PHYS 1210 Spring 2026 Exam 1

Brief Solutions

1. Descending firefighter net force

As he descends, his velocity is constant. Newton's first law tells us that therefore the net force acing on him is zero.

2. Kicked soccer ball

This scenario addresses the two trajectory standards. The relevant parameters are initial position at ground level and initial speed of 22 m/s at 35.0 degrees above **horizontal** (sorry about that). We'll make this easy on ourselves by setting the initial position at $(0, 0)$, our x axis as horizontal, and the y axis as vertical.

A. Initial velocity, vertical component

$$v_{0y} = v_0 \sin\theta = 12.62\,\mathrm{m/s}.$$

B. Initial velocity, horizontal component

$$v_{0x} = v_0 \cos\theta = 18.02\,\mathrm{m/s}.$$

C. Trend in v_{0y}

Gravity constantly pulls the ball downward, so v_{0y} constantly decreases (becomes increasingly negative).

D. Trend in v_{0x}

Nothing perturbs the ball horizontally (we're in the intro physics fantasy world without drag), so v_{0x} remains constant.

E. Trend in v (speed)

This one is more complicated. The speed depends on *both* the vertical and horizontal components of the velocity; $v = \sqrt{\vec{v} \cdot \vec{v}} = \sqrt{v_x^2 + v_y^2}$. The vertical component starts out positive and initially decreases, so v_y^2 initially decreases. After it decreases to zero and v_y takes on negative values, v_y^2 increases. The horizontal contributions v_x and v_x^2 consequently cause the total to first decrease to a nonzero value (the minimum speed is just the value of the x component of the velocity) and then increase after that.

F. Time to apex

The simplest way to find this is the time at which v_y drops to zero.

$$\begin{aligned} v_y &= v_{0y} - gt \\ 0 &= v_{0y} - gt \\ gt &= v_{0y} \\ t &= v_{0y}/g = 1.29\,\mathrm{s} \end{aligned}$$

G. Speed at apex

At the apex, $v_y = 0$, so $v = |v_x|$. From above, that is 18.02 m/s.

H. Height at apex

Here we find the vertical component of position at the time when $v_y = 0$.

$$\begin{aligned} y &= y_0 + v_{0y}t - 1/2\,gt^2 \\ &= 0 - v_{0y}(v_{0y}/g) - 1/2\,g(v_{0y}/g)^2 \\ &= \frac{v_{0y}^2}{g} - \frac{1}{2}\frac{v_{0y}^2}{g} \\ &= \frac{v_{0y}^2}{2g} \\ &= 8.126\,\mathrm{m} \end{aligned}$$

We could also use the shortcut formula

$$\begin{aligned} v_y^2 - v_{0y}^2 &= 2(-g)(y - y_0) \\ 0 - v_{0y}^2 &= -2gy \\ y &= \frac{v_{0y}^2}{2g} \end{aligned}$$

which is the same formula that we got working the other way.

I. Horizontal distance at apex

There is no shortcut formula here; there is nothing horizontally special about the apex position. We need to plug the time into the x formula.

$$x = v_x t = v_{0x}v_{0y}/g = 23.21\,\mathrm{m}$$

3. Leaf in a whirlwind

The relevant parameters are a **radius** of 3.60 meters and a period of 4.10 seconds. We can figure out all the rest from those.

A. Tangential speed v

$$v = 2\pi r/T = 5.52\,\mathrm{m/s}.$$

B. Period T

This was already given to us, as 4.10 seconds.

C. Angular speed ω

$$w = v/r = 2\pi/T = 1.532\,\mathrm{rad/s}.$$

D. Acceleration

There are many formulas we could use. Employing the quantities of radius and period that were given initially, the most fitting is

$$a = \frac{4\pi^2 r}{T^2} = 8.454\,\mathrm{m/s^2}.$$

4. Bowling ball

A. Direction of the bowler's throw

We don't know this precisely. It mostly has a horizontal forward component, and it almost certainly had an upward component to make the ball's starting velocity mostly horizontal.

B. Direction of the ball's weight

Straight down.

C. The normal force

When the ball is in contact with the lane, the normal force is normal to the lane, or vertically upward. (Strictly speaking, bowling lanes are not perfectly horizontal: they slope toward the pins. If we take that into account, the normal force is mostly upward, with a small forward component.)

D. Kinetic friction

The friction will be backward, along (parallel to) the lane.

E. Magnitude of weight in the air

Weight is always mg straight down. For a 5.00-kg ball on Earth, that's 49.0 newtons.

F. Magnitude of normal force in the air

When the ball is not in contact with the lane, the lane does not exert a normal force on it. The normal force is a contact force, not a long-range force like gravity.

G. Magnitude of normal force on the lane

Assuming the lane is level, the normal force simply opposes gravity, giving a magnitude of 49.0 newtons. We'd need to know the slope of the lane to find the normal force if we don't assume the lane is perfectly level.

H. Force stopping the ball's downward motion

This can only be the normal force from the lane.

5. Frog on a thread

We aren't told the mass of the amulet, but we do know that the thread is 20 centimeters long, and that when the car accelerates forward the thread hangs at an angle of 15 degrees off vertical. (This time, I really meant vertical.)

A. Free body diagram

The only forces acting on the amulet are its weight (gravity), which is directed straight downward, and the tension from the thread, which is directed mostly upward, but 15 degrees away from being straight upward.

Notice that these forces *do not* cancel in the horizontal direction: this is *not* a static situation. The car and the amulet within it accelerate forward. The forces do, however, cancel in the vertical direction; nothing says that the amulet is accelerating upward or downward, and in fact the problem specified that the car is on a level road.

B. Vertical component of tension

Because the amulet does not accelerate vertically, the vertical component of its net force is zero. This can only happen if the vertical component of tension cancels the amulet's downward weight, which has magnitude mg. Therefore, the vertical component of tension is also mg, in the opposite direction.

C. Horizontal component of tension

The horizontal and vertical components of tension make the legs of a right triangle with the tension itself as the hypotenuse. The top angle of the right triangle is 15 degrees, and it is opposite the horizontal component. (Draw the triangle if you are not visualizing what that means. It will help you understand better than if I were to draw the triangle for you.) If we define T_x as the horizontal component of tension and T_y as the vertical component, then $\tan(15°) = T_x/T_y$. A little algebra reveals that the horizontal component is $T_x = T_y \tan(15°) = mg \tan(15°)$.

D. Acceleration of the car

The acceleration of the car is the same as the acceleration of the amulet, which Newton's second law tells us is $\Sigma F/m$. The net force Σm is the horizontal component of tension, so

$$a = \Sigma F/m = mg \tan(15°)/m = g \tan(15°) = 2.63\,\mathrm{m/s^2}.$$

6. Stuck in a tree

We are told that the child's mass is 32 kilograms, that the tree trunk is vertical, and that the angle between the tree trunk and the branch is eight degrees. The problem didn't mention friction until the end; bear in mind that while the child's shoe is becoming wedged into the crotch of the tree, the operating friction is kinetic, not static. Once he's stuck, friction may play a part in keeping him from sliding down further, but I'm ignoring that. Friction becomes an issue when the child tries to pull his foot *out* of the tree.

A. Free body diagram

The only forces you need to include in the free body diagram are the child's weight downward, and the two normal forces, from the branch and from the tree trunk. With the trunk and branch positioned as in the diagram, the normal force from the trunk is horizontal to the right, and the normal force from the branch is eight degrees above horizontal to the left. If you included static friction forces, they should have been vertical (along the tree trunk) and eight degrees slanted from vertical (along the branch). Whether up or down, though, depends on how the child is struggling to escape. Friction could also be horizontal, into or out of the page; again depending on what the child is doing at the time.

This *is* a static situation. Consequently, the vertical components of the forces must cancel and the horizontal components of the forces must cancel. The forces with vertical components are weight and the normal force from the branch; the forces with horizontal components are the two normal forces.

B. Vertical component of normal force from the branch

To cancel the child's weight, the vertical component of the normal force from the branch must be opposite the child's weight or $mg = 313.6\,\mathrm{N}$ upwards.

C. Vertical component of normal force from the trunk

The normal force from the trunk is horizontal, so no matter its magnitude, the vertical component is zero.

D. Horizontal component of normal force from the branch

The vertical component of this force is mg, and the force is angled eight degrees above horizontal. Trigonometry requires that $\tan 8° = N_y/N_x$, and $N_y = mg$. Therefore $N_x = mg/\tan 8° = 2231\,\mathrm{N}$. The sign depends on your coordinate axes.

E. Horizontal component of normal force from tree trunk

The horizontal components must cancel, so the horizontal component of the normal force from the trunk must also be 2231 newtons, in the opposite direction. Again, the sign depends on your choice of coordinate axes, but it should be opposite the sign of the horizontal component of the normal force from the branch.

F. Static friction from tree trunk

With a normal force of 2231 N and a coefficient of static friction of 0.50, the maximum magnitude of static friction is $\mu N = 1116\,\mathrm{N}$. Until the child's struggles pull him free (mine didn't—a neighbor had to rescue me), it won't be that much, though.