UNIVERSITY COLLEGE – YANBU

Preparatory Physical Science (PHSC 001)

Module 1- Mechanics
(Solved Problems)

Prepared by
Engr. Hamdy Abou El-Ela
and
Dr. Naseer Ahmed

Reference Textbook
Conceptual Physical Science by P. Hewitt, J. Suchocki and L. Hewitt
3rd Edition, Pearson Addison-Wesley (2004)
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Let's solve few problems on Mechanics!

Question 1: A motorcyclist travels a distance of *15 km* in *20 minutes*. What is his average speed (v) in *m/s* and *km/h*?

Solution

$$Average\ Speed = \frac{distance\ covered}{travel\ time}$$

$$v = \frac{d}{t} = \frac{12\times10^3\ m}{20\times60\ s} = 10\ \frac{m}{s}$$

$$v = \frac{d}{t} = \frac{12\ km}{(20/60)\,h} = 36\ \frac{km}{h}$$

Question 2: A tennis ball covers the full length of a tennis court which is *24 meter* long in *0.5 seconds*. What is its average speed (v) in *km/h*?

Solution

$$Average\ Speed = \frac{distance\ covered}{travel\ time}$$

$$v = \frac{d}{t} = \frac{24\ m}{0.5\ s} = 48\ \frac{m}{s} = \frac{48km/1000}{1h/(60\times60)} = 172.8\ \frac{km}{h}$$

Question 3: Consider two forces $F_1 = 60N$ and $F_2 = 30N$ are acting on a body. What will be the net force in each of the following case?

i) When F_1 is acting towards the east, while F_2 is acting towards the west.

ii) When both F_1 and F_2 are acting towards the north.

Solution

Case I: F_1 and F_2 are acting in the opposite directions, therefore the net force (Resultant), R is given by

$$R = F_1 - F_2 = 60 - 30 = 30N$$

Net force is in the direction of F_1 (the bigger force) i.e. towards the east.

Case II: F_1 and F_2 are acting in the same direction; therefore the net force (R) is given by

$R = F_1 + F_2 = 60 + 30 = 90N$ towards the north

Question 4: A horizontal force of *50N* pushes a box on a horizontal floor at a constant velocity towards the east

i) What is the net force acting on the box?

ii) What is the magnitude and direction of the frictional force on the box?

Solution

Case I: Since the box is moving at a constant velocity (both magnitude and direction) which means acceleration is zero. According to the Newton's Second Law, when acceleration is zero the net force acting on it is also zero.

Case II: Since the net force acting on the box is zero, therefore, the frictional force acting on the box is also *50N*. However, this frictional force will be apposite to the pushing force (i.e. it will act towards the west).

Question 5: A child learns in school that the earth is traveling approximately with a speed of *100,000 km/h* around the sun. He asks a question that if the earth is moving with such a fast speed then why we are not swept off from the earth's surface. What is your explanation?

Solution

We are located on the surface of the earth and moving with the earth and its atmosphere as a SINGLE unit. Though our speed is more than *100,000 km/h* with respect to (relative to) the sun but our speed with respect to the Earth and its atmosphere is zero.

Question 6: A box has a mass of *100 kg* mass. What is its weight in Newton?

Solution

$$Weight = mass \times gravitational\ acceleration$$

$$W = mg$$
$$= 100 \times 9.8 = 980\ Newton$$

Question 7: A box having a mass of *100 kg* is lying on a horizontal plan. If this box is pulled horizontally with a net force of 200N, what is its acceleration?

Solution

From Newton's Second Law:

$$The\ net\ force = mass \times acceleration \qquad i.e.,\ F = ma$$

This implies $200\ N = 100kg \times a$

$$a = 2\ m\ s^{-2}$$

Question 8: An astronaut has a mass of *80kg* on the moon. Find:

a) his mass on the earth,
b) his weight on the earth
c) his weight on the moon

Solution

The mass is the quantity of matter content and its value remains same everywhere whether on moon or on earth. However, the weight of an object depends on the gravitational pull of the planet and hence it does not remain constant. Remember, the gravitational acceleration on the moon is *1/6* of that on the earth, and the gravitational acceleration on the earth is $9.8\ ms^{-2}$. Therefore

a) The mass on the earth = the mass on the moon (for the same object), therefore, the mass of the astronaut on the earth = *80 kg*.

b) *Weight of astronaut on earth*

$$W_e = mg_e = 80 \times 9.8 = 784 \text{ Newton}$$

c) *Weight of astronaut on moon*

$$W_m = mg_m = \frac{80 \times 9.8}{6} = 130.7 \text{ Newton}$$

Question 9: Assume that an orange has a mass of *100 grams*. What is the net force on this orange?

a) When you hold it in your hand and it remains at rest.
b) When you release it.

Solution

a) When the orange is at rest in your hand, then the net force is zero.

b) The net force is its weight (the force of earth attraction to it)

$$F = W = mg = \frac{100 \times 9.8}{1000} = 0.98 \approx 1.0N$$

Question 10: What is the force exerted on a trolley having a mass of *20 kg* to increase its speed from *3.0 m/s* to *6.0 m/s* in *4.0* seconds?

Solution *From Newton's Second Law of Motion*

$$\text{Force} = \text{mass} \times \text{acceleration}$$

$$= \text{mass} \times \frac{\text{change in speed}}{\text{time interval}}$$

$$= \frac{20 \times (6-3)}{4} = \frac{20 \times 3}{4} = 15 \text{ Newton}$$

Question 11: A man punches a paper ball and moves it from rest to a speed of *25 m/s* in *0.05 s*. If the mass of the paper ball is *3 grams*; what force does the boxer exert on it?

Solution $F = ma$

$$= m \times \frac{\Delta v}{\Delta t} = \frac{3 \times (25 - 0)}{1000 \times 0.05} = 1.5 \text{ Newton}$$

Question 12: If you stand next to the wall on a frictionless skateboard and push the wall with a force of *40N*. How hard does the wall will push you back? If your mass is *80 kg* what will be your acceleration?

Solution According to Newton's Third Law, the wall exerts a force of 40N on you.

According to Newton's Second Law

$F = ma \qquad 40 = 80\,a$

This implies that $a = 0.5 m\, s^{-2}$

Question 13: If you exert a force of *200N* to slide a cart on a factory floor at a constant velocity, how much friction the floor exerts on the cart? What is that force?

Solution

Since the cart moves at a constant velocity, the frictional force exerted by the floor will be equal to the push because the net force must be equal to zero (remember that cart with constant velocity will have no acceleration). Therefore the frictional force by the floor must be equal to *200N*.

Question 14: If in the case of Question 13, the factory floor is frictionless, what will happen in this case?

Solution

If frictional force is zero, then the net force will be equal to

$$F = ma$$

$$200 = ma$$

$$a = \frac{200 \text{ N}}{m \text{ (kg)}}$$

The carte will be accelerated at a value of [200/m] Nkg^{-1}. The value of the acceleration depends on the mass of the cart.

Question 15: What is the impulse needed to stop a 10 kg bowling ball moving at 6 m s^{-1}?

Solution

$$Impulse = force \times time\ interval = F\,t$$

$$Impulse = m \times a \times t = m \times \frac{\Delta v}{t} \times t = m \times \Delta v = change\ of\ momentum$$

$$Impulse = m \times \Delta v = 10\,(6-0) = 60\ kg.\ ms^{-1}$$

Question 16: A car of *1000 kg* mass is moving with a speed of *20 ms^{-1}*. Calculate the amount of force (applied by the brakes) needed to bring this car to a rest in *10 s*.

Solution

$$a = \frac{\Delta v}{\Delta t} = \frac{(0-20)}{10} = -2\ ms^{-2}$$

$$F = ma = 1000\,(-2) = -2000\ N$$

The negative sign shows that the force applied by the brakes opposes the initial motion of the car.

Question 17: A car crashes into a wall with a speed of 25 ms^{-1} and comes to rest in 0.1 s. Calculate the average force exerted by the seat belt on a dummy passenger having a mass of 75 kg?

Solution

$$a = \frac{\Delta v}{\Delta t} = \frac{(0-25)}{0.1} = 250\ ms^{-2}$$

$$F = ma = 75 \times 250 = 18750\ \text{N}$$

Note that this is quite big force. It is about the same as if a mass of more than 1913 kg has fallen on the dummy.

Question 18: A boy (*40 kg mass*) while skating on ice with a speed of *1.5 ms^{-1}* collides with his friend (*mass 50 kg*) who is also skating with a speed of *2.0 ms^{-1}*. What is the speed of the boy and his friend after the collision?

Solution

This is an inelastic collision. The momentum in such collision remains conserved. Therefore, we can write

sum of momentum before collision = sum of momentum after collision,

i.e., $m_1 v_1 + m_2 v_2 = (m_1 + m_2)\,v'$

$40(1.5) + 50(2.0) = (40 + 50)\,v'$

$120 = (90)v'$ $\qquad v' = \frac{120}{90} = 1.33\ m\,s^{-1}$

Question 19: A *4 kg* fish swimming at $1 ms^{-1}$ swallows a smaller fish of *0.5 kg* that was swimming towards it at a velocity (say, *v m/s*) that brings both fish to halt immediately after swallow. Determine the value of v (*velocity of smaller fish before swallow*)?

Solution

From the Law of Conservation of Momentum,

sum of momentum before swallow = sum of momentum after swallow

i.e., $m_1 v_1 + m_2 v_2 = (m_1 + m_2) v'$

In the present case $4(1) + 0.5v = (4 + 0.5)(0)$

$4(1) + 0.5v = (4 + 0.5)(0) \therefore v = -\frac{4}{5} = -0.8 \, ms^{-1}$

Question 20: How much work is done when you push a cart horizontally with *120 N* over a distance of *12 m*?

Solution

Work = Force × Distance

$W = Fd$

W = 120 × 12 = 1440 joule

Question 21: If a bird of mass *0.5 kg* flies with a speed of $0.4 \, ms^{-1}$. Calculate the kinetic energy of this bird.

Solution

$$KE = \frac{1}{2} mv^2 = \frac{1}{2}(0.5 \, kg)(0.4 m/s)^2 = 0.04 \, J$$

Question 22: Suppose you apply a force of *10 N* on a wooden block in moving it over a distance of *4 m* in *1 second.* Determine how many watts of power you have spent on moving this block.

Solution

Power = Work done / Time interval

$$P = W/t = \frac{F \times d}{t} = \frac{10 \times 4}{1} = 40 \, watt$$

Question 23: A block of *200 N* is lifted to a vertical height of *3 m*. What is the work done in lifting this block?

Solution

The work (W) is done against the gravitational force, therefore:

$$W = mgh$$

mg is the weight of the block which is equivalent to the applied force *F*

$$= F \times h$$

$$= 200\ (3) \ = \ 600\ J$$

Question 24: Find the change in the force of gravity between two planets if the masses of both planets are tripled and the distance between them is doubled.

Solution

According to the Newton's Law of Universal Gravitation.

$$F = G\,\frac{m_1\,m_2}{d^2}$$

If the masses are tripled and the distance between is doubled then we can write

$$F' = G\,\frac{3m_1 \times 3m_2}{(2d)^2}$$

$$F' = 9\,G\,\frac{m_1 m_2}{4d^2} = \frac{9}{4}\,G\,\frac{m_1 m_2}{d^2} = \frac{9}{4}\,F$$

Question 25: The mass of the Earth is 6×10^{24} *kg* and that of the Sun is 2×10^{30} *kg*. If the average distance between them is 1.5×10^{11} *m*, what is the force of attraction between the Earth and Sun?

Solution

$$F = G\,\frac{m_1\,m_2}{d^2}$$

$$F = 6.67 \times 10^{-11} \left[\frac{6 \times 10^{24} \times 2 \times 10^{30}}{\left(1.5 \times 10^{11}\right)^2}\right] = 35.57 \times 10^{21}\ N$$