Spring 2001 Physics 2048 Test 3 solutions

Problem 1. (Short Answer: 15 points)

a. 1

b. 3

c. 4*

d. 9

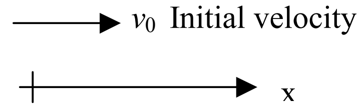
e. 8

f. 9

*remember that since KE = ½ mv^2, KE must be positive

Problem 2 (Estimation Problem: 15 points)

Use momentum-impulse theorem



$$\Delta\vec{p}_{car} = \vec{I}_{car}$$

$$\left|\vec{I}_{car}\right| = \left|\int_{t_1}^{t_2} \vec{F}_{car}^{\,net}\, dt\right| = \frac{1}{2} F_{\max}\,\Delta t$$

$$\Delta\vec{p} = m\vec{v}_f - m\vec{v}_0$$

$\Delta p_x = mv_{xf} - mv_{x0}$, note that the final velocity is in the opposite direction of the initial velocity

so $v_{xf} = -\alpha\, v_{x0}$, , where $\alpha = 90\%$

$$\Delta p_x = m\,(v_{xf} - v_{x0}) = m\,[(-\alpha\, v_{x0}) - v_{x0}] = -(1+\alpha) m v_{x0}$$

Taking the magnitude of Δp_x and setting it equal to the magnitude of the impulse

$$(1+\alpha) m v_{x0} = \frac{1}{2} F_{\max}\,\Delta t$$

$$F_{\max} = 2(1+\alpha)\, m v_{x0} / \Delta t$$

Given:

v_{x0} = 25 mi/hr * 0.62 km/hr * 1 hr/3600 sec * 1000 m/ km = 4.306 m/s

$\alpha = 0.90$

Estimate time interval and mass of the car

Reasonable estimates	500 kg < m < 3000 kg	for mass
	0.2 s < Δt < 1 s	for time interval

Let m = 1000 kg and Δt = 0.5 s

$F_{\max} = 2(1+\alpha)\, m v_{x0} / \Delta t$ = 2 (1 + 0.90) (1000 kg) (4.306 m/s) / (0.5 s) = 33,000 N = 33 kN

Given quantities are good to 2 significant digits

Problem 3 (Essay 10 points)
You may use diagrams and equations but no calculations in your response for this problem.

Student Response 1:

When the brakes of a car lock up, then the car slides. When the car is sliding, then kinetic friction is involved. When the wheels are turning, then static friction is involved. In the case of rubber on wet concrete, the coefficient of kinetic friction (sliding) is less than that of static friction (rolling). And when trying to stop it is best to have the most friction possible for faster deceleration. Therefore, it would be best to have static friction in this case (in the rain) *which means the wheels need to be turning. Anti-lock brakes keep the wheels turning which means there is more friction between the tires and the road.*

This is good essay that hits most of the key points. The only points that are missed are that the friction force governs the braking of the car (bring the car to a stop) and why you want maximum deceleration in the rain. The following response addresses these points.

Student Response 2

Static friction is larger than kinetic friction. When stopping, if the wheels lock up kinetic friction is used to slow the car down. However, since static friction is larger, what anti-lock brakes do pump the breaks so that the tires do not experience kinetic friction but static, which in turn slows the car faster and in a shorter distance. Since the coefficient of static and kinetic friction drop dramatically on a wet road, anti-lock brakes are particularly safer.

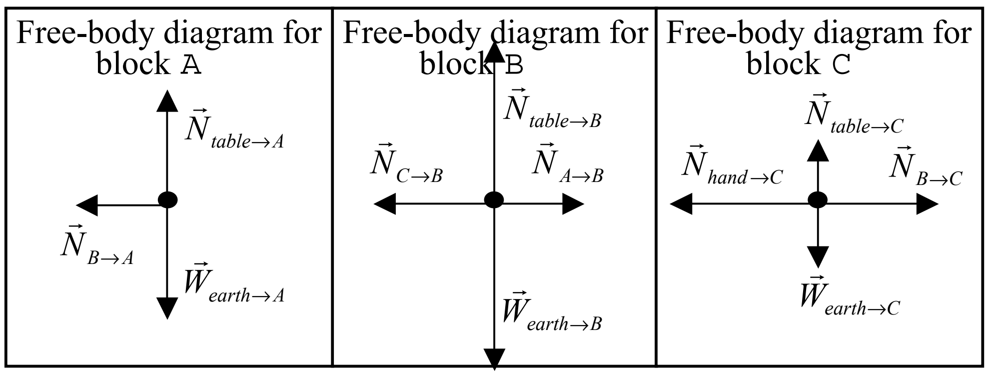
The small friction force due to skidding in the rain also reduces your control over the car, so the anti-lock brakes reduce your stopping distance and help you maintain control of your car in the rain.

Key points:

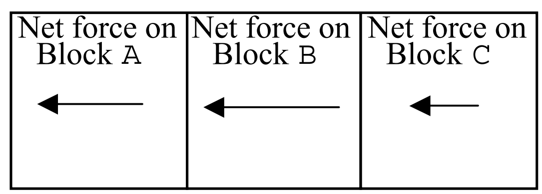
- When the wheels are locked and skidding, braking is by kinetic friction
- When the wheels are rotating, braking is by static friction
- The coefficient of static friction is greater than that of kinetic friction
- The larger the coefficient of friction, the greater the frictional force from breaking. A larger frictional force means the car stops in less time and less distance.
- Both coefficients of friction for rubber and concrete are reduced when it is raining and the car is wet. This means that in the rain, the driving will be more slippery and it will take longer to stop.
- Since driving in the rain is more slippery, you would like the largest frictional force possible to minimize your breaking distance and maximize your ability to keep the car under control.
- Anti-lock brakes prevent the wheels from locking up and skidding so that the braking force is from static friction instead of kinetic friction.

Problem 4 (15 points)

A. [6 pts] Draw separate free-body diagrams for each of the three blocks. Label your forces to make clear (1) the object on which the force acts, (2) the object exerting the force, and (3) the type of force (normal, frictional, gravitational, etc.)



B. [4pts] In the spaces at right, draw a vector that represents the *net force* on each block. Make sure your vectors are drawn with correct relative magnitudes. Explain how you knew to draw the net force vectors as you did.



Each block is accelerating to the left at the same rate so by Newton's 2nd law, the net force for each block is inversely proportional to the mass so that the ratio of F^{net}/m is constant for each block.

C. [5 pts] Suppose the mass of block B were doubled (the other blocks are left unchanged) and the hand pushes with the ***same force*** as in part A.

i. Has the *magnitude* of the acceleration of block A *increased, decreased,* or *remained the same?* Explain.

Decreased, the three blocks accelerate as one system and since $\vec{a} = \frac{\vec{F}^{net}}{m}$*, if you increase the mass of the system and keep the net force on the system the same (i.e. the force of the hand), the acceleration of the system of three blocks must decrease*

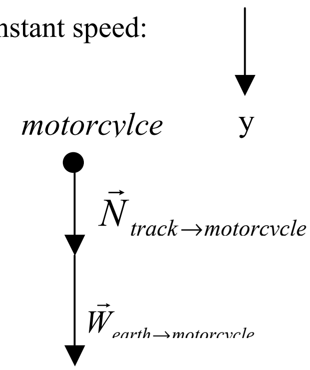
ii. Has the *magnitude* of the net force on block A *increased, decreased,* or *remained the same?* Explain.

Decreased, if the acceleration of block A decreases and the mass of A doesn't change, then the net force needed to cause that acceleration is less.

Problem 5 (20 points)

Part A

Looking at the forces acting on the motorcycle moving through a circular loop at constant speed:



Circular motion at constant speed => $|\vec{F}^{net}| = \frac{mv^2}{R}$ everywhere on the loop.

At the top of the loop, $\vec{F}^{net} = \vec{N}_{tract \to motorcycly} + \vec{W}_{earth \to motorcycle}$, $\sum F_y^{net} = N + mg$

Note that both forces point downward.

$\frac{mv^2}{R} = N + mg$, Since m, R, and g are constant, v will be a minimum when $N = 0$.

$$v = \sqrt{Rg} = \sqrt{(5.0m)(9.8m/s^2} = 7.0m/s * \frac{3600s}{h} * \frac{1km}{1000m} = 25km/h$$

Note the bigger the radius R is, the higher the minimum speed v needed to go through the loop

Part B

Only gravity acts on the motorcycle + rider when they are in the air

$a_y = -9.8\ m/s^2$ and $a_x = 0\ m/s^2$, since a = constant => use kinematics equations

$\Delta x = v_{0x}\,\Delta t$, $\Delta y = v_{0y}\,\Delta t - 1/2\, g\, \Delta t^2$

If we knew Δt, we could find Δx for the jump => let $\Delta y = 0$

$0 = v_{0y}\,\Delta t - 1/2\, g\, \Delta t^2$, $\Delta t = 0$ or $v_{0y} - 1/2\, g\, \Delta t = 0$

Since $\Delta t = 0$ is the start of the jump, $\Delta t = 2v_{0y}/g = 2\, v_0 \sin\theta / g$ is the time it take the motorcycle to make the jump.

$\Delta x = v_{0x}\,\Delta t = (v_0 \cos\theta)(2\, v_0 \sin\theta /g) = v_0^2 \sin 2\theta / g)$

$= (50\ km/h \times 1000m/km \times 1\ h / 3600\ s)^2 \sin(2*30°) / 9.8\ m/s^2 = 17\ m$

The landing should be placed 17 m to the right of the jump ramp