NCERT ANSWERS
CHAPTER 4

1. State, for each of the following physical quantities, if it is a scalar or a vector :

   volume, mass, speed, acceleration, density, number of moles, velocity, angular frequency, displacement, angular velocity.

Ans. Scalar – volume, mass, speed, density, number of moles, angular velocity

Vector – acceleration, velocity, angular frequency, displacement

2. Pick out the two scalar quantities in the following list :

   force, angular momentum, work, current, linear momentum, electric field, average velocity, magnetic moment, relative velocity.

Ans. Work and current

3. Pick out the only vector quantity in the following list :

   Temperature, pressure, impulse, time, power, total path length, energy, gravitational potential, coefficient of friction, charge.

Ans. Impulse

4. State with reasons, whether the following algebraic operations with scalar and vector physical quantities are meaningful :

   (a) adding any two scalars,

   (b) adding a scalar to a vector of the same dimensions ,

   (c) multiplying any vector by any scalar,

   (d) multiplying any two scalars,

   (e) adding any two vectors,

   (f) adding a component of a vector to the same vector.

Ans.

Operation	Y/N	Reason
adding any two scalars	Y	Only if they represent same physical quantity
adding a scalar to a vector of the same dimensions	N	
multiplying any vector by any scalar	Y	Example Work = force x distance
multiplying any two scalars	Y	Two scalars can be multiplied whether they have same or different dimensions
adding any two vectors	Y	Only if they represent same physical quantity

adding a component of a vector to the same vector	Y	If both have same dimensions

5. Read each statement below carefully and state with reasons, if it is true or false :

(a) The magnitude of a vector is always a scalar,

(b) each component of a vector is always a scalar,

(c) the total path length is always equal to the magnitude of the displacement vector of a particle.

(d) the average speed of a particle (defined as total path length divided by the time taken to cover the path) is either greater or equal to the magnitude of average velocity of the particle over the same interval of time,

(e) Three vectors not lying in a plane can never add up to give a null vector.

Ans.

Operation	T/F	Reason
The magnitude of a vector is always a scalar	T	Magnitude being a number is always scalar
each component of a vector is always a scalar	F	each component of a vector is also a vector.
the total path length is always equal to the magnitude of the displacement vector of a particle.	F	Total path length is distance which is only equal to magnitude of displacement vector when a body travels in a straight line.
the average speed of a particle (defined as total path length divided by the time taken to cover the path) is either greater or equal to the magnitude of average velocity of the particle over the same interval of time	T	Because the total path length is greater than or equal to the magnitude of the displacement vector of a particle
Three vectors not lying in a plane can never add up to give a null vector.	T	Three vectors not lying in a plane can't be represented by sides of a triangle taken in the same order and hence no triangle law.

6. Establish the following vector inequalities geometrically or otherwise :

(a) $|a+b| \leq |a|+|b|$

(b) $|a+b| \geq |a|-|b|$

(c) $|a-b| \leq |a|+|b|$

(d) $|a-b| \geq |a|-|b|$

When does the equality sign above apply?

Ans.

7. Given **a** + **b** + **c** + **d** = **0**, which of the following statements are correct :

(a) **a**, **b**, **c**, and **d** must each be a null vector,

(b) The magnitude of (**a** + **c**) equals the magnitude of (**b** + **d**),

(c) The magnitude of **a** can never be greater than the sum of the magnitudes of **b**, **c**, and **d**,

(d) **b** + **c** must lie in the plane of **a** and **d** if **a** and **d** are not collinear, and in the line of **a** and **d**, if they are collinear?

Ans.

Operation	T/F	Reason
a, **b**, **c**, and **d** must each be a null vector	F	it is not necessary to have all the four given vectors to be null vectors. There are many other combinations which can give the sum zero.
The magnitude of (**a** + **c**) equals the magnitude of (**b** + **d**)	T	$\mathbf{a}+\mathbf{b}+\mathbf{c}+\mathbf{d}=0$ $\mathbf{a}+\mathbf{c}=-(\mathbf{b}+\mathbf{d})$ $\lvert\mathbf{a}+\mathbf{c}\rvert=\lvert-(\mathbf{b}+\mathbf{d})\rvert$ $\lvert\mathbf{a}+\mathbf{c}\rvert=\lvert\mathbf{b}+\mathbf{d}\rvert$
The magnitude of **a** can never be greater than the sum of the magnitudes of **b**, **c**, and **d**	T	$\mathbf{a}+\mathbf{b}+\mathbf{c}+\mathbf{d}=0$ $\mathbf{a}=-(\mathbf{b}+\mathbf{c}+\mathbf{d})$ $\lvert\mathbf{a}\rvert=\lvert-(\mathbf{b}+\mathbf{c}+\mathbf{d})\rvert$ $\lvert\mathbf{a}\rvert=\lvert\mathbf{b}+\mathbf{c}+\mathbf{d}\rvert$ $\lvert\mathbf{a}\rvert\le\lvert\mathbf{b}+\mathbf{c}+\mathbf{d}\rvert$
b + **c** must lie in the plane of **a** and **d** if **a** and **d** are not collinear, and in the line of **a** and **d**, if they are collinear	T	The resultant sum of the three vectors **a**, (**b + c**), and **d** can be zero only if (**b + c**) lie in a plane containing **a** and **d**, assuming that these three vectors are represented by

		the three sides of a triangle. If **a** and **d** are collinear, then it implies that the vector (**b** + **c**) is in the line of **a** and **d**. This implication holds only then the vector sum of all the vectors will be zero.

8. Three girls skating on a circular ice ground of radius 200 m start from a point *P* on the edge of the ground and reach a point **Q** diametrically opposite to *P* following different paths as shown in Fig. 4.20. What is the magnitude of the displacement vector for each? For which girl is this equal to the actual length of path skate?

Ans. Displacement is the shortest distance between the initial and final position of an object so it same i.e 400m for all the three girls irrespective of their paths.

For B it is equal to the actual length of the path skated.

9. A cyclist starts from the centre *O* of a circular park of radius 1 km, reaches the edge *P* of the park, then cycles along the circumference, and returns to the centre along **QO** as shown in Fig. 4.21. If the round trip takes 10 min, what is the (a) net displacement, (b) average velocity, and (c) average speed of the cyclist ?

Ans. (a) Zero as it returned to O.

(b) Zero as average velocity is net displacement per unit time and net displacement is zero.

(c)

$$Total\,\text{distance} = OP + PQ + OQ = 1 + \frac{2\times 3.14\times 1}{4} + 1 = 3.5km$$

$$Total\,time = 10\,\text{min.} = \frac{10}{60}hr = \frac{1}{6}hr$$

$$Av.speed = \frac{Total\,\text{distance}}{Total\,time} = \frac{3.5}{\frac{1}{6}} = 3.5\times 6 = 21kmhr^{-1}$$

10. On an open ground, a motorist follows a track that turns to his left by an angle of 60^0 after every 500 m. Starting from a given turn, specify the displacement of the motorist at the third, sixth and eighth turn. Compare the magnitude of the displacement with the total path length covered by the motorist in each case.

Ans.

11. A passenger arriving in a new town wishes to go from the station to a hotel located 10 km away on a straight road from the station. A dishonest cabman takes him along a circuitous path 23 km long and reaches the hotel in 28 min. What is (a) the average speed of the taxi, (b) the magnitude of average velocity? Are the two equal?

Ans. (a)

$$\text{Total distance} = 23km$$

$$Total\,time = 28\min. = \frac{28}{60}hr$$

$$Average\,speed = \frac{\text{Total distance}}{Total\,time} = \frac{23}{\frac{28}{60}} = 23 \times \frac{60}{28} = 49.29kmhr^{-1}$$

(b)

$$\text{Total displacement} = 10km$$

$$Total\,time = 28\min. = \frac{28}{60}hr$$

$$Average\,speed = \frac{\text{Total distance}}{Total\,time} = \frac{10}{\frac{28}{60}} = 10 \times \frac{60}{28} = 21.43kmhr^{-1}$$

12. Rain is falling vertically with a speed of 30 m s^{-1}. A woman rides a bicycle with a speed of 10 m s^{-1} in the north to south direction. What is the direction in which she should hold her umbrella?

Ans.

13. A man can swim with a speed of 4 km/h in still water. How long does he take to cross a river 1.0 km wide if the river flows steadily at 3 km/h and he makes his strokes normal to the river current? How far down the river does he go when he reaches the other bank?

Ans.

14. In a harbour, wind is blowing at the speed of 72 km/h and the flag on the mast of a boat anchored in the harbour flutters along the N-E direction. If the boat starts moving at a speed of 51 km/h to the north, what is the direction of the flag on the mast of the boat?

15. The ceiling of a long hall is 25 m high. What is the maximum horizontal distance that a ball thrown with a speed of 40 m s^{-1} can go without hitting the ceiling of the hall?

$$H = \frac{u^2 \sin^2 \theta}{2g}$$

$$25 = \frac{(40)^2 \sin^2 \theta}{2 \times 9.8}$$

$$\sin^2 \theta = \frac{50 \times 9.8}{40 \times 40}$$

$$\sin \theta = \sqrt{\frac{50 \times 9.8}{40 \times 40}}$$

$$\sin \theta = \frac{7\sqrt{10}}{40}$$

$$\cos \theta = \frac{\sqrt{1110}}{40}$$

$$R = \frac{2u^2 \sin \theta \cos \theta}{g} = \frac{2 \times 40 \times 40}{9.8} \times \frac{7\sqrt{10}}{40} \times \frac{\sqrt{1110}}{40} = \frac{2 \times 70 \times \sqrt{111}}{9.8} = 150.5m$$

16. A cricketer can throw a ball to a maximum horizontal distance of 100 m. How much high above the ground can the cricketer throw the same ball?

$$R_{\max} = \frac{u^2}{g}$$

$$100 = \frac{u^2}{g}$$

$$For \max . height\, \theta = 90^0$$

$$H = \frac{u^2 \sin^2 \theta}{2g} = \frac{u^2 \sin^2 90^0}{2g} = \frac{100}{2} = 50m$$

17. A stone tied to the end of a string 80 cm long is whirled in a horizontal circle with a constant speed. If the stone makes 14 revolutions in 25 s, what is the magnitude and direction of acceleration of the stone?

$Given: \; r = 80cm = 0.8m$

$n = 14$

$t = 25s$

$To\ find : v = ?, \omega = ?, a = ?$

$$Sol^n: \quad v = \frac{n}{t} = \frac{14}{25} Hz$$

$$\omega = 2\pi v = 2 \times \frac{22}{7} \times \frac{14}{25} = \frac{88}{25} rad.s^{-1}$$

$$a = \omega^2 r = \frac{88}{25} \times \frac{88}{25} \times 0.8 = 9.9ms^{-2}$$

18. An aircraft executes a horizontal loop of radius 1 km with a steady speed of 900 km/h. Compare its centripetal

acceleration with the acceleration due to gravity.

$Given: \ r = 1km = 1000m$

$$v = 900kmhr^{-1} = 900 \times \frac{5}{18} = 250ms^{-1}$$

$To\ find: a = ?$

$Sol^n: \quad a = \frac{v^2}{r} = \frac{250 \times 250}{1000} = 62.5ms^{-2}$

$$g = 9.8ms^{-2}$$

$$\frac{a}{g} = \frac{62.5}{9.8}$$

$$a = 6.38g$$

19. Read each statement below carefully and state, with reasons, if it is true or false :

(a) The net acceleration of a particle in circular motion is *always* along the radius of the circle towards the centre

(b) The velocity vector of a particle at a point is *always* along the tangent to the path of the particle at that point

(c) The acceleration vector of a particle in *uniform* circular motion averaged over one cycle is a null vector

Statement	T/F	Reason
The net acceleration of a particle in circular motion is always along the radius of the circle towards the centre	F	It happens only in the case of uniform circular motion.
The velocity vector of a particle at a point is always along the tangent to the path of the particle at that point	T	At a point on a circular path, a particle appears to move tangentially to the circular path.
The acceleration vector of a particle in uniform circular motion averaged over one cycle is a null vector	T	In uniform circular motion, the direction of the acceleration vector points toward the centre of the circle. However, it constantly changes with time. The average of these vectors over one cycle is a null vector.

20. The position of a particle is given by $\vec{r} = 3t\hat{i} - 2t^2 j + 4k\ m$ where t is in seconds and the coefficients have the proper units for **r** to be in metres.

(a) Find the **v** and **a** of the particle?

(b) What is the magnitude and direction of velocity of the particle at $t = 2.0$ s ?

(a)

$$\vec{r} = 3t\hat{i} - 2t^2 j + 4k$$

$$\vec{v} = \frac{d\vec{r}}{dt} = \frac{d}{dt}\left(3t\hat{i} - 2t^2 j + 4k\right) = \frac{d}{dt}\left(3t\hat{i}\right) + \frac{d}{dt}\left(-2t^2 j\right) + \frac{d}{dt}\left(4k\right) = 3\hat{i} - 4t\,j$$

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}\left(3\hat{i} - 4t\,j\right) = \frac{d}{dt}\left(3\hat{i}\right) + \frac{d}{dt}\left(-4t\,j\right) = -4\,j$$

(b)

$$\vec{v} = 3\hat{i} - 4t\,j$$

$$\overrightarrow{v_2} = 3\hat{i} - 8\,j$$

$$\left|\overrightarrow{v_2}\right| = \sqrt{(3)^2 + (-8)^2} = \sqrt{73}ms^{-1}$$

$$\tan\theta = \frac{-8}{3}$$

$$\theta = \tan^{-1}\left(\frac{-8}{3}\right)$$

21. A particle starts from the origin at $t = 0$ s with a velocity of $10\,j$ m/s and moves in the x-y plane with a constant acceleration of ($8\hat{i} + 2\,j$) ms^{-2}. (a) At what time is the x- coordinate of the particle 16 m? What is the y-coordinate of the particle at that time? (b) What is the speed of the particle at the time?

(a)

$$Given: \ \vec{u} = 10j$$

$$\vec{a} = 8\hat{i} + 2j$$

$$To\ find:$$

$$Sol^n: \quad \vec{a} = \frac{d\vec{v}}{dt}$$

$$d\vec{v} = \vec{a}.dt$$

$$\int d\vec{v} = \int \vec{a}.dt$$

$$\vec{v} = \int \left(8\hat{i} + 2j\right)dt = \int 8\hat{i}dt + \int 2jdt = 8\hat{i}t + 2jt + c$$

$$When \quad t = 0, \ c = 10j$$

$$So, \quad \vec{v} = 8\hat{i}t + 2jt + 10j$$

$$Now, \quad \vec{v} = \frac{d\vec{r}}{dt}$$

$$d\vec{r} = \vec{v}.dt$$

$$\int d\vec{r} = \int \vec{v}.dt$$

$$\vec{r} = \int \left(8\hat{i}t + 2jt + 10j\right)dt \quad = \int 8\hat{i}tdt + \int 2jtdt + \int 10jdt \quad = 8\hat{i}\int tdt + 2\widehat{j}\int tdt + 10\widehat{j}\int dt \quad = 8\hat{i}\frac{t^2}{2} + 2\widehat{j}\frac{t^2}{2} + 10\widehat{jt}$$

$$\vec{r} = 4\hat{i}t^2 + \widehat{jt^2} + 10\widehat{jt}$$

$$\vec{r} = 4t^2\hat{i} + \left(t^2 + 10t\right)\widehat{j}$$

$$x\hat{i} + y\widehat{j} = 4t^2\hat{i} + \left(t^2 + 10t\right)\widehat{j}$$

$$\therefore x = 4t^2, \quad y = t^2 + 10t$$

$$Now, \ 16 = 4t^2$$

$$t = 2s$$

$$y = (2)^2 + 10(2) = 24m$$

(b)

$$\vec{v} = 8\hat{i}t + 2jt + 10j$$

$$\overrightarrow{v_2} = 16\hat{i} + 14j$$

$$\left|\overrightarrow{v_2}\right| = \sqrt{(16)^2 + (14)^2} = \sqrt{452}ms^{-1}$$

22. $\hat{i}$ and j are unit vectors along x- and y- axis respectively. What is the magnitude and direction of the vectors $\hat{i} + j$, and $\hat{i} - j$? What are the components of a vector $\mathbf{A} = 2\hat{i} + 3j$ along the directions of $\hat{i} + j$, and $\hat{i} - j$? [You may use graphical method]

$\vec{B} = \hat{i} + j$

$|\vec{B}| = \sqrt{(1)^2 + (1)^2} = \sqrt{2}$

$\tan\theta = \frac{1}{1}$

$\theta = 45^0$

$\vec{C} = \hat{i} - j$

$|\vec{C}| = \sqrt{(1)^2 + (-1)^2} = \sqrt{2}$

$\tan\theta = \frac{-1}{1}$

$\theta = 45^0$

$\vec{C} = 2\hat{i} + 3j$

$|\vec{C}| = \sqrt{(2)^2 + (3)^2} = \sqrt{13}$

23. For any arbitrary motion in space, which of the following relations are true :

(a) $\mathbf{v}_{average} = \frac{1}{2}\left(\mathbf{v}(t_1) + \mathbf{v}(t_2)\right)$

(b) $\mathbf{v}_{average} = \frac{[\mathbf{r}(t_2) - \mathbf{r}(t_1)]}{(t_2 - t_1)}$

(c) $\mathbf{v}(t) = \mathbf{v}(0) + \mathbf{a}\,t$

(d) $\mathbf{r}(t) = \mathbf{r}(0) + \mathbf{v}(0)t + \frac{1}{2}\mathbf{a}t^2$

(e) $\mathbf{a}_{average} = \frac{[\mathbf{v}(t_2) - \mathbf{v}(t_1)]}{(t_2 - t_1)}$

(The 'average' stands for average of the quantity over the time interval t_1 to t_2)

Statement	T/F	Reason
$\mathbf{v}_{average} = \frac{1}{2}\left(\mathbf{v}(t_1) + \mathbf{v}(t_2)\right)$	F	As the motion of the particle is arbitrary so, the average velocity of the particle cannot be given by this equation.
$\mathbf{v}_{average} = \frac{[\mathbf{r}(t_2) - \mathbf{r}(t_1)]}{(t_2 - t_1)}$	T	The arbitrary motion of the particle can be represented by this equation.
$\mathbf{v}(t) = \mathbf{v}(0) + \mathbf{a}\,t$	F	• As the motion of the particle is arbitrary so, the

		acceleration of the particle may also be non-uniform. • Hence, this equation cannot represent the motion of the particle in space.
$\mathbf{r}(t)=\mathbf{r}(0)+\mathbf{v}(0)t+\frac{1}{2}\mathbf{a}t^2$	F	• As the motion of the particle is arbitrary so, the acceleration of the particle may also be non-uniform. • Hence, this equation cannot represent the motion of the particle in space.
$\mathbf{a}_{average}=\frac{[\mathbf{v}(t_2)-\mathbf{v}(t_1)]}{(t_2-t_1)}$	F	The arbitrary motion of the particle can be represented by this equation.

24. Read each statement below carefully and state, with reasons and examples, if it is true or false :

A scalar quantity is one that

(a) is conserved in a process

(b) can never take negative values

(c) must be dimensionless

(d) does not vary from one point to another in space

(e) has the same value for observers with different orientations of axes.

Statement	T/F	Reason/Example
scalar quantity is conserved in a process	F	energy is not conserved in inelastic collisions
scalar quantity can never take negative values	F	temperature can take negative values
scalar quantity must be dimensionless	F	Total path length is a scalar quantity. Yet it has the dimension of length
scalar quantity does not vary from one point to another in space	F	gravitational potential can vary from one point to another in space
scalar quantity has the same value for observers with different orientations of axes	T	

25. An aircraft is flying at a height of 3400 m above the ground. If the angle subtended at a ground observation point by the aircraft positions 10 s apart is 30°, what is the speed of the aircraft?

$OC = 3400m$

$t = 10s$

$\tan 15^0 = \frac{AC}{OC}$

$AC = 3400 \tan 15^0 = 3400 \times 0.268 = 911.2m$

$AB = 2AC = 2 \times 911.2 = 1822.4m$

$v = \frac{AB}{t} = \frac{1822.4}{10} = 182.24ms^{-1}$