## Group Problem

You are driving a pickup truck along a country road where the speed limit is 45 mi/hr (20 m/s) when you notice a stop sign 47.0 meters ahead. You slam on your brakes and the truck stops just in front of the stop sign. The sudden stop causes two unfortunate circumstances. First, a 30.0 kg crate in the back of the truck slides from the rear of the bed to the front of the bed, hitting and cracking the rear window in the truck. Second, a police officer who saw the whole incident stops you and gives you a ticket for speeding. The policeman says, "I saw that package slide from the back to the front of the truck's cargo area. To make it slide like that you must have had to brake very hard, so you must have been speeding." You're not sure if you were speeding or not so you decide to calculate your minimum possible speed before braking. You read in the owner's manual that the pickup has a mass of 1500 kg. You also find out that the coefficient of static friction between the crate and the truck is 0.30 and the coefficient of kinetic friction between the crate and the truck is 0.20. After going to court, will you have to pay for the ticket and the broken window or just the broken window?

<u>FOCUS the PROBLEM:</u> Draw a picture of the situation including ALL information given in the problem.

$m = 30.0\,kg$

$M = 1500\,kg$

$47.0\,m$

STOP

SPEED LIMIT $= 20\,m/s$

$\mu_k = 0.30$

$\mu_s = 0.20$
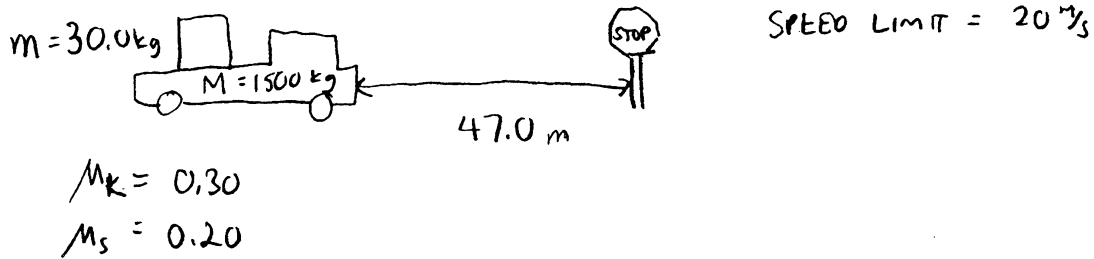
Question(s): What is the problem asking you to find?
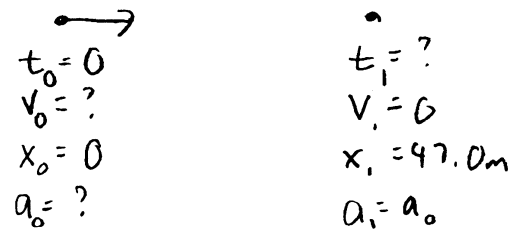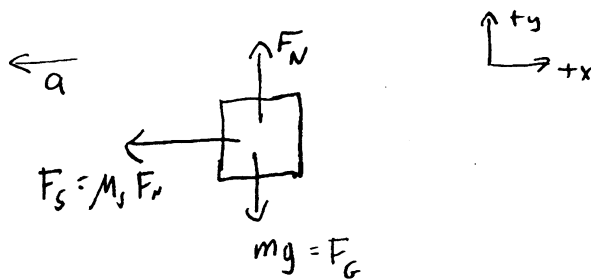
Was I speeding. what was my initial velocity?

Approach: Outline the approach you will use.

1) Use Newton's second law to find the minimum acceleration needed to cause the crate to slide

2) Use that minimum acceleration to determine possible initial speed using kinematic equations

3) Compare to speed limit

<u>DESCRIBE the PHYSICS:</u> Draw physics diagram(s) and define ALL quantities uniquely.

<u>Free body diagram for Crate</u>

$\overleftarrow{a}$

F_N

$F_s = \mu_s F_r$

$mg = F_G$

$+y$
$+x$

<u>Motion diagram for truck</u>

$t_0 = 0$
$V_0 = ?$
$X_0 = 0$
$a_0 = ?$

$t_1 = ?$
$V_1 = 0$
$x_1 = 47.0\,m$
$a_1 = a_0$

Which of your defined quantities is your Target variable(s)?

V_0

Write general forms of all equations you think you will use.

$$\sum \vec{F} = m\vec{a} \qquad V^2 = V_0^2 + 2a(x - x_0)$$

PLAN the SOLUTION
Construct Specific Equations (Same Number as Unknowns)
Put in actual numbers as little as possible and reasonable.

$$\cancel{V_1^2}^{=0} = V_0^2 + 2a(x_1 - \cancel{x_0})^{=0}$$

UNKNOWNS

(I) $\quad V_0^2 = -2ax_1$

a, V_0

To just get the crate moving, what is minimum acceleration?

$$\sum F_x = ma_x$$

(II) $\quad -F_s = -\mu_s F_N = ma$

F_N

$$\sum F_y = 0$$

(III) $\quad F_N - mg = 0$

3 eq. 3 unknowns

Plug (III) in (II)

$$-\mu_s \cancel{m}g = \cancel{m}a \implies a = -\mu_s g$$

Plug this in (I)

$$V_0^2 = -2(-\mu_s g)x_1$$

$$= 2\mu_s g x_1$$

Check Units:

$$V_0^2 = \left[\frac{m}{s^2}\right]m = \left(\frac{m}{s}\right)^2 \text{ ok}$$

EXECUTE the PLAN
Calculate Target Variable(s)

$$V_0 = \left\{2(.30)(9.8\ ^m/_{s^2})(47.0m)\right\}^{1/2}$$

$$= 17 \ ^m/_s$$

EVALUATE the ANSWER
Is Answer Properly Stated?

Yes, in $^m/_s$

Is Answer Unreasonable?

No, this is less than speed limit of $20\ ^m/_s$

Is Answer Complete? No,
Any velocity greater than $17\ ^m/_s$ would cause the crate to slide. So there is no proof I was speedi

(extra space if needed) I only have to pay to fix the glass.