AP Physics KEY
Tipper #3 - Unit 2 - Dynamics

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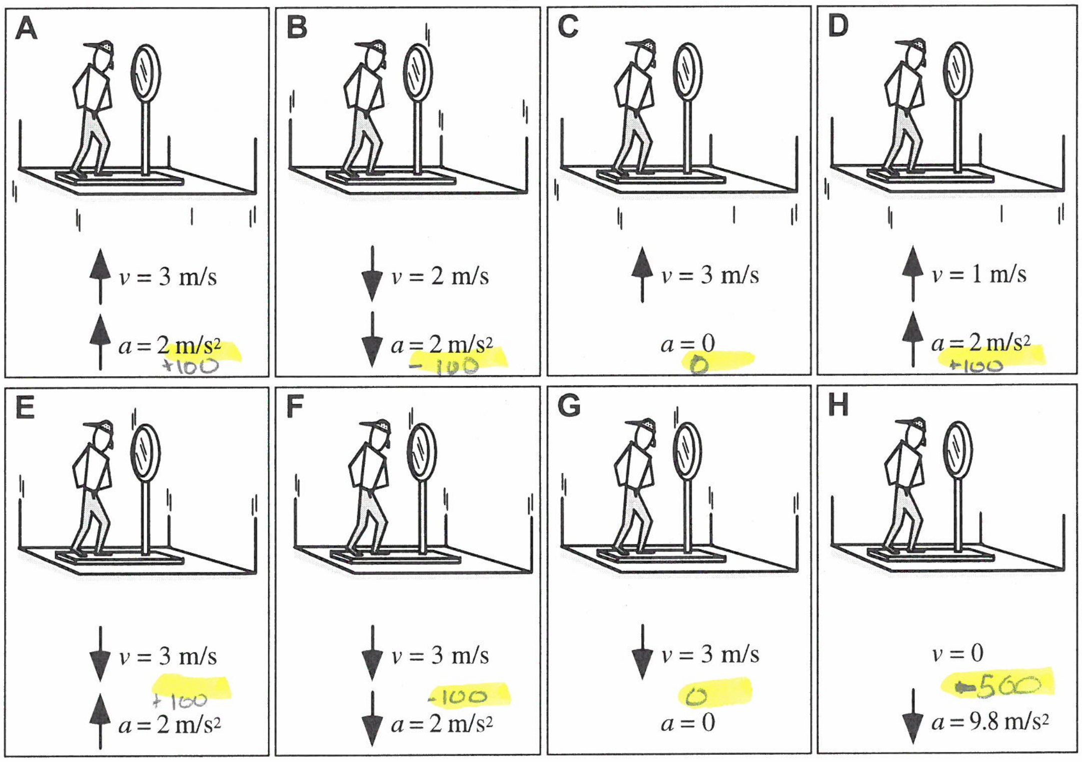
#1

B3-QRT63: Person in an Elevator—Scale Reading

A person who weighs 500 N is standing on a scale in an elevator. The elevator is identical in all cases. The velocity and acceleration of the elevators at the instant shown are given.



FBD
F_N
$F_W = 500N$
$F_N - F_W = ma$
$F_N = ma + F_W$

$F_W = mg$
$500 = m(10)$
$m = 50$

F_N = Scale!

Velocity ≠ not in Eqn

(a) List the cases where the scale reading is *greater than* 500 N. _____

Explain your reasoning.

Answer: A, D, and E.
The reading on the scale will be larger than the person's weight (500 N) when he/she is being accelerated upward by the scale. When that occurs the scale has to both balance the weight of the person and provide the force to accelerate the person upward.

(b) List the cases where the scale reading is *less than* 500 N. _____

Explain your reasoning.

Answer: B, F and H.
Here the reading is less than the person's weight because the scale doesn't have to balance the whole weight of the person.

(c) List the cases when the scale reading is *equal to* the scale reading of 500 N. _____

Explain your reasoning.

Answer: C and G.
Since there is no acceleration the net force has to be zero, so the scale has to balance the weight of the person.

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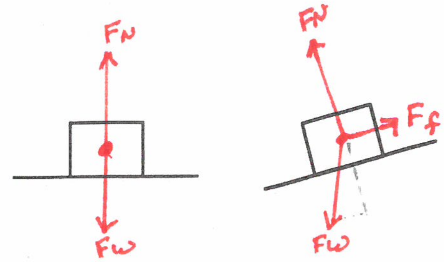


#2 **B3-WWT66: Two Blocks at Rest—Normal Force**

The two blocks are identical and both are at rest. A student comparing the normal force exerted on the block by the surface in the two cases states:

"Since both blocks are identical, I think the normal forces are the same because in each case the normal force will be equal to the weight."

What, if anything, is wrong with this contention? If something is wrong, identify it and explain how to correct it. If this contention is correct, explain why.

Answer: The student's contention is wrong.
The net force is equal to zero in both cases since the block is not accelerating. In the case on the left, the normal force and the weight point in opposite directions and have the same magnitude. In the case on the right, the normal force points perpendicular to the surface up and to the left and the weight points straight down. There is also a friction force pointing up and to the right, parallel to the surface. These three forces must add to zero. As can be seen in the vector sum diagram, the weight vector in this case is the hypotenuse of a right triangle, and is longer than the vector representing the normal force, which is one of the sides of this triangle.

Block 1

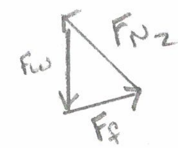
$\Sigma F_y = F_N - F_w = ma$ At Rest

$F_{N_1} = F_w$

Block 2

$\Sigma F_y = F_{N_2} - F_w \cos\theta = ma$ 0

$F_{N_2} = F_w \cos\theta$

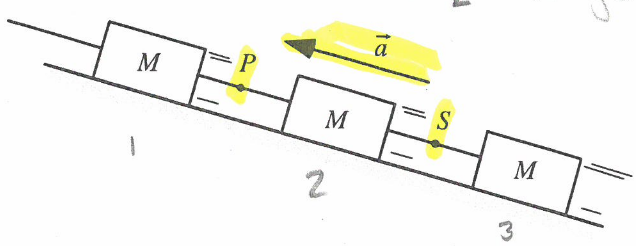


F_{N_2} is Longer than F_1

#3 **B3-WWT80: Blocks on a Smooth Incline—Tension**

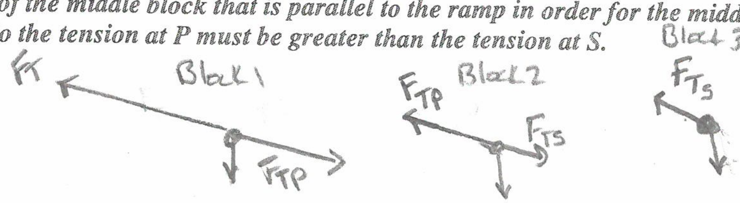
Three identical blocks are tied together with ropes and pulled up a smooth (frictionless) incline. The blocks accelerate up the incline. A student who is asked to compare the tension in the rope at point *P* to the tension at point *S* states:

"Each rope is pulling one block. All three blocks are accelerating at the same rate and they are identical. I think the tensions at points P and S will be the same."



What, if anything, is wrong with this contention? If something is wrong, identify it and explain how to correct it. If this contention is correct, explain why.

Answer: The student's contention is incorrect.
From a free-body diagram of the lower block, the tension at point S must be larger than the component of the weight of that block that is parallel to the ramp in order for the lower block to accelerate up the ramp. From a free-body diagram of the middle block, the tension at point P must be larger than the tension at point S plus the component of the weight of the middle block that is parallel to the ramp in order for the middle block to accelerate up the ramp. So the tension at P must be greater than the tension at S.



weight keeps Increasing

∴ Tension ↑

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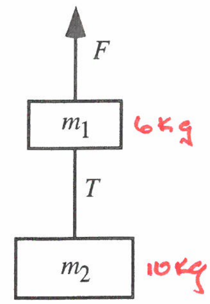
#4 **B3-SCT79: TWO CONNECTED OBJECTS ACCELERATING DOWNWARD—TENSION**

↓a=3 m/s²

Two objects with masses of $m_1 = 6$ kg and $m_2 = 10$ kg are connected by a massless string. They are pulled upward by an applied force F. Since this force is smaller than the total weight of the objects, there is a constant downward acceleration of 3 m/s^2. The tension in the string connecting the objects is T. Four students discuss this tension:



Anh: "The tension in the string is the net force on the lower object. Using Newton's Second law, we get $F_{net} = ma = 30$ N for the tension, since the lower object has a mass of 10 kg and it is accelerating at 3 m/s^2."

Brandon: "The tension in the string is more than the net force of 30 N since the lower object has a weight of about 100 N. The tension should be 130 N since the 30 N, the net force, is added to 100 N, the weight."

Cathy: "The tension in the string is upward and should be less than the weight since the system is accelerating downward. It should be 70 N by applying Newton's Second law and taking into account the directions of the forces."

Deshi: "We cannot answer it until we know which direction the system is moving. Is it moving upward or downward? Won't that make a big difference on the tension?"

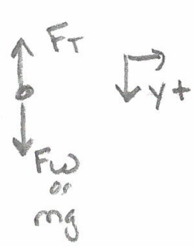
With which, if any, of these students do agree?

Anh _____ Brandon _____ Cathy _____ Deshi _____ None of them _____

Explain your reasoning.

Answer: Cathy is correct.
From a free-body diagram for the lower mass, and choosing up as the positive direction, we can apply Newton's 2nd Law to the lower mass. The tension T minus the weight of the lower mass equals the mass m_2 times its acceleration. F_{net} *(on* m_2*)* $= m_2a = (10\text{kg})(-3\ \text{m/s}^2) = -30$ *N. So* $T - m_2g = T - (10\text{kg})(10\text{m/s}^2)$ *or* $+98\ \text{N} - 30\ \text{N} = T = 70\text{N}.$

M2



$\Sigma F_y = -F_T + F_W = ma$

$-F_T = ma - F_W$ (mg)

$F_T = mg - ma$

$= (10\text{ kg})(9.8\text{ m/s}^2) - (10\text{ kg})(3\text{ m/s}^2)$

$F_T = 68$, sig figs

$F_T = 70\text{ N}$

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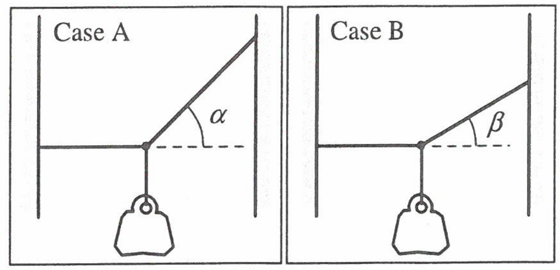
#5

B3-SCT78: Hanging Mass—Tension in Three Strings

A hanging mass is suspended midway between two walls. The string attached to the left wall is horizontal while the string attached to the right wall makes an angle with the horizontal as shown. This angle (α) in Case A is larger than the angle (β) in Case B. Four students make the following claims about the tensions in the strings:



$\alpha > \beta$

Abbie: "I think the tensions in any string in Case A is going to be the same as the equivalent string in Case B. The weight is the same, and the weight is still going to be divided up among the three ropes."

Bobby: "I think the tensions in the horizontal and vertical strings are the same, because they are exactly the same in both cases. But in Case B the diagonal rope is shorter, so the tension is more concentrated there." Length doesn't matter

Che: "The diagonal string (NO) still has to hold the weight up by itself, because the horizontal string can't lift anything. So the diagonal string still has the same tension. But in Case B it's pulling harder against the horizontal string because of the angle, so the tension in the horizontal string has to go up."

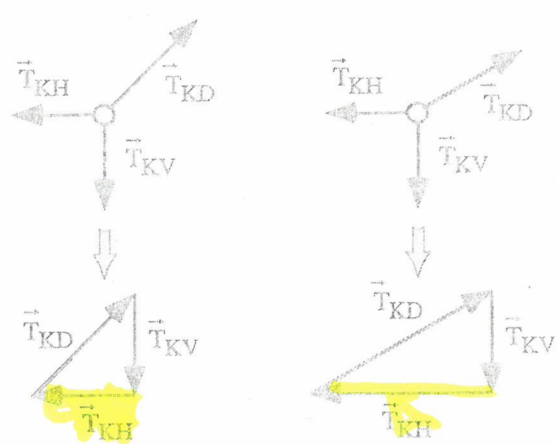
Damian: "But the diagonal string is fighting harder against the weight in Case A—it is pointing more nearly opposite the weight. So it has to have a greater tension in Case A. And since the tension in the diagonal string is greater, and the tension in the vertical string is the same, the tension in the horizontal string must be less in Case A. The tensions still have to balance out so that they are the same in both cases."

With which, if any, of these students do you agree?

Abbie _____ Bobby _____ Che _____ *Damian* _____ None of them_____

Explain your reasoning.

Answer: None of these responses is correct.
The weight is the same for both cases, and because the weight is at rest we can conclude from a free-body diagram of the weight that the tension in the vertical string must be the same in both cases. But since the knot connecting the strings is at rest in both cases vector sum of forces acting on the knot is zero in both cases. Comparing vector sums, (with subscripts K, H, V, and D for knot, horizonal, vertical, and diagonal) we can see that the horizontal tension must be greater in case B. The tension in the diagonal string will also be larger in case B.



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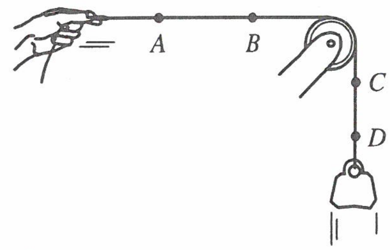
#6

B3-RT75: Moving String Passing over a Pulley—Tension at Points

A student pulls on a massless string that passes over a frictionless pulley and is attached to a suspended mass. He is pulling the string horizontally so that, at the instant shown, the mass is moving upward at a constant speed.



↑ V = Constant ∴ a = 0

Rank the tension at the labeled points.

1 Greatest	2	3	4 Least	OR	All the same	All zero	Cannot determine

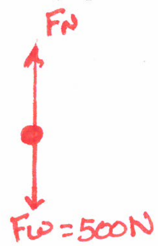
Explain your reasoning.

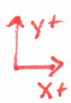
Answer: All the same.
In the approximation that the string is massless, any small section of the string must have no net force acting on it (since it is not accelerating). So the tension on one end of that small section must have the same magnitude as the tension on the other end. By extension, the tension must be the same everywhere along the horizontal section of string and everywhere along the vertical section of string. The tension in the horizontal section of string exerts a counterclockwise torque on the pulley, and the tension in the vertical section of string exerts a clockwise torque on the pulley. Since the pulley has no angular acceleration, the net torque on it is zero. The tension in the horizontal portion of the string between the pulley and the hand must be equal to the tension in orce and the pulley pivot is the radius of the pulley, and is the same for both sections of string.)

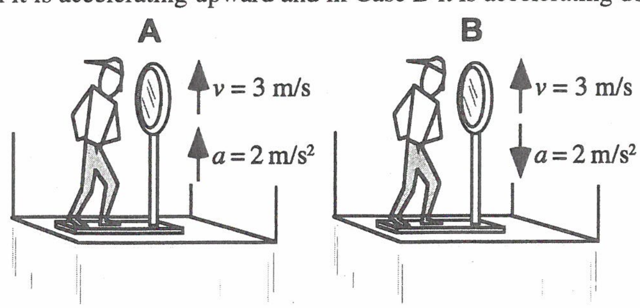
#7

B3-CT59: Person in an Elevator Moving Upward—Scale Reading

A person who weighs 500 N is standing on a scale in an elevator. In both cases the elevator is identical and is moving upward, but in Case A it is accelerating upward and in Case B it is accelerating downward.







velocity doesn't matter

Will the scale reading be (i) *greater* in Case A, (ii) *greater* in case B, or (iii) *the same* in both cases? _____

Explain your reasoning.

Answer: The scale reading will be greater in Case A.
By Newton's Second Law the net force on the person must point upward in Case A since the acceleration is upward and the net force will point downward in Case B since the acceleration is downward. So the normal force on the person by the scale (which is the reading on the scale) must be larger than the weight of the person in Case A, and smaller than the weight of the person in Case B. The direction of the velocity of the elevator is not relevant to the scale reading.

CASE A

$\Sigma F_y = F_N - F_W = ma$

$F_N = ma + F_W$

$a = 2\ m/s^2$

$= (50\ kg)(2\ m/s^2) + 500$

$F_N = 600\ N$

CASE B

$F_N = ma + F_W$

$a = -2\ m/s^2$

$= (50\ kg)(-2\ m/s^2) + 500\ N$

$F_N = 400\ N$

$F_W = mg$

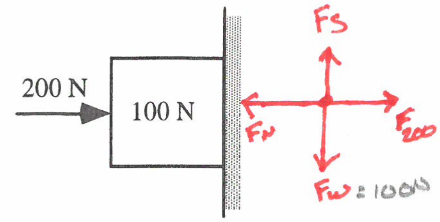
$500 = m(10)$

$m = 50\ kg$

$u_k = 0.4$
$u_s = 0.6$

#8 B3-SCT88: Box Held Against Vertical Surface—Frictional Force on Box

A constant horizontal force on a 200 N is applied to a box in contact with a vertical surface. The coefficient of static friction between the box and the surface is 0.6, and the coefficient of kinetic friction is 0.4. Several students are discussing the frictional force on the box 1 second after the force is first applied:



Art: "The frictional force is 60 N since the box will not be moving and the coefficient of static friction is 0.6."

Bratislav: "The frictional force is 100 N upward since the box has a weight of 100 N downward."

Celeste: "The frictional force will be 120 N since the box will not be moving and the normal force will be 200 N."

Dorothy: "The frictional force will be 40 N for the kinetic frictional force and 60 N for the static frictional force. The weight is 100 N and the coefficient of kinetic friction is 0.4, giving 40 N for the kinetic friction. Likewise, for the static frictional force it has a coefficient of static friction of 0.6, giving a static frictional force of 60 N."

With which, if any, of these students do you agree?

Art _____ Bratislav _____ *Celeste* _____ *Dorothy* _____ None of them _____

Explain your reasoning.

Answr: Bratislav is correct.

The coefficient of static friction is 0.6, so the maximum static frictional force is 0.6 times the normal force acting to the left on the box by the vertical surface. Since the box is not moving horizontally, this normal force must have the same magnitude as the horizontal applied force, 200 Newtons. The maximum frictional force will then be 120 Newtons. This is greater than the weight of the box, so the box will not slip downward. The static frictional force will be less than its maximum possible value, and will equal 100 Newtons, keeping the box at rest.

static

$\Sigma F_x = F_A - F_N = ma^0$ $\Sigma F_y = F_S - F_W = ma^0$

$F_N = F_A$ $F_S = F_W$

$F_A = 200N$ $F_W = 100N$

$F_S = 100N$

$\therefore F_N = 200N$

$F_{S_{MAX}} = U_s F_N$

$F_{S_{max}} = 0.60(200)$

$F_{S_{max}} = 120N >$ 100N of Box weight $\therefore$ Box will Not Slide down

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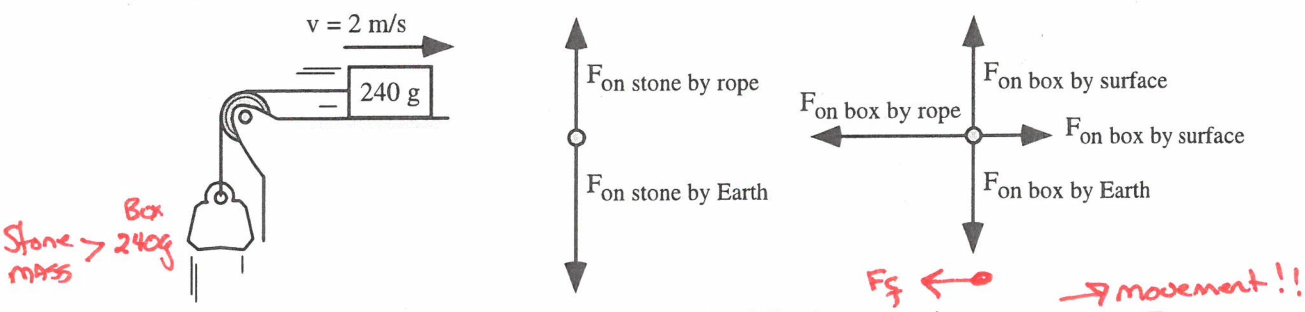
#9

B3-SCT70: Hanging Stone Connected to Box—Free-Body Diagrams

A massless rope connects a box on a horizontal surface and a hanging stone as shown below. The rope passes over a massless, frictionless pulley. The box is given a quick tap so that it slides to the right along the horizontal surface. The figure below shows the block after it has been pushed while it is still moving to the right. The mass of the hanging stone is larger than the mass of the box. There is friction between the box and the horizontal surface. Free-body diagrams that a student has drawn to scale for the box and for the hanging stone are shown.



Four students discussing these free-body diagrams make the following contentions:

Ali: "There is a problem with the free-body diagram for the hanging stone. The two forces should have the same magnitude."

Brianna: "But the stone is moving upward—there should be a larger force in that direction."

Carlos: "No, the diagram for the hanging stone is okay, but there is a problem with the diagram for the box. The frictional force is in the wrong direction."

Dante: "Both free-body diagrams are correct because they show the way the objects would be accelerating."

With which, if any, of these students do you agree?

Ali _____ Brianna _____ Carlos _____ Dante _____ None of them _____

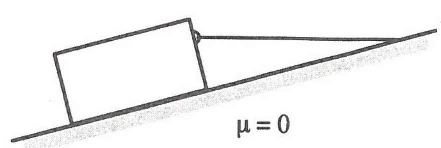
Explain your reasoning.

Answer: For the instant shown, Carlos is correct.
Since the box is sliding to the right, the friction on the box by the surface will be to the left. So all horizontal forces on the box would be to the left and the block would slow down (as we expect). If, as Ali claimed, the forces on the stone had the same magnitude, the stone would have no net force and would not accelerate, and if (as Brianna claimed) the force on the stone by the rope was greater then the stone would speed up.

#10

B3-CT65: Block Held on Smooth Ramp—Weight and Normal Force

A block is tethered to a frictionless ramp by a horizontal string as shown. The block is at rest.



Is the normal force exerted on the block by the ramp (i) *greater than*, (ii) *less than*, or (iii) *equal to* the weight of the block? _____

Explain your reasoning.

Answr: The normal force is greater than the weight.
Since the block is at rest, the net force on the block is zero. There are three forces acting on the block, as shown in the free-body diagram, and they must add to zero as shown in the vector sum diagram. The normal force is the hypotenuse of the resulting right triangle, and must therefore be the largest force.