PHYS 1210 Spring 2026 Quiz

Brief Solutions

1. Unit for mass

The SI unit of mass is the kilogram.

2. Unit for momentum

Momentum was defined as mass times velocity. Mass has units of kg and velocity has units of m/s, so momentum units are kg · m/s.

3. Convert miles per hour to meters per second

$$45\,\frac{\text{mi}}{\text{h}} \cdot \frac{5280\,\text{ft}}{1\,\text{mi}} \cdot \frac{12\,\text{in}}{1\,\text{ft}} \cdot \frac{2.54\,\text{cm}}{1\,\text{in}} \cdot \frac{1\,\text{m}}{100\,\text{cm}} \cdot \frac{1\,\text{h}}{60\,\text{min}} \cdot \frac{1\,\text{min}}{60\,\text{s}} = 20.1\,\text{m/s}$$

4. The cookie thief

This story is fictional. Any resemblance to actual persons, living or dead, is coincidental.

A. The thief's head start

If we set the table as being at position $x = 0$, Dr. Darrans's position at any time is given by $x_D = v_D t$. where his speed $v_D = 1.80\,\text{m/s}$. He has 4.0 seconds before Amy starts after him, so

$$x_D = (1.80\,\text{m/s})(4.0\,\text{s}) = 7.20\,\text{m}.$$

B. Time to catch a thief

Here it makes sense to restart the time so that $t = 0$ is when Amy begins running. In that case, Amy's initial position is at $x = 0$, and Dr. Darrans's initial position is his head start distance, $x_{D0} = 7.2\,\text{m}$. The position equation for Amy, then, is $x_A = v_A t$, and the position equation for Dr. Darrans is $x_D = x_{D0} + v_D t$. We want to find the time at which Amy and Dr. Darrans are in the same place.

$$\begin{aligned}
x_A &= x_D \\
v_A t &= x_{D0} + v_D t \\
v_A t - v_D t &= x_{D0} \\
(v_A - v_D)t &= x_{D0} \\
t = \frac{x_{D0}}{v_A - v_D} &= \frac{7.2\,\text{m}}{0.9\,\text{m/s}} = 8.0\,\text{s}.
\end{aligned}$$

It's worth interpreting the formula we just used. $(v_A - v_D)t = x_{D0}$ is the time it takes to travel distance x_{D0} at speed $v_A - v_D$. That makes sense; $v_A - v_D$ is the speed at which Amy is closing the distance to Dr. Darrans.

C. Pursuit distance

To find where they are, substitute the time from the previous part into either position equation.

Using Amy's position equation,

$$x_A = v_A t = (2.70\,\mathrm{m/s})(8.0\,\mathrm{s}) = 21.6\,\mathrm{m}$$

Using Dr. Darrans's position equation,

$$x_D = x_{D0} + v_D t = 7.2\,\mathrm{m} + (1.80\,\mathrm{m/s})(8.0\,\mathrm{s}) = 7.2\,\mathrm{m} + 14.4\,\mathrm{m} = 21.6\,\mathrm{m}$$

Seeing that both position equations give the same result is a good check on our work.

The punchline to the story is that while Amy was chasing after Dr. Darrans to get her cookie back, his accomplice took Amy's sandwich.

5. Velocity-time plot

A. Story

You need to tell a story in which something is initially at rest, remains at rest for a short time (until time t_1), starts moving with increasing speed until t_2, maintains a constant forward velocity until t_3, then comes to a stop (gradually, in a longer time than it took to come up to speed) by time t_4.

B. Acceleration-time plot

Acceleration is zero througout the time except between t_1 and t_2, when it is large and positive, and between t_3 and t_4, when it is negative and of smaller absolute value.

C. Position-time plot

You can start the graph anywhere on the vertical axis; it doesn't *have* to start at $x = 0$, but we often set the formula that way because it's simplest. The $x - t$ plot should be horizontal until t_1, concave up between t_1 and t_2, linear and increasing between t_2 and t_3, concave down between t_3 and t_4, and horizontal after t_4. The whole graph should be continuous and smooth, and should never decrese.

6. Kickball

In this scenario, the ball travels uphill with a decreasing speed. Its equations of motion going uphill are

$$v = v_0 + at$$
$$x = v_0 t + 1/2\, at^2,$$

where $v_0 = 6.50$ m/s and $a = -2.00$ m/s.

A. Time to travel uphill

The simplest way to approach this problem is to realize that the ball only travels uphill while its velocity is positive. Thus, you need to find the time at which its velocity has decreasd to zero.

$$0 = v = v_0 + at$$
$$at = -v_0$$
$$t = -v_0/a = \frac{-6.50\,\mathrm{m/s}}{-2.00\,\mathrm{m/s^2}} = 3.25\,\mathrm{s}$$

B. Distance traveled uphill

We can approach this in two primary ways: to find how far the ball travels in the time just calculated, or to directly find the distance at which the speed is zero.

Using travel time:

The equation for position as a function of time is $x = v_0 t + 1/2\, at^2$, which gives us $(6.50\,\text{m/s})(3.25\,\text{s}) + 1/2\,(2.00\,\text{m/s}^2)(3.25\,\text{s})^2 = 10.6\,\text{m}$.

Using speed and distance:

We can use the shortcut equation $v^2 - v_0^2 = 2a(x - x_0)$ to find $x - x_0$, the distance traveled. This gives us

$$x - x_0 = \frac{0 - v_0^2}{2a} = \frac{-(6.50\,\text{m/s})^2}{-4.00\,\text{m/s}^2} = 10.6\,\text{m}$$

C. Return velocity

In this part of the motion, we need new equations because the acceleration has changed. We could set $x = 0$ at the farthest point of the ball's path, but I prefer to keep $x = 0$ where Arthur kicked the ball in the first place. As the ball rolls back downhill, both its velocity and acceleration are negative. The ball's initial position is 10.5625 m (when doing a calculation, you want to keep all the digits you have; round only when reporting significant figures), its final position is zero, its initial velocity is zero, and its constant acceleration is $-1.30\,\text{m/s}^2$. This gives kinematic equations of $v = at$ and $x = x_0 + 1/2\, at^2$.

To find the speed at $x = 0$, the shortcut equation is definitely the way to go, rather than first finding the time at which the ball has traveled 10.5625 meters.

$$v^2 - 0^2 = 2a(x - x_0) = (-2.60\,\text{m/s}^2)(-10.5625\,\text{m}) = 27.4625\,\text{m}^2/\text{s}^2$$
$$v = \sqrt{27.4625\,\text{m}^2/\text{s}^2} = 5.24\,\text{m/s}$$

That's slower than the initial speed, because the ball didn't speed up going downhill as quickly as it slowed down going uphill.

7. Vector operations

$\vec{A}$ has magnitude 2.00 and direction 25°.

$\vec{B}$ has magnitude 3.50 and direction 120°.

A. $\vec{A}$ as components

$A_x = 2.00 \cos(25°) = 1.8126$

$A_y = 2.00 \sin(25°) = 0.8452$

We can express $\vec{A}$ as $\vec{A} = 1.8126\hat{\imath} + 0.8452\hat{\jmath}$.

B. $\vec{B}$ as components

$B_x = 3.50 \cos(120°) = -1.75$

$B_y = 3.50 \sin(120°) = 3.0311$

We can express $\vec{B}$ as $\vec{B} = -1.75\hat{\imath} + 3.0311\hat{\jmath}$.

C. $\vec{A} + \vec{B}$

Do this by components.

$$\begin{aligned}\vec{A} + \vec{B} &= 1.8126\hat{\imath} + 0.8452\hat{\jmath} + (-1.75)\hat{\imath} + 3.0311\hat{\jmath} \\ &= (1.8126 - 1.75)\hat{\imath} + (0.8452 + 3.0311)\hat{\jmath} \\ &= 0.0626\hat{\imath} + 3.8763\hat{\jmath}\end{aligned}$$

If you must see it as magnitude and direction, that would be a magnitude of 3.877 and angle of $\arctan(3.8763/0.0626) = 89°$.

D. $\vec{B} - 2\vec{A}$

Components again.

$$\begin{aligned}\vec{B} - 2\vec{A} &= -1.75\hat{\imath} + 3.0311\hat{\jmath} - 2(1.8126\hat{\imath} + 0.8452\hat{\jmath}) \\ &= -1.75\hat{\imath} + 3.0311\hat{\jmath} - 3.6252\hat{\imath} - 1.6904\hat{\jmath} \\ &= (-1.75 - 3.6252)\hat{\imath} + (3.0311 - 1.6904)\hat{\jmath} \\ &= -5.3752\hat{\imath} + 1.3407\hat{\jmath}\end{aligned}$$

As magnitude and angle, that is 5.540 at an angle of 166°. (Remember, when the x component is negative, you must add 180° to the arctangent of y/x.)

E. $\vec{A} \cdot \vec{B}$

We could either do this by components or by magnitudes and angle. We were originally given angles, so that's simplest.

The angle between the two vectors is $120° - 25° = 95°$. This gives

$$\vec{A} \cdot \vec{B} = (2.00)(3.50)\cos(95°) = (7.00)(-0.08716) = -0.610.$$

By components, if you are so inclined, we have

$$\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y = (1.8126)(-1.75) + (0.8452)(3.0311) = -3.172 + 2.562 = -0.610.$$

The dot product is much smaller than the product of the magnitudes of the two vectors, because the vectors are nearly perpendicular. They do not overlap very much.

F. $\vec{A} \times \vec{B}$

Again, we could also do this by magnitudes and angle or by components. Using magnitudes and angle, we obtain

$$AB\sin\theta = (2.00)(3.50)\sin 95° = (7.00)(0.9962) = 6.973$$

The cross product's magnitude is close to the product of the magnitudes of the two vectors, because they are nearly perpendicular. The right-hand rule tells us that the cross product is in the direction of the $+z$ axis, so $\vec{A} \times \vec{B} = 6.973\hat{k}$.

We can also find the cross product in terms of components.

$$\begin{aligned}\vec{A} \times \vec{B} =& (1.8126\hat{\imath} + 0.8452\hat{\jmath}) \times (-1.75\hat{\imath} + 3.0311\hat{\jmath}) \\ =& (1.8126)(-1.75)(\hat{\imath} \times \hat{\imath}) + (1.8126)(3.0311)(\hat{\imath} \times \hat{\jmath}) \\ &+ (0.8452)(-1.75)(\hat{\jmath} \times \hat{\imath}) + (0.8452)(3.0311)(\hat{\jmath} \times \hat{\jmath}) \\ =& -3.172\,\vec{0} + 5.494\hat{k} + (-1.479)(-\hat{k}) + 2.562\,\vec{0} \\ =& (5.494 + 1.4789)\hat{k} \\ =& 6.973\,\hat{k}\end{aligned}$$