Past Exam 2024: Ch.1 to Ch.4

Physics 103: Classical Mechanics

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Version 1

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1. Ch.1: Physics and Measurement

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Question 1.1

Assume the equation used to describes a physical phenomenon has been given by **A= k *B* D,** where ***k*** is dimensionless, **A** in $\mathbf{kg^2\ m^2/s^4}$, **B** in $\mathbf{kg\ m/s^3}$, Using the dimensional analysis, the dimension of **D** is:

A) $M\ L\ T^{-1}$ B) $M\ L^{-1}\ T$ C) $M\ L\ T^{-2}$ D) $M\ L^{-2}\ T$

Answer 1.1

$$[A] = [K \times B \times D]$$

$$\frac{M^2L^2}{T^4} = \frac{ML}{T^3}\,[D]$$

$$\Longrightarrow\ [D] = \frac{ML}{T} = MLT^{-1}$$

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Question 2.2

A car travelled east **6 km** in **3 min**, then it reversed its direction and travelled **8 km** in **5 min**. what is the average velocity in (**km/h**)

A) 15 B) -105 C) 105 D) -15

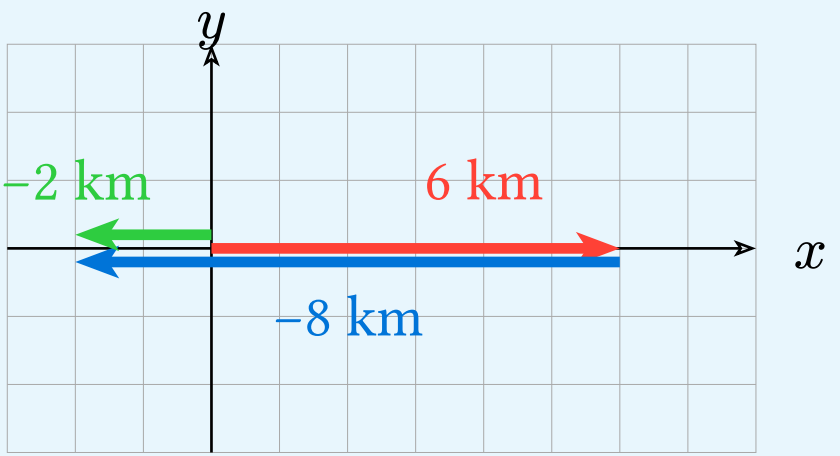
Answer 2.2

- Convert total time $(5 + 3)$ from min to hour:

$$8 \text{ min} \left(\frac{1 \text{ h}}{60 \text{ min}} \right) = 0.133 \text{ h}$$

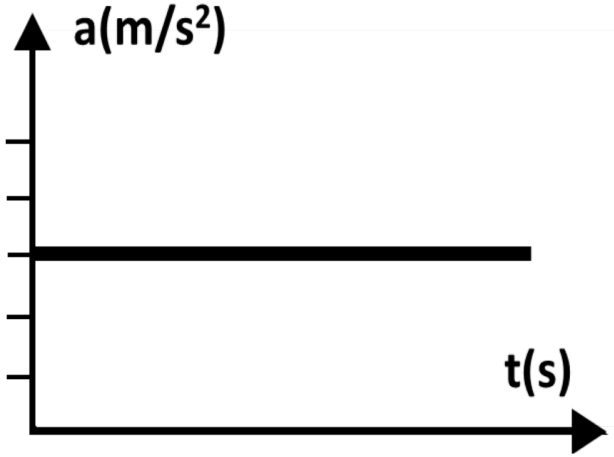
- Average velocity is:

$$\begin{aligned} v_{\text{avg}} = \frac{\text{Displacement}}{t_1 + t_2} &= \frac{R_1 + R_2}{t_1 + t_2} \\ &= \frac{+6 - 8}{0.133} \\ &= -15 \text{ km/h} \end{aligned}$$



Question 2.3

The following graph represents the relation between acceleration (**a**) and time (**t**) in 1D motion. Which of the following velocities ($\boldsymbol{v}$) could be correct? (assume $\boldsymbol{v_i} = 0$)



A) $3t^2$ B) $-3t$ C) $3t$ D) $-3t^2$

Answer 2.3

- From the graph, the acceleration is **positive** 3 and **constant**. Therefore, the velocity is **increasing linearly** with time. This make (C) the correct answer.

- Alternatively, from the definition of acceleration:

$$a = \frac{\mathrm{d}v}{\mathrm{d}t}$$

We can find v by integrating a (which is constant) over time:

$$v = \int a \, \mathrm{d}t = at + C$$

where C is the initial velocity at $t = 0$ and can be zero. Therefore,

$$v = at = +3t$$

Question 2.4

An airport runway is **200 m** long. What is the **maximum** initial landing speed for an airplane, if the accelerattion is assumed to be constant at **5.8 m/s^2** and the airplane comes to stop at the end of the runway?

A) $24.5\,\frac{m}{s}$ B) $34.1\,\frac{m}{s}$ C) $48.2\,\frac{m}{s}$ D) $17.3\,\frac{m}{s}$

Answer 2.4

x_i	x_f	v_i	v_f	a	t
0 m	200 m	?	0	-5.8 m/s^2	-

- Since time t is not given, we can use the following equation:

$$v_f^2 = v_i^2 + 2a\left(x_f - x_i\right)$$

- Rearranging the equation to find v_i gives:

$$v_i = \sqrt{v_f^2 - 2a\left(x_f - x_i\right)} = \sqrt{0 + 2 * 5.8 * 200} = 48.2 \text{ m/s}$$

Question 2.5

Under which of the following conditions is the magnitude of the average velocity of a particle moving in one dimension smaller than the average speed over some time interval:

A) A particle moves in the +x direction without reversing

B) There are no conditions for which this is true

C) A particle moves in the -x direction without reversing

D) A particle moves in the +x direction and then reverses the direction of its motion

Answer 2.5

The correct answer is (**D**) because reversing direction means the displacement is smaller than the distance traveled. Therefore, the average velocity (which depends on displacement) is smaller than the average speed (which depends on distance traveled).

Question 2.6

A stone is dropped from the rest from a top of tall building. After **3 s** of free fall, its displacement from top of the building is:

A) – 44.1 m B) – 23.3 m C) + 54.2 m D) + 38.2 m

Answer 2.6

y_i	y_f	v_i	v_f	a	t
0 m	?	0	-	$-g$	3 s

$$y_f = y_i + v_i t + \frac{1}{2}at^2 = 0 + 0 + \left(\frac{1}{2}\right)(-9.8)(3)^2 = -44.1 \text{ m}$$

Question 2.7

A stone is thrown from the top of building with an initial velocity of **20 m/s** downward. The height of the building is **60 m** above the ground. How much time elapses between the instant of release and the instant of impact with the ground?

A) 2 s B) 9 s C) 4 s D) 5 s

Answer 2.7

y_i	y_f	v_i	v_f	a	t
0 m	-60 m	-20 m/s	-	$-g$	?

- From:

$$y_f = y_i + v_i t + \frac{1}{2} a t^2$$

$$-60 = 0 + (-20)t + \frac{1}{2}(-9.8)t^2$$

Rearranging the equation gives:

$$4.9t^2 + 20t - 60 = 0$$

$$\Longrightarrow t = \frac{-20 \pm \sqrt{20^2 - 4 * 4.9 * (-60)}}{2 * 4.9} \approx +2 \text{ s}$$

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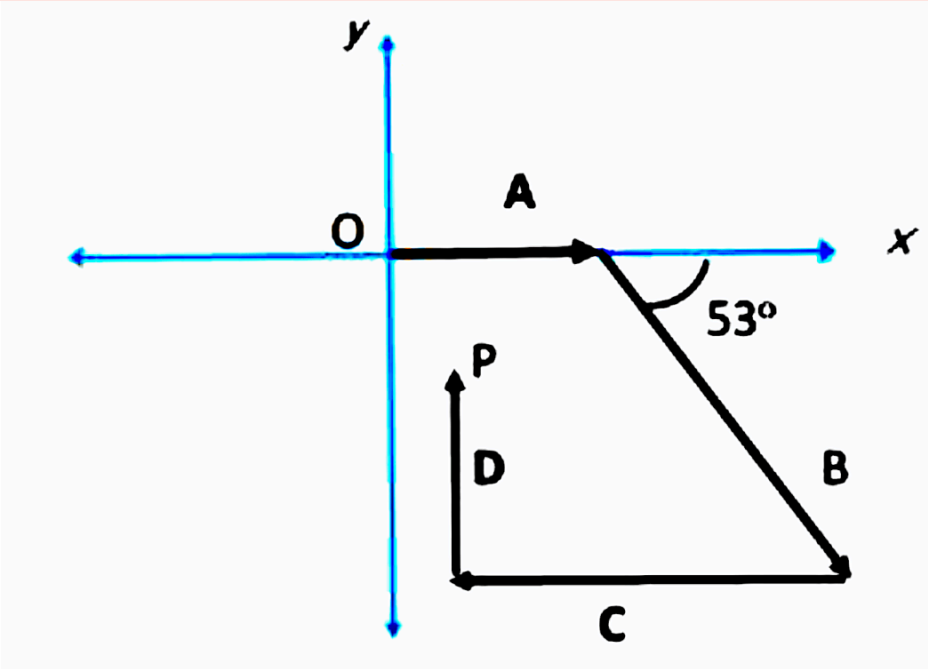
Question 3.8

A boy walks from **O** to **P** in four straight lines as shown in the diagram. Let **A= 50 m**, **B = C = 100 m** and **D = 70 m**. **D** is parallel to the y-axis. The magnitude of the boy's displacement as he travels from **O** to **P** is:



A) 12.8 m

B) 14.17 m

C) 16.4 m

D) 22.5 m

Answer 3.8

$$\begin{aligned}\vec{R} &= \vec{A} + \vec{B} + \vec{C} + \vec{D} \\ &= (50, 0) + (100\cos 53°, -100\sin 53°) + (-100, 0) + (0, 70) \\ &\approx (50 + 60 - 100 + 0, \quad 0 - 80 + 0 + 70) \\ &= (10, -10)\ \text{m}\end{aligned}$$

- The magnitude of the resultant vector R is:

$$|\vec{R}| = \sqrt{(-10)^2 + (-10)^2} = \sqrt{200} = 14.1\ \text{m}$$

Question 3.9

A vector **A** has magnitude **8.0** and an ***x***-component equal to (**- 5.0)** and lies in the **3rd quadrant**. What is its ***y***-component?

A) 7.2 B) 6.2 C) - 6.2 D) - 7.2

Answer 3.9

$$\left|\vec{A}\right|^2 = x^2 + y^2$$

$$\Longrightarrow \quad y^2 = 8^2 - (-5)^2 = 39$$

$$y = \pm\sqrt{39} = \pm 6.2$$

Since $\vec{A}$ is in the third quadrant, the y component must be negative. Therefore,

$$y = -6.2$$

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Question 4.10

A projectile is launched horizontally from a cliff with a speed of **20 m/s**. If the cliff is **50 m** high, how far horizontally will the projectile travel before hitting the ground?

A) 112 m B) 77.5 m C) 63.9 m D) 213 m

Answer 4.10

- First, we need to find the time of flight using the vertical motion:

$$y_f = y_i + v_{iy}t + \frac{1}{2}a_y t^2$$

$$-50 = 0 + 0t + \frac{1}{2}(-9.8)t^2$$

$$\implies t^2 = 10.2 \text{ s} \quad \implies t = 3.2 \text{ s}$$

- Then, we find the horizontal distance traveled using the horizontal motion:

$$x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2$$

$$x_f = 0 + 20(3.2) + 0$$

$$= 64 \text{ m}$$

Question 4.11

A particle moves in the ***xy***-plane with a constant acceleration of **2.0 m/s²** in the positive ***x***-direction. If the particle's initial position is **(0, 0)** and its initial velocity is $\boldsymbol{v} = 3\,\boldsymbol{i} + 4\,\boldsymbol{j}$, what is its position vector after **2.0 seconds** (in **m**)?

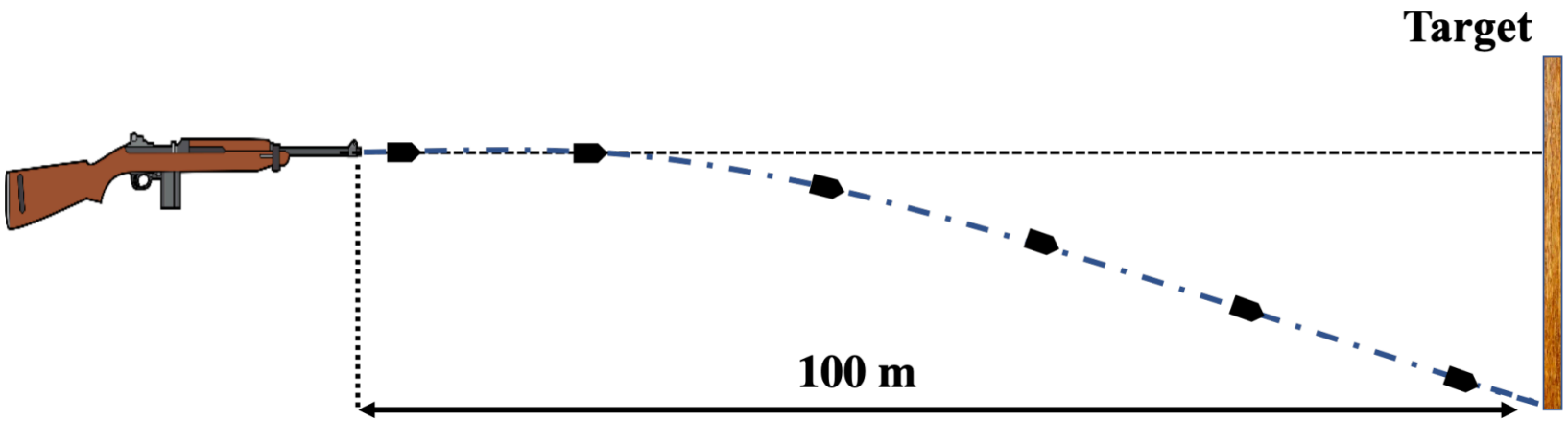
A) $\boldsymbol{r} = 7\,i + 8\,j$ B) $\boldsymbol{r} = 10\,i + 12\,j$ C) $\boldsymbol{r} = 7\,i + 12\,j$ D) $\boldsymbol{r} = 10\,i + 8\,j$

Answer 4.11

$$
\begin{aligned}
\vec{r}_f &= \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2 \\
&= (0, \quad 0) + (3, \quad 4)(2) + \frac{1}{2}(2, \quad 0)(2)^2 \\
&= (0 + 6 + 4, \quad 0 + 8 + 0) \\
&= (10, \quad 8)\ \mathrm{m} \\
&= 10\hat{\boldsymbol{\imath}} + 8\hat{\boldsymbol{\jmath}}
\end{aligned}
$$

Question 4.12

A rifle is aimed horizontally at the center of a large target **100 m** away. The bullet deviates from its horizontal path due to its weight. If the time to hit the target is **4 seconds**, the magnitude of the velocity of the bullet when it's hit the target is:



A) 25.6 m/s B) 12.4 m/s C) 32.8 m/s D) 46.5 m/s

Answer 4.12

- Givens: $d = 100\ \text{m}, \quad t = 4\ \text{s}, \quad a_y = -g, \quad v_{iy} = 0$
- Goal: Find $|\vec{v}_f| = \sqrt{v_{fx}^2 + v_{fy}^2}$
- First, find v_{fy} using the horizontal motion:

  $v_{fy} = v_{iy} + a_y t = 0 + (-g)(4) = -39.2\ \text{m/s}$ ✓

  Then, find v_{fx} using the horizontal motion:

  $$v_{fx} = v_{ix} = \frac{d}{t} = \frac{100}{4} = 25\ \text{m/s}$$ ✓

  Finally, find the magnitude of the final velocity:

  $$|\vec{v}_f| = \sqrt{v_{fx}^2 + v_{fy}^2} = \sqrt{25^2 + (-39.2)^2} = 46.5\ \text{m/s}$$

Question 4.13

A projectile is launched at an angle θ above the horizontal. Which of the following statements is true about the projectile's motion at its highest point?

(A) The projectile's velocity is zero.

(B) The projectile's vertical velocity is zero.

(C) The projectile's horizontal velocity is zero.

(D) The projectile's acceleration is zero.

Answer 4.13

- The Correct answer is (**B**).
- Answer (A) is wrong because the projectile velocity has x and y components, and the x component is not necessarily zero at the highest point.
- Answer (C) is wrong because the horizontal velocity remains constant throughout the motion, and it does not change at the highest point.
- Answer (D) is wrong because the acceleration due to gravity is always constant ($a_y = -g$) at all points in the trajectory, including the highest point.

Question 4.14

A particle moves along a path and its speed increases with time. In which of the following cases are its acceleration and velocity vectors perpendicular everywhere along the path?

A) the path is circular B) never C) the path is a parabola D) the path is straight

Answer 4.14

- The answer is (**B**).
- (A) is wrong because the speed is increasing, not constant. Therefore, the acceleration is NOT exactly perpendicular to the velocity.
- (C) is wrong because the acceleration direction is NOT constant.
- (D) is wrong because the acceleration direction is parallel to the velocity.

Question 4.15

A particle moves at a constant speed in a circular path with a radius of **2.06 cm**. If the particle makes **four revolutions each second**, what is the magnitude of its acceleration?

A) 20 m/s^2 B) 18 m/s^2 C) 13 m/s^2 D) 14 m/s^2

Answer 4.15

- The magnitude of the acceleration is given by:

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

The velocity can be found from the period (T) as:

$$v = \frac{2\pi r}{T}$$

Since there are four revolutions per second, then the period of one revolution is:

$$T = \frac{1}{\text{Number of Revolutions}} = \frac{1}{4} = 0.25 \text{ s}$$

Therefore, the velocity is:

$$v = \frac{2\pi(2.06 \times 10^{-2}\ \text{m})}{0.25\ \text{s}} = 0.52\ \text{m/s}$$

Finally, the acceleration is:

$$a = \frac{v^2}{r} = \frac{(0.52\ \text{m/s})^2}{2.06 \times 10^{-2}\ \text{m}} = 13\ \text{m/s}^2$$