

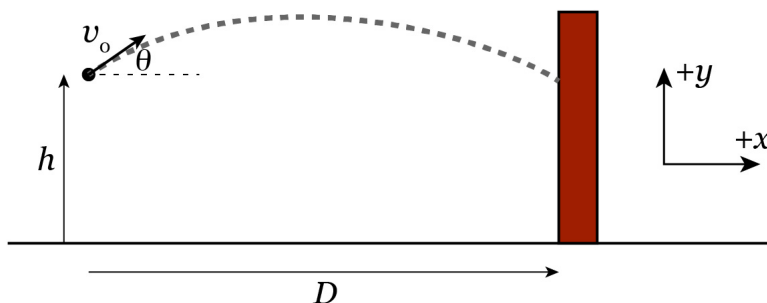
PHYS 1110-02 Fall 2026 Quiz 2

Brief Solutions

1. Trebuchet

A. Diagram

This isn't intended to test anything directly; it's to prompt you to organize what you know about the problem and to make sure that everyone uses the same coordinate system to make grading easier.



The diagram should show the launch a height $h = 6.00$ m above the ground, a wall a distance $D = 45.0$ m away, a launch speed of $v_0 = 28.5$ m/s at an angle of $\theta = +55^\circ$ above horizontal, and axes with $+y$ vertically upwards and $+x$ horizontal in the direction from the trebuchet to the wall.

B. v_{0y}

$$v_{0y} = v_0 \sin \theta = (28.5 \text{ m/s}) \sin(55^\circ) = 23.35 \text{ m/s}$$

C. v_{0x}

$$v_{0x} = v_0 \cos \theta = (28.5 \text{ m/s}) \cos(55^\circ) = 16.35 \text{ m/s}$$

D. a_x

The acceleration of a projectile is purely downward, so its horizontal component is zero. $a_x = 0$.

E. a_y

The acceleration is purely downward with magnitude $g = 9.8 \text{ m/s}^2$. In our coordinates, downward is the $-y$ direction, so the y component is $g = -9.8 \text{ m/s}^2$.

F. Height at the wall

This is a classic projectile problem. To find the height of the projectile, we can use the equation for the y coordinate as a function of time:

$$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$$

This requires knowing *when* the boulder reaches the castle. This can be found using the equation for the x coordinate as a function of time:

$$x = x_0 + v_{0x}t$$

Here, we do not know t , but we know v_{0x} , so we can find t when $x = D$.

$$D = v_{0x}t$$

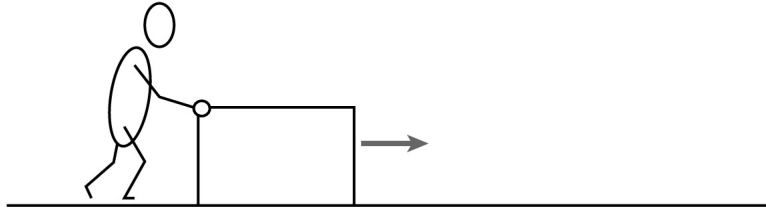
$$t = D/v_{0x}$$

$$t = (45 \text{ m})/(16.35 \text{ m/s}) = 2.75 \text{ s}$$

Now we use this time to find the height.

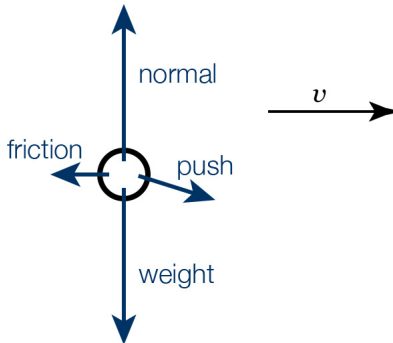
$$\begin{aligned}
 y &= y_0 + v_{0y}(D/v_{0x}) - \frac{1}{2}g(D/v_{0x})^2 \\
 &= y_0 + D \tan \theta - \frac{1}{2}g(D/v_{0x})^2 \\
 &= 6 \text{ m} + (45 \text{ m})(1.428) - \frac{1}{2}(9.8 \text{ m/s}^2)(2.75 \text{ s})^2 \\
 &= 33.1 \text{ m}
 \end{aligned}$$

2. Sliding crate



The crate is on a level floor, so it moves horizontally. The mass of the worker isn't needed to solve any part of the question.

A. Free body diagram for the crate



The forces acting are the weight of the crate straight down with magnitude mg , the normal force directly upward with a magnitude making the vertical component of the net force zero (so slightly more than the weight), friction horizontally backwards, and the worker's push forward and (20°) downward. The arrow indicating velocity should be horizontal, directly opposite the direction of the friction.

B. Magnitude of net force

It's almost a surprise that we can determine the net force without knowing all the forces. Specifically, we don't know the magnitude of the normal force. But we know that the vertical component of the net force is zero, which is all we need to know for now. Later we'll determine the magnitude of the normal force, and then we can use our knowledge of the net force to find it.

To find the horizontal component of the normal force, we need to sum the horizontal components of all the forces. The horizontal components of the weight and the normal force are both zero. The forces with nonzero horizontal components are friction f , with a magnitude of 65 newtons backward, and the worker's push F_P . We are told the magnitude (80 newtons) and direction (-20°) of the push, so its horizontal component is $F_{Px} = (80 \text{ N}) \cos(-20^\circ) = 75.2 \text{ N}$. The net horizontal force then is $(75.2 - 65) \text{ N} = 10.2 \text{ N}$.

C. Magnitude of acceleration

Newton's second law tells us that acceleration is the net force divided by the mass.

$$a_y = \Sigma F_y / m = 0 / (26 \text{ kg}) = 0$$

$$a_x \Sigma F_x / m = (10.2 \text{ N}) / (26 \text{ kg}) = 0.39 \text{ m/s}^2$$

The y component is zero, so the magnitude of the acceleration is the absolute value of the x component.

D. Direction of acceleration

Acceleration is in the forward direction; we can call that $+x$ if we like. The key point is that acceleration is in the direction of the horizontal component of the push.

E. Magnitude of weight

Weight is $mg = (26 \text{ kg})(9.8 \text{ m/s}^2) = 254.8 \text{ N} = 255 \text{ N}$. The quiz didn't ask for the direction, because of course it is vertically downward.

F. Magnitude of normal force

As mentioned above, the normal force is whatever it needs to be to ensure that the crate does not accelerate downward. That means, in the y direction, taking $\uparrow$ up to be positive, that the net force is non-negative.

$$\begin{aligned}\Sigma F_y &\geq 0 \\ N - mg + F_P \sin(-20^\circ) &\geq 0 \\ N &\geq mg - F_P \sin(-20^\circ) \\ N &\geq 254.8 \text{ N} + 27.4 \text{ N} = 282.2 \text{ N}\end{aligned}$$

The normal force needed to just keep the crate from accelerating downward is 282 newtons.

G. Direction of friction

Friction is opposite the direction of the crate's slide, which I am calling positive.

H. Coefficient of friction

For kinetic friction, $f_k = \mu_k N$, so $\mu_k = f_k / N$. We are told the magnitude of friction f_k and we just found the normal force N , so

$$\mu_k = (65 \text{ N}) / (282.2 \text{ N}) = 0.23.$$

I. Type of friction

The crate slides across the floor, so this is kinetic friction.

J. Object exerting normal force

The normal force is an interaction between the crate and the surface of the floor. The floor exerts the normal force on the crate.

K. Object exerting force of weight

The crate's weight is an interaction between the crate and the Earth. The Earth pulls down on the crate.

L. Vertically upward force exerted by the crate

i. Object on which the crate exerts the upward force

This is the other force in the action-reaction pair between the crate and the Earth. The Earth pulls vertically downward on the crate, and the crate pulls with a force of equal magnitude vertically upward on the Earth.

ii. Magnitude of the upward force

This upward force is equal and opposite to the crate's weight, which is 255 newtons.

3. Unmoving crate

If the crate does not move when pushed, that means that static friction exactly counteracts the horizontal component of the push.

A. Type of friction

This is static friction.

B. Magnitude of friction

The static friction cancels the forces parallel to the surface of the floor. The only such force in this case is the worker's push at $F_P \cos(-20^\circ) = (40 \text{ N})(0.940) = 37.6 \text{ N}$. Friction does not cancel the vertical component of the worker's push; the normal force does that. (The normal force also cancels the weight of the crate.)

4. Zero net force

Zero net force is the condition of applicability of Newton's first law, which tells us that zero net force makes for zero acceleration. That means the body's velocity is constant. The velocity can be zero, or it can be something else, but whatever it is, the velocity does not change when the net force is zero.