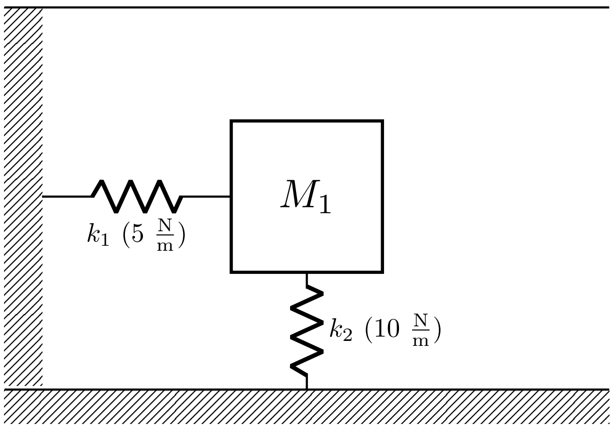
AP/Honors Quiz 5 **(Solutions)**

Full Name, Period, AP/Honors:

1 Bet you can't pick just one!

1. *Two springs are connected to a 1.7 kg mass as shown. The whole system is in the back of a truck on Earth where the gravity is $-10\ \frac{\mathrm{m}}{\mathrm{s}^2}\hat{z}$. The spring with constant k_1 has been* ***extended*** *by a length Δx_1 and the spring with k_2 has been* ***compressed*** *by a length $\Delta x_2 = 2\Delta x_1$. The block is not moving relative to the truck.*



(a) (3 pt, **All**) *What is the magnitude of the acceleration of the truck?*

A. 0 $\frac{\mathrm{m}}{\mathrm{s}^2}$

$\boxed{\text{B.}}$ 2.5 $\frac{\mathrm{m}}{\mathrm{s}^2}$

C. 5 $\frac{\mathrm{m}}{\mathrm{s}^2}$

D. 20 $\frac{\mathrm{m}}{\mathrm{s}^2}$

E. 40 $\frac{\mathrm{m}}{\mathrm{s}^2}$

Solution:

The block isn't moving, so it must have only balanced forces. From the x̂ and ŷ directions, we get

$$\hat{\mathrm{x}} : k_1 \Delta x_1 = M_1 a$$

$$\hat{\mathrm{y}} : k_2 \Delta x_2 = M_1 g$$

We want to write the ŷ equation in terms of k_1 and Δx_1 for simplicity

$$\hat{\mathrm{y}} : (2k_1)(2\Delta x_1) = 4k_1\Delta x_1 = M_1 g$$

Now we divide the equations

$$\frac{k_1 \Delta x_1}{4k_1 \Delta x_1} = \frac{M_1 a}{M_1 g}$$

Almost everything cancels to get

$$\frac{1}{4} = \frac{a}{g}$$

So

$$\boxed{a = \frac{g}{4}}$$

(b) (2 pt, **All**) *What is the direction of the acceleration of the truck?*

A. Right

$\boxed{\text{B.}}$ Left

C. Up

D. Down

E. Into or out of the page

(c) (2 pt, **All**) *Explain in two sentences or less why you chose the direction that you did.*

We need the spring to be extended, which indicated pulling. The spring will only pull if the wall is trying to leave the mass behind, ie accelerating left.

2. (4 pt, **Honors**) *A laptop is left on the (flat) roof of a car. Which of these would the driver need to do to ensure that the laptop didn't fall off? Assume the surface of the road does not have bumps and air resistance is negligible.* ***Select all that apply***

A. Limit his maximum speed

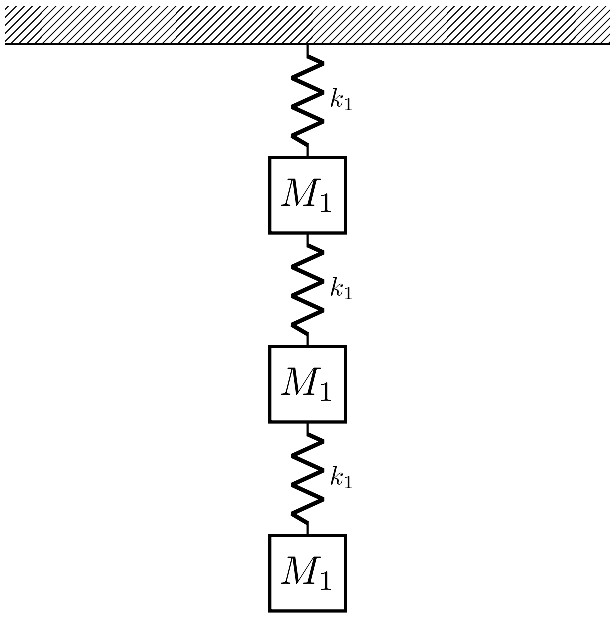
$\boxed{\text{B.}}$ Avoid rapidly speeding up

C. Avoid backing up

$\boxed{\text{D.}}$ Slow down before going around corners

We basically need to avoid large accelerations because they give rise to large forces in the book's reference frame. The only things here that involve acceleration are speeding up or driving around corners.

3. (4 pt, **AP**) *You create the following system consisting of three identical, massless, springs and 3 identical large masses and hang it from the ceiling. What will be the total extension of the springs? Total extension in this case means add all the extensions of the individual springs together.*



A. $\frac{3M_1g}{k_1}$

$\boxed{\text{B.}}$ $\frac{6M_1g}{k_1}$

C. $\frac{9M_1g}{k_1}$

D. This arrangement is guaranteed to break the springs

I'm going to number the springs 1, 2, 3, starting from the bottom.

For spring 1 to be static:

$$k_1\Delta x_1 = M_1 g$$

which implies

$$\Delta x_1 = \frac{M_1}{k_1}$$

The second spring effectively needs to be holding up the first and second mass, so

$$\Delta x_2 = \frac{2M_1}{k_1}$$

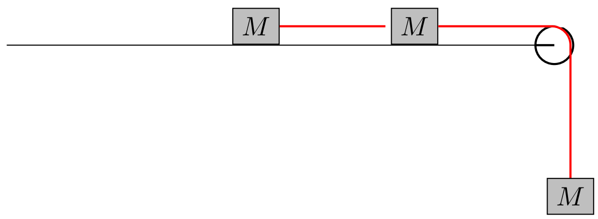
And the third must be holding up all three masses, so

$$\Delta x_3 = \frac{3M_1}{k_1}$$

The total extension is $\Delta x_1 + \Delta x_2 + \Delta x_3$

2 Flashbacks to math class

(**All**) *You have a large number of identical masses, a string, and a pulley. You place N masses on the table, and Q masses hanging from the string one after another. All masses have a coefficient of kinetic friction of μ_k with the surface. You release the system and notice that it starts to move. Below is a diagram with $N = 2$ and $Q = 1$ to help you visualize.*



1. (3 pt, **All**) *Find the acceleration of the system.*

$$F_{net} = F_g - F_f = QMg - NMg\mu_k$$

$$M_{tot} = (Q + N)M$$

Then the acceleration is

$$a = \frac{F_{net}}{M_{tot}} = \frac{Mg(Q - N\mu_k)}{M(Q + N)}$$

or

$$\boxed{\frac{Q - N\mu_k}{Q + N} g}$$

2. (3 pt, **All**) *You remove hanging masses 1 at a time until the system moves with constant velocity once started. If the current number of masses on the table is $N_1 = 100$ and the current number hanging off is $Q_1 = 75$, what is the coefficient of kinetic friction?*

Moving with constant velocity requires a net force of 0, so

$$F_g - F_f = 0$$

or

$$Q_1 Mg = N_1 Mg\mu_k$$

$$\mu_k = \frac{Q_1}{N_1}$$

$$\boxed{\mu_k = 0.75}$$

3 Living the Dream!

(3 pt, **All**) *Adrian is having a dream. In his dream, he inexplicably finds himself in a glass elevator (poor Adrian). He has a spring with a known spring constant* k*, and a block that has known friction coefficients with the floor of the elevator* (μ_k, μ_s) *and a known mass* M*. The block is far too heavy to lift, but he can slide it without too much trouble. He also has his lucky ruler. He can look through the glass and see the ground directly below, so he deduces that there is still gravity* g *downward. Help Adrian design an experiment to determine the acceleration of the elevator.*

If we could lift the block, we could just hang it from the spring, but since it is too heavy, we need another approach.

1. Measure the equilibrium length of the spring.
2. Place the block on the elevator floor. Place the meter stick next to it oriented conveniently.
3. Attach the spring to one side of the block.
4. Slowly start pulling on the spring until the block begins to move. Use the meterstick on the floor to find and record the spring extension just as the block starts to move.
5. Repeat the measurement and average the answers.
6. Find the acceleration by using the condition for static equilibrium

$$F_f = F_s$$

$$F_N \mu_s = k\Delta x$$

$$M(g + a) = k\Delta x$$

$$a = \frac{k\Delta x}{M} - g$$

If the number is positive, that indicates acceleration upwards.