PHYS 111 K
HOMEWORK #6

Solutions

1. This is a problem where we apply Newton' s first law. Before the train accelerates, you are moving at a constant speed. Your tendency (inertia) is to remain at rest with respect to the train, so that when the train accelerates in the direction of motion, you (tend to) fall backward since the train' s reference frame has changed. You may have experienced this when riding in a car that speeds up rapidly. Conversely, if the train stop suddenly, your inertia is to continue moving forward at a constant speed, so you continue to do this while the train stops (and you lurch forward).

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2. Since the objects are touching, we can regard the force as acting on a single object of 3 kg. Thus, if the value of **F** is 3 N, we know the acceleration of the entire system is 1 m/s^2. Now, let's focus on the red block. The red block experiences two forces: the force of **F** acting toward the right, and the reaction force of the blue block acting toward the left. Applying Newton's second law to the red block, we obtain:

$$\Sigma\,\mathbf{Forces} \;=\; \mathrm{m_{red}\,a_{red}}$$

or the sum of forces acting on the red block equals its mass times its acceleration. We know the mass of the red block = 1 kg, and its acceleration is 1 m/s^2, so we can write:

$$\Sigma\mathbf{Forces} \;=\; \mathrm{F} \;-\; \mathrm{r}\mathbf{eaction}\,\mathrm{force} \;=\; (1\,\mathrm{kg})\left(1\,\mathrm{m}/\mathrm{s}^2\right)$$

$$\text{or}: \quad 3\,\mathrm{N} \;-\; \text{reaction force} \;=\; 1\,\mathrm{N}$$

which yields immediately that the reaction force between the blocks has a magnitude of 2 N.

If the force **F** pushes directly on the blue block (the 2 kg block), the acceleration of the system is still 1 m/s^2 since the total mass of the system is still 3 kg. Applying Newton' s second law to the blue block :

$$\Sigma\mathbf{Forces} = \;\mathrm{F} \;-\; \text{reaction force} \;=\; (2\,\mathrm{kg})\left(1\,\mathrm{m}/\mathrm{s}^2\right) \;\rightarrow\; \text{reaction force} \;=\; 2\,\mathrm{N} - 3\,\mathrm{N} \;= -1\,\mathrm{N}$$

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3. We can find the acceleration of the whole system by thinking of the three masses as components of a single larger system of total mass 60 kg. Therefore, since a force of 60 N acts on a system of 60 kg, the total acceleration of the system (and the acceleration of each individual mass) is 1 m/s^2 in the direction of **F.**

We can find the tensions in the ropes by applying the second law to individual masses. If we consider m_3, we note that the only forces acting on m_3 are **F** (to the right) and T_2 (to the left). We can write the second law for m_3 as:

$$\text{sum of forces acting on } m_3 = F - T_2 = (30\,\text{kg})\left(1\,\text{m}/\text{s}^2\right) \rightarrow 60\,\text{N} - T_2 = 30\,\text{N}$$

$$\rightarrow |\mathbf{T_2}| = 30\,\text{N}$$

where right is the positive direction and left is negative. Applying the second law to m_2, we have:

$$T_2 - T_1 = (20\,\text{kg})\left(1\,\text{m}/\text{s}^2\right)$$

Here, T_2 has magnitude 30N and acts to the right; T_1 acts to the left, so we get:

$$30\,\text{N} - T_1 = 20\,\text{N} \rightarrow |\mathbf{T_1}| = 10\,\text{N}$$

We can check our answer for consistency by applying the second law to the 10 kg mass. The only force directly acting on m_1 is the tension in T_1, so we have simply:

$$T_1 = m\,a = 10\,\text{kg}\left(1\,\text{m}/\text{s}^2\right) = 10\,\text{N} \text{ as before.}$$

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4. If you suspend a weight from a cord, then the tension in the cord would have to equal the weight of the object in order for the object to remain in equilibrium. In this case given here, we cannot do this since the weight of the object exceeds the breaking strength of the cord. Similarly, if we lowered the weight at a constant speed, the cord would still snap. However, let' s consider what the second law suggests if we allow the cord to accelerate as we lower it. The forces acting on the object are its weight (downward) and the tension in the cord (upward). Let' s adopt a coordinate system in which down is positive, then the second law for the object is :

$$W - T = m\,a \text{ or } T = W - m\,a$$

if we allow the object to accelerate as it is lowered, we can reduce the tension in the cord so that it won' t break. If the object weighs 1000 N, its mass is (1000 N/9.8 m/s/s = 102 kg). We can determine the acceleration needed to keep the tension from exceeding the breaking strength of 800 N :

$$a = \frac{W - T}{m} = \frac{1000\,\text{N} - 800\,\text{N}}{102\,\text{kg}} = 1.96\,\text{m}/\text{s}^2$$

If we allow the block to accelerate at this (or a greater) rate, the cord will not snap.

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5. In these three scenarios, a horizontal rope is attached to a block of 10 kg on a level, frictionless surface. In parts a and b), the box is not accelerating (it is either at rest of moving at constant speed). The tension in the rope must be zero. If there were any tension in the rope, then there would be some force acting on the box, and that would cause an acceleration. In part c), there is an acceleration, so we easily compute the tension in the rop e from :

$$\mathbf{F} = m\,\mathbf{a} \rightarrow T = (50\,\text{kg})\left(5\,\text{m}/\text{s}^2\right) = 250\,\text{N}$$

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6. In this problem, we have to remember that weight is equal to the normal force acting on an object in the Earth' s gravitational field. If the object is stationary or not accelerating with respect to the surface of the earth, the normal force is equal to m g for the object. So, in parts a) and c), the measured weight of the person will just be 60 g (or 588 N) since the person is not accelerating. In part b), there is an acceleration (and the acceleration acts up), so we apply Newton' s second law to the person in the accelerating frame :

$$\text{sum of forces} = N - m\,g = m\,a$$

N is the normal force of the floor acting up on the person, m g is the force of the Earth' s gravity (acting down), and this combination of forces results in an acceleration. To find the value of N, we need to compute the value of the acceleration. We are told that the elevator moves from rest to a cruising speed of 10 m/s in 4 s, which tells us the acceleration is $2.5\, m/s^2$, so the normal force acting on the person is:

$$N = m g + m a = m(g+a) = 60\,\text{kg}\left(9.8\,\text{m}/\text{s}^2 + 2.5\,\text{m}/\text{s}^2\right) = 738\,\text{N}$$

If the person were standing on a scale in the elevator, this value would be the weight indicated on the scale.

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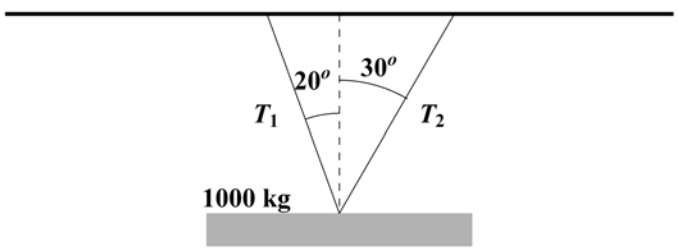
7. In this problem, the 1000 kg beam is in equilibrium. This means that the sum of horizontal forces must be zero, and also that the sum of vertical forces must be zero. Let' s consider the diagram below :



We first delineate the forces acting on the beam. These are the weight of the beam, and the tension in the two ropes. The weight acts down, and each tension has both a vertical and horizontal component. Newton' s second law gives :

$$\Sigma F_{\text{horizontal}} = T_2 \sin 30 - T_1 \sin 20 = 0$$
$$\Sigma F_{\text{vertical}} = T_1 \cos 20 + T_2 \cos 30 - W = 0$$

Notice that in the horizontal equation, the horizontal components of the forces act in opposite directions. In the vertical equation, both ropes have a component of tension upward, while the weight (= 1000 **g** = 9800N) acts down.

The horizontal equation allows us to write :

$$T_2 \sin 30 = T_1 \sin 20 \rightarrow T_2 = T_1 \frac{\sin 20}{\sin 30} = 0.68\, T_1$$

Using this relationship in the vertical equation gives :

$$T_1 \cos 20 + 0.68\, T_1 \cos 30 = 1000\, g = 9800\,\text{N}$$

which yields :

$$0.94\, T_1 + 0.59\, T_1 = 9800\,\text{N} \rightarrow T_1 = 6405\,\text{N}$$
$$\text{and } T_2 = 0.68\,(6405\,\text{N}) = 4355\,\text{N}$$

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8. In this problem we want to determine whether there is a net force in the vertical direction, and if there is, the direction in which it acts. The vertical forces acting on the block are its weight (down), the force of friction (which will act to oppose the motion) and the vertical component of the 12 N force (up). The information about friction is imbedded in the statement “a wood block is pressed

against a vertical wood wall...”. This statement informs us that there will be an amount of friction equal to:

$$f = \mu N$$

where μ is the coefficient of friction between two wooden surfaces (we can get values for these coefficients from Table 6.1 on p. 149). Since the block is initially at rest, we are interested in the coefficient of static friction (which is listed as 0.5). The frictional force is then μ_s N, where N is the normal force pushing the surfaces together; in this geometry, the normal force equals the horizontal component of the 12 N force.

It is easy to see that the weight of the block exceeds the vertical component of the 12N force, so we know the block will not slide up the wall. Now, let’s see if the block will slide down. Let’s compare the magnitude of the static friction force acting up the wall to the net vertical force:

$$\Sigma F_{\text{vertical}} = 12 \sin 30 - m\,g \;\; 12 \sin 30 = 6\text{ N} - (1\text{ kg})\left(9.8\text{ m} / \text{s}^2\right) = -3.2\text{ N}$$

$$f_s = \mu_s N = 0.5\,(12 \cos 30) = 5.2\text{ N} > |(m\,g - 12 \sin 30)|$$

Since the magnitude of the static friction force opposing motion is greater than the magnitude of the net force down, there is sufficient frictional force to keep the object from sliding down the wall; the block remains at rest.