Past Exams: Ch.1 to Ch.4

Physics 103: Classical Mechanics

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Version 1

Outline

1. Ch.1: Physics and Measurement

2. Ch.2: Motion in One Dimension

3. Ch.3: Vectors

4. Ch.4: Motion in Two Dimensions

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Question 1.1

If the change of position x of a train is given by $x = \frac{1}{2}at^2 + bt^3$ (where a is the acceleration). The dimension of ***a*** is:

A) LT^{-2} B) LT^{3} C) LT^{-1} D) LT^{-3}

Answer 1.1

- The dimension of each term in the equation must be the same. Therefore,

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- The dimension of time t is T, so,

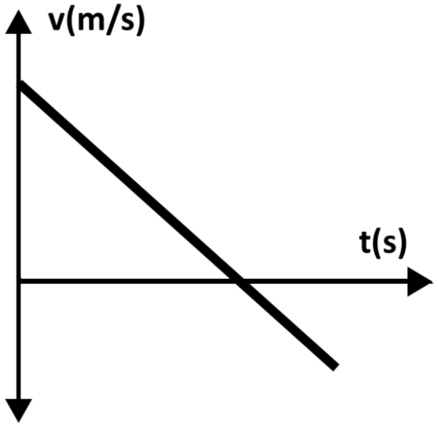
$$[a]\ T^2 = L$$

- Finally, the dimension of acceleration a is:

$$\boxed{[a] = LT^{-2}}$$

Question 2.2

the next graph represents the change in velocity (**v**) with time (**t**) of motorcycle along a straight path. Which of the following accelerations ($\boldsymbol{a}$) could be correct?



A) $-5t$ B) $5t$ C) -5 D) 5

Answer 2.2

The car is **slowing** down **linearly**, so the acceleration

$$a = \text{slope} = \frac{\Delta v}{\Delta t}$$

must be a constant number and a negative value at all times.

Therefore the only possible answer is **(C)**

Question 2.3

An airplane intial landing speed is **50 m/s**. If it stops in **500 m**, then the accelerattion (assumed to be constant) is:

A) - 7.5 $\frac{m}{s^2}$ B) 10 $\frac{m}{s^2}$ C) - 2.5 $\frac{m}{s^2}$ D) 5.0 $\frac{m}{s^2}$

Answer 2.3

x_i	x_f	v_i	v_f	a	t

Answer 2.3

x_i	x_f	v_i	v_f	a	t
0 m					

Answer 2.3

x_i	x_f	v_i	v_f	a	t
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Answer 2.3

x_i	x_f	v_i	v_f	a	t
0 m	500 m	50 m/s			

Answer 2.3

x_i	x_f	v_i	v_f	a	t
0 m	500 m	50 m/s	0 m/s	?	-

- Since time t is not given, we can use the following equation to find the acceleration a:

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

Answer 2.3

x_i	x_f	v_i	v_f	a	t
0 m	500 m	50 m/s	0 m/s	?	-

- Since time t is not given, we can use the following equation to find the acceleration a:

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

- Rearranging the equation to find a gives:

$$a = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{0 - 2500}{2 * 500} = -2.5 \text{ m/s}^2$$

Question 2.4

A car travelled north, and its initial speed was **100 km/h**, then it reversed its direction and reached a final speed of **50 km/h**. If the total time was **10 s**, what is the average car acceleration in (**m/s^2**)

A) 1.4

B) -1.4

C) 4.2

D) -4.2

Answer 2.4

- Since the car is decreasing its speed from $+100\ \text{Km/h}$ to $-50\ \text{Km/h}$, it means that the acceleration is negative at all times.

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- To find the value of average acceleration, we need first to convert the speeds from Km/h to m/s:

$$100\ \text{km/h} * \left(\frac{1000\ \text{m}}{1\ \text{km}}\right) * \left(\frac{1h}{3600s}\right) = 27.78\ \text{m/s}$$

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- Now, we can find the average acceleration using the formula:

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

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- Now, we can find the average acceleration using the formula:

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} = \frac{-13.89 - 27.78}{10 - 0} = -4.2\ \text{m/s}^2$$

Question 2.5

As a free-falling object speeds-up, what is happening to its acceleration due to gravity?

A) decreases B) none of these answers C) increases D) stays the same

Answer 2.5

Free-falling objects always experience a **constant** acceleration due to gravity

$$a_y = -g = -9.8 \text{ m/s}^2$$

regardless of their velocities, mass, ... etc.

Answer 0.5

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- Therefore, the correct answer is the acceleration **stays the same**.

Question 0.6

A worker ascending at **7m/s** in an open elevator **20 m** above the ground accidently drops a stone.The velocity of the stone just before touching the ground is :

A) - 21 m/s   B) 58 m/s   C) - 14 m/s   D) 18 m/s

Answer 0.6

y_i	y_f	v_i	v_f	a	t
0 m	-20 m	$+7$ m/s	?	$-g$	-

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Answer 0.6

y_i	y_f	v_i	v_f	a	t
0 m	-20 m	$+7$ m/s	?	$-g$	-

- Since time t is not given, we can use the following equation to find the final velocity v_f:

$$v_f^2 = v_i^2 + 2a\left(y_f - y_i\right)$$

Answer 0.6

y_i	y_f	v_i	v_f	a	t
0 m	−20 m	+7 m/s	?	$-g$	-

- Since time t is not given, we can use the following equation to find the final velocity v_f:

$$v_f^2 = v_i^2 + 2a(y_f - y_i)$$

- Rearranging the equation to find v_f gives:

$$v_f = \sqrt{v_i^2 + 2a(y_f - y_i)} = \sqrt{49 + 2 * (-9.8) * (-20)} = \pm 21 \text{ m/s}$$

Answer 0.6

y_i	y_f	v_i	v_f	a	t
0 m	-20 m	$+7 \text{ m/s}$	?	$-g$	-

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- The positive value indicates that the stone is moving in the positive direction (upwards) when it hits the ground, which is not true. Therefore, the correct answer is *only* the negative value ($v_f = -21 \text{ m/s}$).

Question 0.7

A freely falling body is found to be moving downwards at **- 27.2 m/s** at one instant. If it continues to fall, **1 second** later the object would be moving with a downward velocity?

A) 27 m/s B) - 57 m/s C) - 37 m/s D) 47 m/s

Answer 0.7

- Quick analysis: Every second, the velocity increases by -9.8 m/s under gravity. Therefore, after $1s$, the speed should be:

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- Formal solution:

$$v_f = v_i - gt$$

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- Formal solution:

$$v_f = v_i - gt = -27.2 \text{ m/s} + (-9.8 \text{ m/s}^2)(1s) = -37 \text{ m/s}$$

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1. Ch.1: Physics and Measurement

2. Ch.2: Motion in One Dimension

3. Ch.3: Vectors

4. Ch.4: Motion in Two Dimensions

Question 3.8

If $\mathbf{A} = (6\,\mathbf{i} - 8\,\mathbf{j})$ units, $\mathbf{B} = (-\,8\,\mathbf{i} + 3\,\mathbf{j})$ units, and $\mathbf{C} = (26\,\mathbf{i} + 19\,\mathbf{j})$ units, the values of a and b respectively in units such that ($a\mathbf{A} + b\mathbf{B} + \mathbf{C} = 0$) are:

A) 5 , 7 B) 2 , 3 C) 3 , 7 D) 5 , 9

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Answer 3.8

$$a\vec{A} + b\vec{B} + \vec{C} = 0$$

Answer 3.8

$$a\vec{\boldsymbol{A}} + b\vec{\boldsymbol{B}} + \vec{\boldsymbol{C}} = 0$$

$$a(6\hat{\boldsymbol{\imath}} - 8\hat{\boldsymbol{\jmath}}) + b(-8\hat{\boldsymbol{\imath}} + 3\hat{\boldsymbol{\jmath}}) + (26\hat{\boldsymbol{\imath}} + 19\hat{\boldsymbol{\jmath}}) = 0$$

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$$a\vec{A} + b\vec{B} + \vec{C} = 0$$

$$a(6\hat{\imath} - 8\hat{\jmath}) + b(-8\hat{\imath} + 3\hat{\jmath}) + (26\hat{\imath} + 19\hat{\jmath}) = 0$$

$$(6a - 8b + 26)\hat{\imath} + (-8a + 3b + 19)\hat{\jmath} = 0$$

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Therefore, both components must be zero:

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Checking the options, we find that the correct answer is **(A)**:

Answer 3.8

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Therefore, both components must be zero:

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$$-8a + 3b + 19 = 0$$

Checking the options, we find that the correct answer is **(A)**:

$$6(5) - 8(7) + 26 = 30 - 56 + 26 = 0 \quad \checkmark$$

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Answer 3.8

$$a\vec{A} + b\vec{B} + \vec{C} = 0$$
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$$(6a - 8b + 26)\hat{\imath} + (-8a + 3b + 19)\hat{\jmath} = 0$$

Therefore, both components must be zero:

$$6a - 8b + 26 = 0$$
$$-8a + 3b + 19 = 0$$

Checking the options, we find that the correct answer is **(A)**:

$$6(5) - 8(7) + 26 = 30 - 56 + 26 = 0 \quad ✓$$
$$-8(5) + 3(7) + 19 = -40 + 21 + 19 = 0 \quad ✓$$

Question 3.9

If $\mathbf{A} = [10\ \text{m}, 60°]$ and $\mathbf{B} = [5\ \text{m}, 140°]$, in polar coordinates, what is the magnitude of the sum of these two vectors?

A) 12.5 m

B) 9.3 m

C) 10.2 m

D) 11.9 m

Answer 3.9

$$\vec{A} = 10\cos(60°)\hat{\imath} + 10\sin(60°)\hat{\jmath} = 5\hat{\imath} + 8.66\hat{\jmath}$$

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Answer 3.9

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$$\vec{B} = 5\cos(140°)\hat{\imath} + 5\sin(140°)\hat{\jmath} = -3.83\hat{\imath} + 3.21\hat{\jmath}$$

$$\vec{C} = \vec{A} + \vec{B} = (5 - 3.83)\hat{\imath} + (8.66 + 3.21)\hat{\jmath} = 1.17\hat{\imath} + 11.87\hat{\jmath}$$

Answer 3.9

$$\vec{A} = 10\cos(60°)\hat{\imath} + 10\sin(60°)\hat{\jmath} = 5\hat{\imath} + 8.66\hat{\jmath}$$

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$$|\vec{C}| = \sqrt{(1.17)^2 + (11.87)^2} = 11.9 \text{ m}$$

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Question 4.10

A projectile is launched with an initial velocity of **20 m/s** at an angle of **30°** above the horizontal. What is the maximum height reached by the projectile?

A) 15.5 m B) 21.3 m C) 11.1 m D) 5.1 m

Answer 4.10

$$h = \frac{v_i^2 \sin^2(\theta)}{2g}$$

Answer 4.10

$$h = \frac{v_i^2 \sin^2(\theta)}{2g} = \frac{20^2 \sin^2(30°)}{2 * 9.8} = 5.1 \text{ m}$$

Question 4.11

A particle moves in the *xy*-plane with a constant acceleration of **4 m/s²** at an angle of **30°** above the positive x-axis. If the particle's initial position is **(0, 0)** and its initial velocity is **(2 m/s, 3 m/s)**, what is its velocity vector after **3 seconds**?

A) (16.6 m/s, 13.8 m/s)

B) (12.4 m/s, 9 m/s)

C) (14.5 m/s, 11.7 m/s)

D) (15.3 m/s, 12.2 m/s)

Answer 4.11

The acceleration vector in cartesian coordinates is given by:

$$\vec{a} = 4\cos(30°)\hat{\imath} + 4\sin(30°)\hat{\jmath} = 3.46\hat{\imath} + 2\hat{\jmath}$$

Answer 4.11

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- The velocity vector at after $t = 3s$ is given by:

$$\vec{v} = \vec{v}_0 + \vec{a}t = (2\hat{\imath} + 3\hat{\jmath}) + (3.46\hat{\imath} + 2\hat{\jmath}) \times 3 = 12.4\hat{\imath} + 9\hat{\jmath}$$

Question 4.12

Two particles, **A** and **B**, start from the same point at the same time and move with constant accelerations. Particle **A** has an acceleration of **2 m/s²** in the positive *x*-direction, while particle **B** has an acceleration of **3 m/s²** in the positive *y*-direction. Which particle will be farther from the origin after **5 seconds**?

A) Particle B

B) It depends on the initial velocities of the particles

C) Particle A

D) They will be at the same distance

Answer 4.12

From the equation of motion ($\vec{r} = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2$), we see that when

$$r_i = v_i = 0,$$

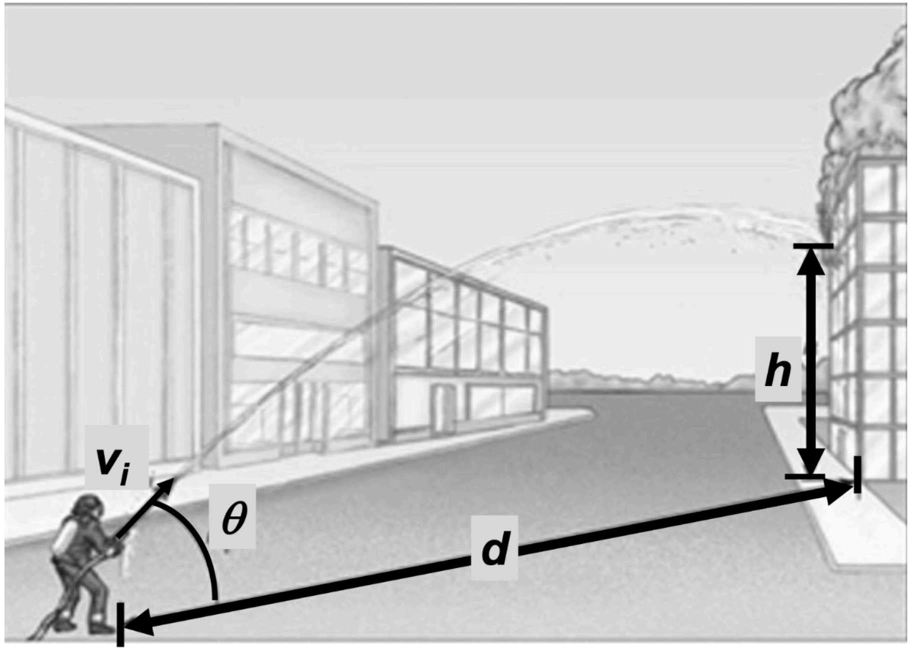
the position vector only depends on the acceleration as:

$$\vec{r} = \frac{1}{2}\vec{a}t^2$$

Therefore, the particle with the largest acceleration will have the largest displacement after the same time interval. In this case, **particle B**.

Question 4.13

A firefighter, at a distance d = **50 m** from a burning building, directs a stream of water from a fire hose at an angle θ = **30°** above the horizontal (as in the Figure). If the initial speed of the water stream is **40 m/s**, the height at which the water strike the building is:



A) 24.3 m B) 18.7 m C) 5.6 m D) 31.2 m

Answer 4.13

- First, we need to find the time at which the stream of water reaches the building.

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Answer 0.13

- First, we need to find the time at which the stream of water reaches the building.

$$d = v_i \cos(\theta) t$$

Answer 0.13

- First, we need to find the time at which the stream of water reaches the building.

$$d = v_i \cos(\theta) t \implies t = \frac{d}{v_i \cos(\theta)} = \frac{50}{40 \cos(30°)} = 1.44s$$

Answer 0.13

- First, we need to find the time at which the stream of water reaches the building.

$$d = v_i \cos(\theta)t \implies t = \frac{d}{v_i \cos(\theta)} = \frac{50}{40\cos(30°)} = 1.44s$$

- Next, we can find the vertical position of the water stream at this time using the following equation:

$$y = v_i \sin(\theta)t - \frac{1}{2}gt^2$$

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Answer 0.13

- First, we need to find the time at which the stream of water reaches the building.

$$d = v_i \cos(\theta) t \implies t = \frac{d}{v_i \cos(\theta)} = \frac{50}{40 \cos(30°)} = 1.44s$$

- Next, we can find the vertical position of the water stream at this time using the following equation:

$$\begin{aligned} y &= v_i \sin(\theta) t - \frac{1}{2} g t^2 \\ &= 40 \sin(30°)(1.44) - \frac{1}{2}(9.8)(1.44)^2 \\ &= 28.8 - 10.2 = 18.64 \text{ m} \end{aligned}$$

Question 0.14

A race car moving with a constant speed of **60 m/s** completes **one lap** around a circular track in **50 s**. What is the magnitude of the acceleration of the race car?

A) 7.5 m/s^2 B) 2.5 m/s^2 C) 3.4 m/s^2 D) 5.4 m/s^2

Answer 0.14

- Since the car is moving in a circular path, the centripetal acceleration is given by v^2/r.

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- Since the car is moving in a circular path, the centripetal acceleration is given by v^2/r. The velocity is given (60 m/s) and the radius r can be found from the period T using:

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

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Answer 0.14

- Since the car is moving in a circular path, the centripetal acceleration is given by v^2/r. The velocity is given (60 m/s) and the radius r can be found from the period T using:

$$T = \frac{2\pi r}{v} \implies r = \frac{vT}{2\pi} = \frac{60 \times 50}{2\pi} = 477.7 \text{ m}$$

Answer 0.14

- Since the car is moving in a circular path, the centripetal acceleration is given by v^2/r. The velocity is given (60 m/s) and the radius r can be found from the period T using:

$$T = \frac{2\pi r}{v} \implies r = \frac{vT}{2\pi} = \frac{60 \times 50}{2\pi} = 477.7 \text{ m}$$

Therefore, the magnitude of the centripetal acceleration is:

$$a = \frac{v^2}{r} = \frac{60^2}{477.7} = 7.5 \text{ m/s}^2$$

Question 0.15

The speed of a particle moving in a circle **2 m** in radius increases at the constant rate of **4.4 m/s²**. At an instant when the magnitude of the total acceleration is **6 m/s²**, what is the speed of the particle?

A) 1.4 m/s B) 4.2 m/s C) 2.9 m/s D) 3.8 m/s

Answer 0.15

$$r = 2\ \text{m}, \quad a_t = 4.4\ \text{m/s}^2, \quad a_{\text{tot}} = 6\ \text{m/s}^2, \qquad \text{Find} \quad v =?$$

Answer 0.15

$$r = 2 \text{ m}, \quad a_t = 4.4 \text{ m/s}^2, \quad a_{\text{tot}} = 6 \text{ m/s}^2, \qquad \text{Find} \quad v = ?$$

$$a_{\text{tot}}^2 = a_r^2 + a_t^2$$

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Answer 0.15

$$r = 2\ \text{m}, \quad a_t = 4.4\ \text{m/s}^2, \quad a_{\text{tot}} = 6\ \text{m/s}^2, \qquad \text{Find} \quad v = ?$$

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$$\implies v^2 = r\sqrt{a_{\text{tot}}^2 - a_t^2}$$

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$$\Longrightarrow v = 2.9\ \text{m/s}$$