AP/Honors Quiz 6 (Solutions)

Full Name, Period, AP/Honors: Instructor-All

1 Sometimes it is the concept that is hard

1. (3 pt, **All**) *An object is placed on a ramp on the surface of a planet at an angle θ from the horizontal. The object begins to accelerate at 12 $\frac{\text{m}}{\text{s}^2}$ down the plane. Which of the following is definitely true?*

   [A.] The planet is not Earth

   B. There is no friction

   C. The angle of the ramp is at least 45°

   D. None of the above

   A ramp produces and acceleration of $g \sin \theta$, so no ramp can ever create an acceleration of larger than g. On Earth $g = 10\ \frac{\text{m}}{\text{s}^2}$.

2. (4 pt, **AP**) *Two people with different masses (a child and an adult) push each other on a surface with very low (but non-zero) friction coefficient μ_k which is located on Earth. Who stops first?*

   A. The child

   [B.] The adult

   C. They stop at the same time

   D. Both move with constant velocity

   Clever intuition: We know that on a surface with friction, all objects will get the same acceleration from friction independent of mass. Since the adult is move massive, the adult gets a smaller initial velocity, so with the same acceleration it will take less time to stop the adult.

   Awful math solution: Let the child's mass be M_c and the adults mass be M_a. Let the adults acceleration during the push be a_a and the child's acceleration during the push be a_c. Then

   $$M_a a_a = M_c a_c$$

   so that

   $$a_a = \frac{M_c}{M_a} a_a$$

   .

   Since the collision time is the same for both

   $$v_a = \frac{M_c}{M_a} v_c$$

   Now we find the acceleration as a result of the friction force

   $$F_f = M g \mu_k$$

   By Newton's second law $F_f = Ma$ so that $M g \mu_k = Ma$ or

   $$a = g \mu_k$$

   for both the child and the adult.

Then the velocity equation for the child is $0 = v_c - at_c$ which simplifies to

$$v_c = at_c$$

and for the adult is $0 = \frac{M_c}{M_a} v_c - at_a$ which simplifies to

$$\frac{M_c}{M_a} v_c = at_a$$

dividing the equations gives

$$\frac{t_c}{t_a} = \frac{M_a}{M_c}$$

Which is greater than one, so the adult stops first.

3. (**All**) You and a friend return to NoFrictionLand™, where there is no friction.

   (a) *(4 pt, **Honors**) You and your friend are at rest. You throw a ball to your friend, after your friend has caught the ball, what happens to his velocity? There is no air resistance.*

   [A.] Your friend moves with constant velocity.
   B. Your friend moves with constant acceleration.
   C. Your friend initially moves, but eventually comes to a stop.
   D. Your friend remains stationary.

   Newton's first law says no accelerations may exist without forces.

   (b) (3 pt, **All**) *Someone allows air into the room and turns on a giant fan. Your initial velocity is* $0 \frac{\text{m}}{\text{s}}$. *The fan creates a constant wind of* $5 \ \frac{\text{m}}{\text{s}} \hat{\text{x}}$, *what is your terminal velocity?*

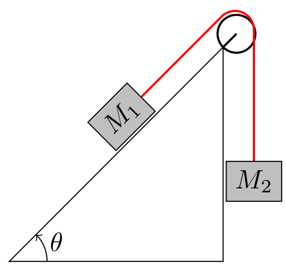
   A. $0 \ \frac{\text{m}}{\text{s}}$
   B. $\frac{5}{2} \ \frac{\text{m}}{\text{s}} \hat{\text{x}}$
   [C.] $5 \ \frac{\text{m}}{\text{s}} \hat{\text{x}}$
   D. There is no terminal velocity.

   Your terminal velocity is when the net force is 0. In the case of the wind there will be a net force that decreases asymptotically to 0 as your velocity gets closer to the wind's velocity.

4. (0 pt, **All**) *Write your name, period, and AP status on the top of the paper. Then write a treatise on what it means to do physics.*

2 Other times it is the math

1. You attach two masses together with a string and place one on a plane inclined with an angle θ as shown. There is no friction.



(a) (3 pt, **All**) *The system is placed on earth and the masses do not move. Find the angle θ in terms of M_1, M_2 and g.*

We need the forces pulling on each side of the rope to balance. Mathematically

$$M_1 g \sin\theta = M_2 g$$

or

$$M_1 \sin\theta = M_2$$

Solving for θ

$$\boxed{\theta = \arcsin\left(\frac{M_2}{M_1}\right)}$$

(b) (3 pt, **All**) *The setup is still on earth as in part a, and everything is identical except that another M_2 is added directly below the original M_2. Find the acceleration of the system.*

If you haven't learned the lesson to slow down and think, learn it now.

We had force balance before. This means that with the new M_2 added, the net force is just $F_{net} = M_2 g$. Since the total mass is $M_1 + 2M_2$ we can write out the acceleration

$$\boxed{a = \frac{M_2 g}{M_1 + 2M_2}}$$

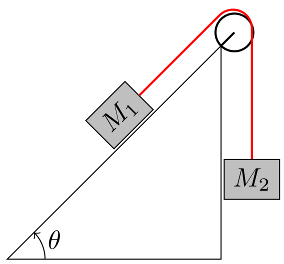
in the direction of M_2.

(c) (3 pt **Honors**) *The system is exactly as it was in part a. Find the tension in the string.*

There is no acceleration. This means that M_2 is in force balance, so the tension must be

$$\boxed{T = M_2 g}$$

I am reproducing the diagram here so you can look at it while thinking about this part.



(d) (3 pt, **AP**) *The system is exactly as it was in part a, except that the whole thing is removed from Earth and placed in an elevator accelerating to the right with $\vec{a} = a_x\hat{\text{x}}$. There is no gravity. Find the acceleration of M_2 as seen from the elevator.*

And now it gets fun. Putting it in the elevator actually makes the problem **easier**. We use the equivalence principle to note that the system behaves exactly the same as it would if there was gravity pointing in the $-\hat{\text{x}}$ direction so we can literally just tilt the paper 90° counterclockwise (so that $-\hat{\text{x}}$ becomes down) to see what would happen.

We see that M_1 will not stay on the plane, instead it will have an effective gravity of $M_1 a_x$. There is no net external force on M_2, so the net force on the whole system is $M_1 g$. Since the mass of the system is $M_1 + M_2$, the acceleration of M_2 is

$$\boxed{\vec{a} = \frac{M_1 a_x}{M_1 + M_2}\hat{\text{z}}}$$