kilograms. What is the acceleration of the plate? In what direction?

4. (Answer, 5 points)

$$F = m \times a$$
$$(0.6\ N) = (0.4\ kg) \times a$$
$$a = \frac{0.6\ N}{0.4\ kg} = \frac{0.6\ kg \times m/s^2}{0.4\ kg}$$
$$a = 1.5\ m/s^2$$

The plate follows the tablecloth.

5. (10) A 60-kilogram person in an elevator is accelerating upwards at a rate of 1.2 meters per square-second. (a) What is the net force acting upon the person? (b) What is the gravitational force acting upon the person? (c) What is the normal force pushing upwards on the person's feet?

5. (Answer, 10 points)

(a)

$$F_{net} = m \times a$$
$$F_{net} = (60\ kg) \times (1.2\ m/s^2)$$
$$F_{net} = 72\ N$$

(b)

$$F_g = m \times g$$
$$F_g = (60\ kg) \times (-\ 9.8\ m/s^2)$$
$$F_g = -\ 558\ N$$

(c)

$$F_{net} = \sum all\ forces$$
$$F_{net} = F_g + F_N$$
$$(72\ N) = (-\ 558\ N) + F_N$$
$$F_N = 72\ N + 558\ N = 630\ N$$

6. (7) A 0.5-kilogram book rests on a table. A downward force of 6 newtons is exerted on the top of the book by a hand pushing down on the book; no movement occurs. (a) What is the magnitude of the gravitational force acting upon the book? (b) What is the magnitude of the normal force exerted by the table on the book?

6. (Answer, 7 points)

(a)

$$F_g = m \times g$$
$$F_g = (0.5\ kg) \times (-\ 9.8\ m/s^2)$$
$$F_g = -\ 4.9\ N$$

(c)

$$Constant\ velocity: \sum F = 0\ N$$
$$(0\ N) = F_g + F_N + F_{hand}$$
$$(0\ N) = (-4.9\ N) + F_N + (-6\ N)$$
$$F_N = 4.9\ N + 6\ N = 10.9\ N$$

7. (6) A car with a mass of 1,200 kilograms is moving around a curve with a radius of 40

meters at a constant speed of 20 meters per second (approximately 45 miles per hour). (a) What is the centripetal acceleration of the car? (b) what is the magnitude of the force required to produce this centripetal acceleration?

7. (Answer, 6 points)

(a)

$$a_c = \frac{v^2}{r}$$

$$a_c = \frac{(20\frac{m}{s})^2}{40\ m}$$

$$a_c = 10\ m/s^2$$

(b)

$$F_c = m \times a_c$$

$$F_c = (1{,}200\ kg) \times (10\frac{m}{s^2})$$

$$F_c = 12{,}000\ N\ towards\ center$$

8. (9) Colonel Murgatroyd has a weight of 720 newtons (about 162 pounds) when he is standing on the surface of the Earth. (a) What is the colonel's mass? (b) What would his weight (the gravitational force exerted by the Earth) be if he doubled his distance from the center of the Earth by flying a spacecraft? Use Newton's Universal Law of Gravitation, and take Earth's radius to be 6,371 km. (b) Compare the forces on the colonel and explain their ratio.

8. (Answer, 9 points)

(a) Since the colonel's weight is defined in the problem at Earth's surface, we can use the close-to-the-surface formula for gravitation:

$$F_g = m \times g$$

$$-720\ N = m \times (-9.8\ m/s^2)$$

$$m_{colonel} = 73.5\ kg$$

(b) Find the force at the doubled distance.

$$F_G = -\frac{Gm_1m_2}{r^2}$$

$$F_G|_{doubled\ distance} = -\frac{Gm_{colonel}m_{\oplus}}{(2r_{\oplus})^2}$$

Notice how the whole doubled distance gets squared! We double first, then square; we don't square first, then double.

$$F_G = -\frac{\left(6.67 \times 10^{-11}\ \frac{m^3}{kg \times s^2}\right) \times (73.5\ kg) \times (5.972 \times 10^{24} kg)}{(2 \times (6{,}371 \times 10^3\ m))^2}$$

$$F_G = -\,180.326\ N$$

(b)

Step 1: Comparison.

$$\frac{-180\ N}{-720\ N} = \frac{1}{4}$$

So, when we doubled the distance from the Earth, the colonel's weight was quartered.

Step 2: Consistency?

Newton's Universal Law of Gravitation is inversely proportional to the square of the distance between the two objects; so, if we double that distance, we quarter the force between them. Our answer is right.