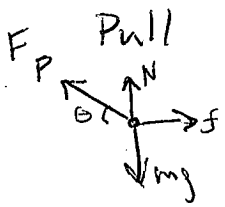
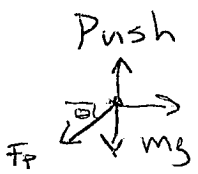
AP Physics 1: Friction and forces review

Friction

1. Compare the ease of pulling a lawn mower and pushing it. In particular, in which case is the friction force that the grass exerts on the mower greater and why?



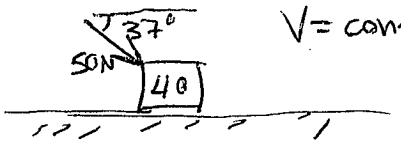
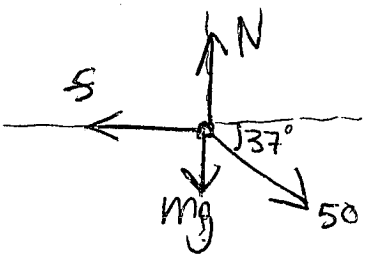
$N = -F_P \sin\theta + mg$



$N = F\sin\theta + mg$

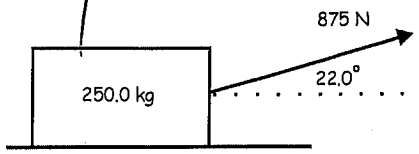
Greater N means more f. When you push you increase the normal force. Pulling decreases N.

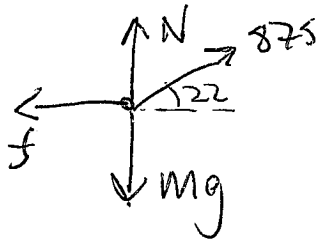
2. Two of your neighbor's children (40 kg together) sit on a sled. You push on the back child, exerting a 50 N force on him directed 37° below the horizontal. The sled slides forward with a constant velocity. Complete the table below to answer the question: What is the coefficient of kinetic friction between the snow and the sled?

Sketch the situation described in the problem; provide all known information.	
Draw a force diagram for the system object. Label the forces. Make sure the diagram is consistent with the motion of the system object. Include perpendicular *x* and *y* axes.	
Apply Newton's Second Law in component form (*x* and *y* axes) to the situation shown in the force diagram you drew.	X| $50\cos37 - f = 0$ $50\cos37 - \mu N = 0$ Y| $-50\sin37 - mg + N = 0$ $N = mg + 50\sin37$ $= 40(10) + 50\sin37$ $= 430\,N$
Solve the equations for the unknown quantities. Evaluate the results to see if they are reasonable (units, magnitudes, and values for limiting situations).	$50\cos37 - \mu(430) = 0$ $39.9 = \mu(430)$ $\boxed{\mu = 0.092}$

No accel in X or Y

3. A 250.0 kg crate is being pulled across the floor with a rope that makes an angle of 22.0° to the horizontal. If the force applied is equal to 875 N and the block is moving at a constant velocity, what is the coefficient of kinetic friction?





X) $875\cos 22 - f = 0$

$875\cos 22 - \mu N = 0$

Y) $N + 875\sin 22 - mg = 0$

$N = mg - 875\sin 22$

$N = 250(10) - 875\sin 22$

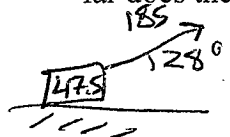
$= 2172\,N$

$875\cos 22 - \mu(2172) = 0$

$\frac{811.3}{2172} = \mu$

$\mu = 0.37$

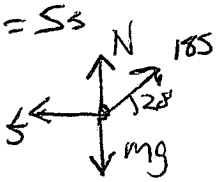
4. A boy pulls a 47.5 kg crate with a rope. The rope makes an angle of 28.0° to the horizontal. The coefficient of kinetic friction for the crate and the deck is 0.300. The boy exerts a force of 185 N. How far does the crate travel in 5 seconds?



$\mu = .3$

$t = 5s$

Find a 1st



X) $185\cos 28 - f = ma$

$185\cos 28 - \mu N = ma$

$185\cos 28 - (.3)(388) = (47.5)a$

$46.9 = (47.5)a$

$a = 0.99\ m/s^2$

Y) $185\sin 28 + N - mg = 0$

$N = mg - 185\sin 28 = 475 - 86.9 = 388$

Distance

$x = \frac{1}{2}at^2$

$x = \frac{1}{2}(.99)(5)^2$

$= 12.4\,m$

5. A 91kg refrigerator sits on the floor. The coefficient of static friction between the fridge and the floor is 0.60. What is the minimum force that one needs to exert on the fridge to make it slide?

$f = \mu N$

$f = \mu mg$

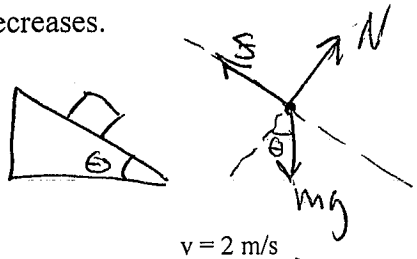
$f = 0.6(91)(10)$

$= 546\,N$

$N = mg$

$f = F$

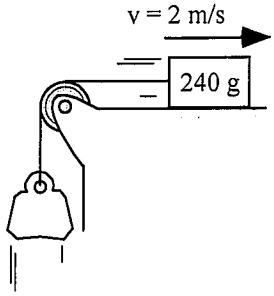
6. Explain and show with equations why as the angle of incline is increased, the maximum friction force decreases.

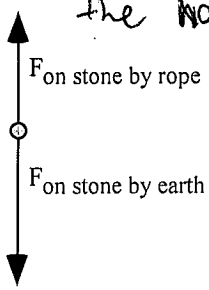


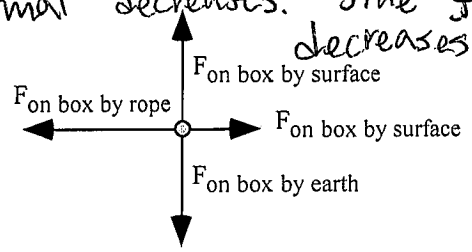
$f = \mu N$ $\sum N - mg\cos\theta = 0$

$N = mg\cos\theta$

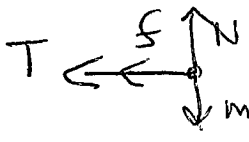
As the angle increases in the equation $N = mg\cos\theta$ from 0° to 90° the value of the normal decreases. Since $f = \mu N$ & N decreases so does f.





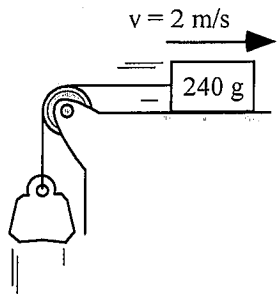


7. What, if anything, is wrong with these free-body diagrams above? If something is wrong, identify it and explain how to correct it. If nothing is wrong, explain why the diagrams are appropriate.



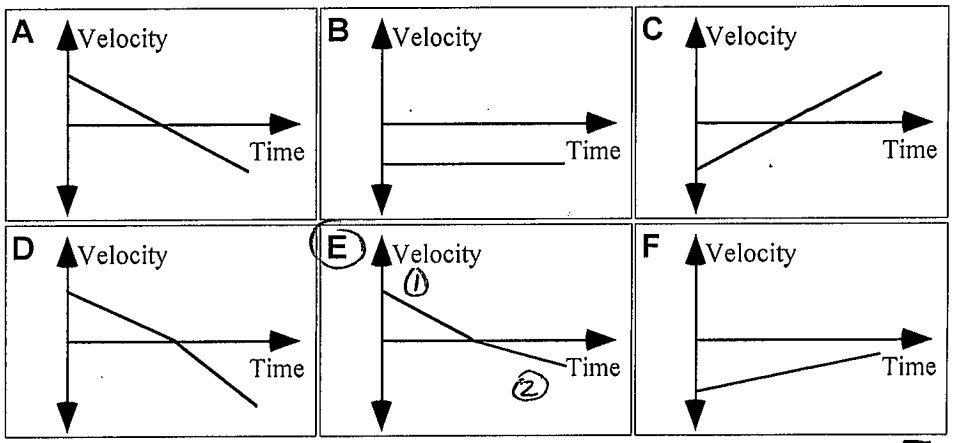
The force on the box by friction should switch. Friction opposes the motion.

8. A box is sliding to the right along a horizontal surface with a velocity of 2 m/s. There is friction between the box and the horizontal surface. The box is tied to a hanging stone by a massless rope running over a massless, frictionless pulley. The mass of the stone is larger than the mass of the box. The box will slow down, come to rest at an instant, and then move to the left with increasing speed. Assume that a positive velocity represents motion to the right.



Which, if any, of the velocity versus time graphs below represent the movement of the sliding box?

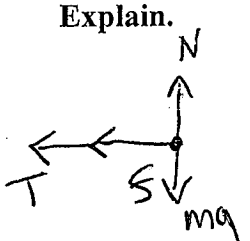
Not A because there is friction



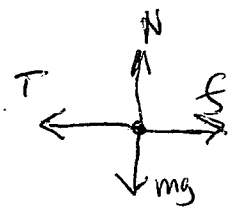
① Start T+f cause F which makes a high acceleration (high slope)

② T-f cause lower accel (low slope)

Explain.

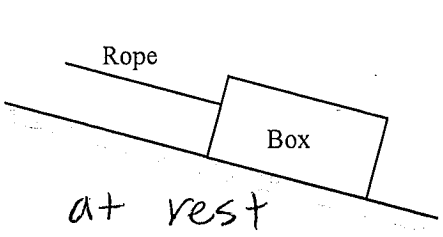


Start (away)

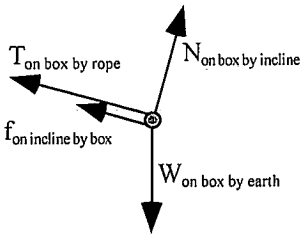


End (toward pulley)

9. A heavy box is sitting at rest on an incline. There is friction between the box and the incline and a rope is pulling on the box in a direction up and to the left, parallel to the incline. A physics student draws a free-body diagram below for the box.



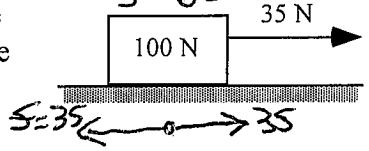
at rest



What, if anything, is wrong with this student's free-body diagram? If something is wrong, explain the error and how to correct it. If this free-body diagram is correct, explain why.

Correct The block is at rest. Both tension and friction act to keep the block up the ramp

10. A 100 N box is initially at rest on a rough horizontal surface. The coefficient of static friction between the box and the surface is 0.6 and the coefficient of kinetic friction is 0.4. A constant 35 N force is applied to the box horizontally as shown.



$f = 0.6(100)$
$f = 60$ max static

$f = 35$ ← → 35

$\mu_s = 0.6$
$\mu_k = 0.4$

Identify from choices (1)-(5) how each change described below will affect the frictional force on the box by the surface *1 second after the horizontal force is first applied.*

Compared to the case above, this change will:

(1) *increase* the frictional force exerted on the box by the surface.
(2) *decrease* the frictional force exerted on the box by the surface but not to zero.
(3) *decrease* the frictional force exerted on the box by the surface to zero.
(4) *have no effect* on the frictional force exerted on the box by the surface.
(5) *have an indeterminate* effect on the frictional force exerted on the box by the surface.

All of these modifications are changes to the initial situation shown in the diagram.

a) The weight of the box is changed to 50 N. 2

$f_s = 0.6(50)$

max static = 30 $F_p = 35N$ so the object is in motion (greater than max static) since it is moving the kinetic friction will take over $.4(50) = 20N$

b) The weight of the box is changed to 200 N. 4

Increasing weight increases max static friction since the horizontal force is already being opposed there is no change

c) The applied force is increased to 50 N. 1

Static friction increases to oppose the push

d) The applied force is increased to 80 N. 1

80N breaks the static friction causing kinetic friction which is a force of 40N (.4)100 so f increases

e) The coefficient of static friction is increased to 0.7. 4

No change. Max static changes but not the friction present.

f) The coefficient of kinetic friction is increased to 0.5. 4

Same as above

g) The coefficient of kinetic friction is increased to 0.5 and the coefficient of static friction is increased to 0.7. 4

Same as above

h) The weight of the box is changed to 200 N and the coefficient of static friction is increased to 0.7. 4

Same as above

i) The weight of the box is changed to 200 N and the coefficient of kinetic friction is increased to 0.5. 4

~~Static~~ Same as above

k) The weight of the box is changed to 200 N and the applied force is increased to 50 N. 1

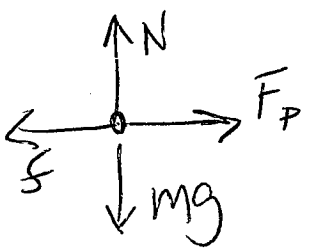
$f_s = .6(100)$ ← Max
$= 120N$

Friction will match the 50N

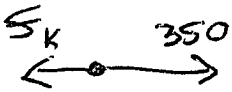
11. A 50kg box rest on the floor. The coefficent of static friction is 0.7 and the coefficient of kinetic friction is 0.5. A) What is the minimum force a person needs to exert to start the box sliding? B) After the box is sliding, the person continues to push it with the same force. What is the acceleration of the box?

A) Min sliding is max static

$f_s = 0.7(500)$
$= 350N$



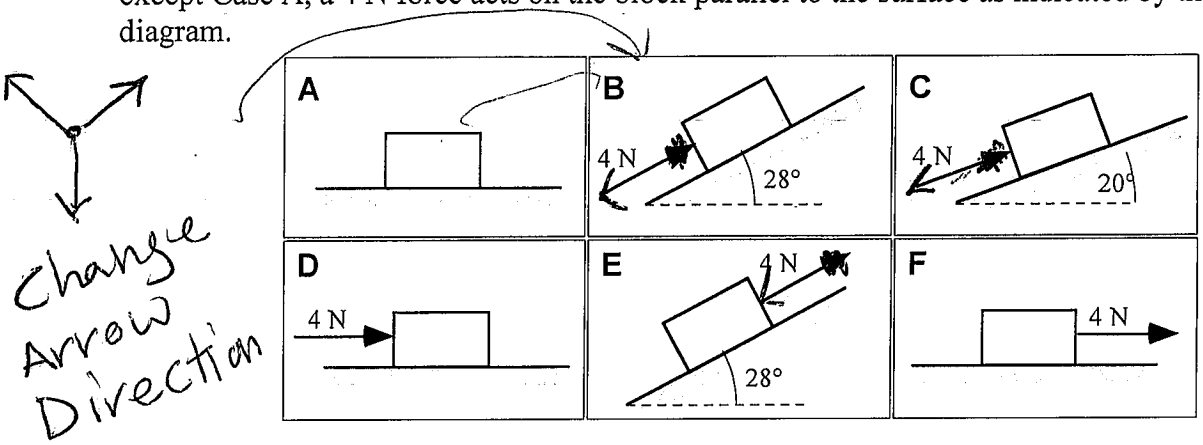
$N = mg$

B) 

$f_k = .5(500)$
$= 250N$

$F_p - f_k = ma$
$350 - 250 = 50a$
$100 = 50a$
$a = 2\ m/s^2$

12. The figures below show six situations where the same block, which has a mass of 5 kg, remains at rest on either a horizontal or an inclined surface. The surfaces are all made of the same material. In all cases except Case A, a 4 N force acts on the block parallel to the surface as indicated by the arrow in the diagram.



Change Arrow Direction

$N = mg\cos\theta$
$= 50\cos 28$
$= 44$

47

Rank these situations on the basis of the magnitude of the frictional force on the block.

Greatest 1 B 2 E 3 C 4 D 5 F 6 A Least

OR, The magnitude of the frictional force is the same but not zero for all these cases. ___

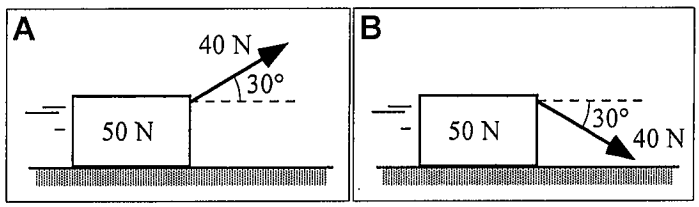
OR, The magnitude of the frictional force is zero for all these cases. ___

OR, We cannot determine the ranking for the magnitude of these frictional forces. ___

Please explain your reasoning.

A has no friction because there is no normal force. D & F just need to oppose the 4N force. C has to oppose the 4N force & the force from gravity. B & E need to oppose the force of the push/pull & the gravity.

13. In both cases below, a moving 50 N box has a force on it of 40 N that makes an angle of 30° with the horizontal. The coefficient of static friction between the box and the rough surface is 0.6 and the coefficient of kinetic friction is 0.4.

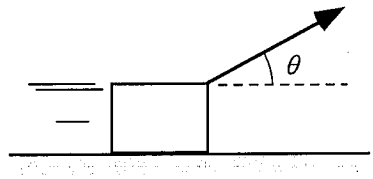


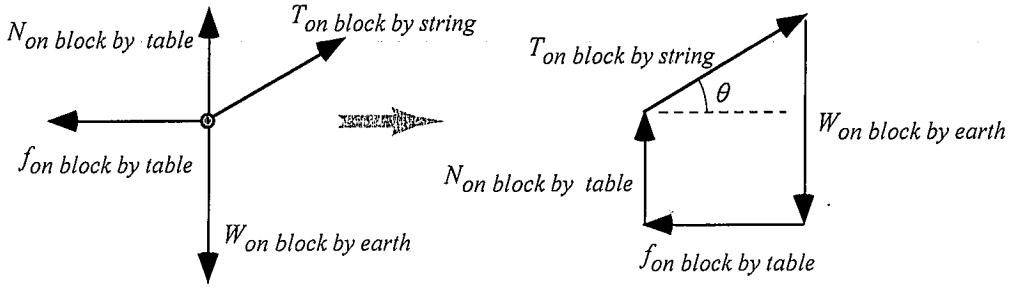
Will the frictional force exerted on the box by the rough surface in Case A be *greater than, less than*, or *equal to* the frictional force on the box by the rough surface in Case B?

Explain.

It will be greater in case B. The force is angled down which increases the normal force and thus increases the friction.

14. A student uses a string to pull a block across a table at a constant speed of 2 meters per second. The string makes an angle θ with the horizontal. A second student makes a free-body diagram of the block, and then uses this free-body diagram to generate a vector sum diagram as shown.





Three students are comparing the magnitudes of the forces in the vector sum diagram:

Anja: The vector sum diagram allows us to compare the magnitudes of all four forces: The weight is the largest, then the tension, then friction, then the normal force.

Barb: Well, the weight is definitely greater than the normal force. But there should be a net force to the right in the vector sum because that's the way the block is moving, and there isn't. I don't think we can use it to rank the other forces.

Cole: I think we can use it to say that the weight is greater than the normal force. Also, the tension is greater than the friction, since the friction is the same length as the dashed line, and this is equal to the tension times the cosine of theta (θ). But we can't compare the vertical forces with the horizontal ones.

Which, if any, of these students do you agree with?

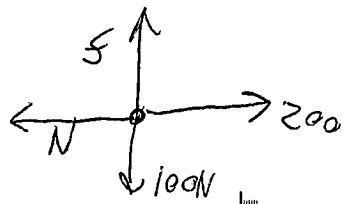
Anja X *Barb* _____ *Cole* _____ None of them_____

Please explain your reasoning.

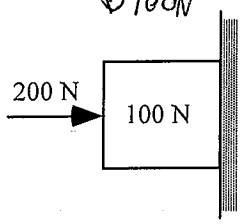
The weight is equal to the normal force plus the y part of the tension.

15. What do objects that are already in motion on a smooth surface need in order to maintain the same motion? Explain.
    a. A constant push
    b. A steadily increasing push
    c. Nothing

Object don't need a force to maintain constant motion



16. A woman is applying a horizontal force on a 100 N box to the right (positive x-direction) to hold it in place against a rough 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 she first applies a constant horizontal force of 200 N:



Ari: "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."

Deshi: "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."

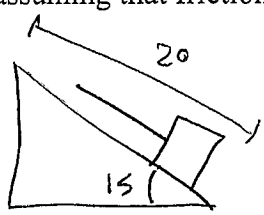
Which, if any, of these students do you think is right?

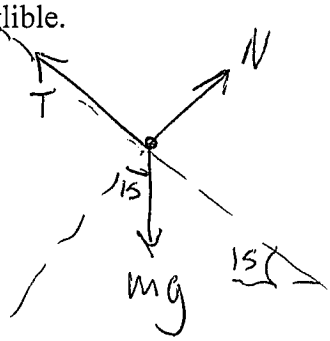
Ari _____ Bratislav __X__ *Celeste* _____ *Deshi* _____ None of them _____

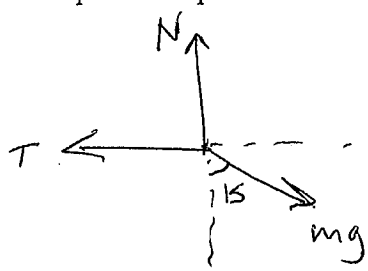
Explain your reasoning.

The force of friction opposes the weight. (see FBD)

17. You agree to build a backyard rope tow to pull your siblings up a 20m slope that is tilted at 15 degrees. Determine the force that the rope should exert on your sister to pull her up the hill at a constant velocity assuming that friction is neglible.







$m = 100 kg$

$T - mg\sin 15 = 0$

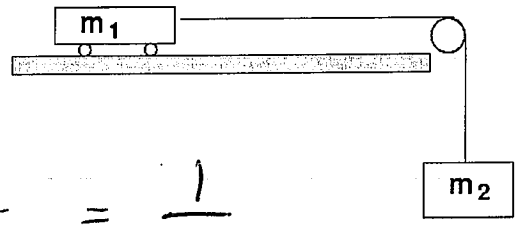
$T = mg\sin 15$

$T = 259 N$

Pulley problems

Say $m_1 = m_2$

18. Find what affects the acceleration of the system. If the mass of both carts is doubled, what happens to the acceleration?

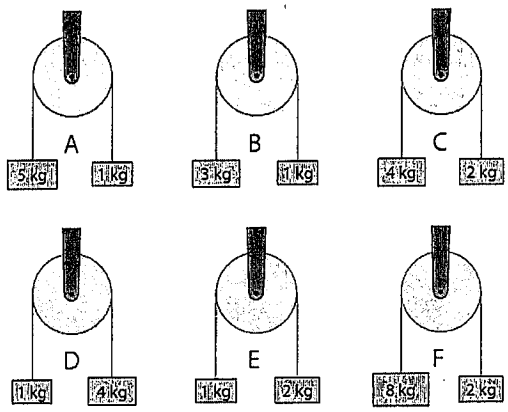


$$a = \frac{F_{net}}{m_{tot}} = \frac{m_2 g}{m_1 + m_2} \qquad \frac{2}{2+2} = \frac{1}{2}$$

$$\frac{1}{1+1} = \frac{1}{2}$$

Acceleration is the same

19. Two masses are hung from a light string over an ideal frictionless massless pulley. The masses are shown in various scenarios in the diagram at right. Rank the acceleration of the masses from greatest to least.



$\frac{m_1 g - m_2 g}{m_1 + m_2}$

A) $\frac{40}{6} = 6.67$

B) $\frac{20}{4} = 5$

C) $\frac{20}{6} = 3.33$

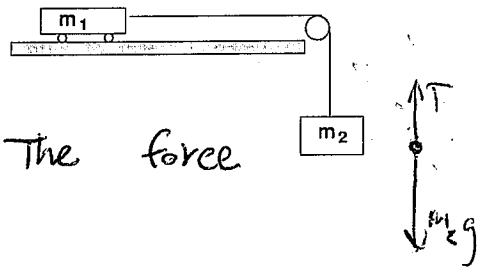
D) $\frac{30}{5} = 6$

E) $\frac{10}{3} = 3.33$

F) $\frac{60}{10} = 6$

A > F > D > B > C > E

20. You hold a block on a horizontal, frictionless surface as seen to the right. After releasing the block is the acceleration greater than g, less than g, or equal to g? Explain.



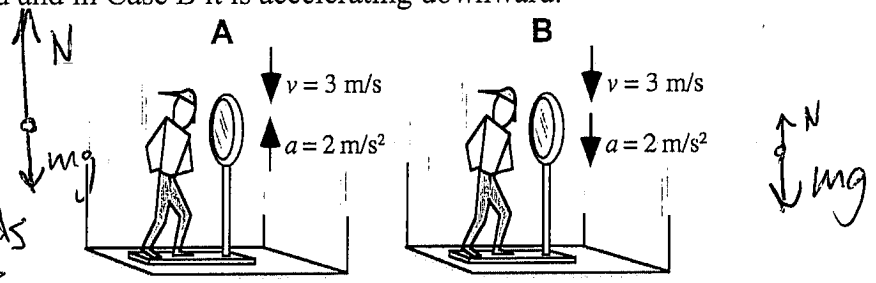
Acceleration is less than g. The force has to accelerate the m_1 & m_2.

21. In reference to the previous question, what is the magnitude of the force exerted by the string on the horizontal block after it has been released? Is it:

a. Equal to the force that Earth exerts on the hanging block
b. Less than the force that Earth exerts on the hanging block
c. More than the force exerted by Earth on the hanging block.

Vertical motion

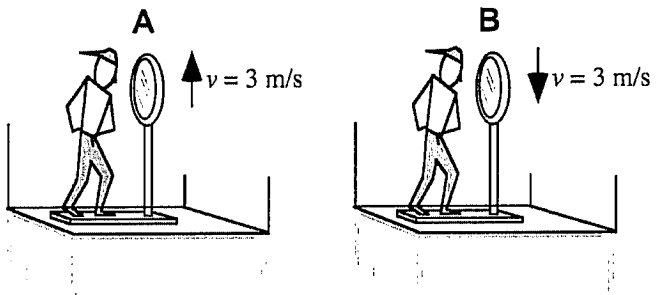
22. In the two cases shown below, a person is standing on a scale in an elevator. The elevators are identical, and the person weighs 500 N. In both cases the elevator is moving downward, but in Case A it is accelerating upward and in Case B it is accelerating downward.



The scale reads the normal force

A) Will the scale reading in Case A be *greater than, less than,* or *the same as* the scale reading in Case B?

Explain. Scale reads the normal. When accelerating up the force up needs to be greater so case A is greater.

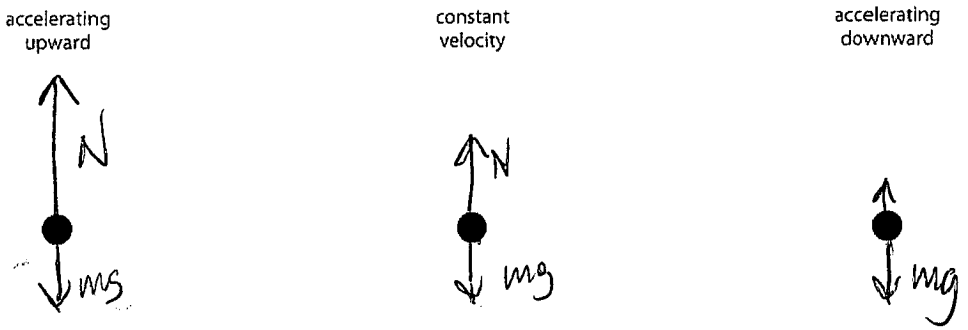


B) Now the elevator is moving at a constant speed. Will the scale reading in Case A be *greater than, less than,* or *the same as* the scale reading in Case B?

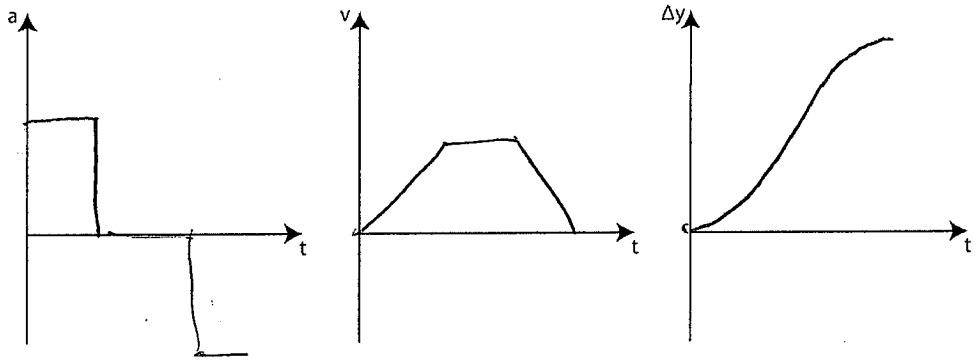
Explain.

Case A = Case B
constant velocity

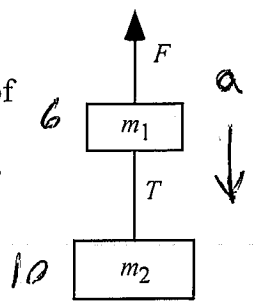
23. A student, standing on a scale in an elevator at rest, sees that the scale reads 840 N. As the elevator rises, the scale reading increases to 945 N for 2 seconds, then returns to 840 N for 10 seconds. When the elevator slows to a stop at the 10th floor, the scale reading drops to 735 N for 2 seconds while coming to a stop.
    a. Explain why the apparent weight of the student increased at the beginning of the motion.
    b. Draw the free body diagram for the student while the student is accelerating upward, then moving at a constant velocity, and finally accelerating downward at the end. Draw the length of the force vectors to show when forces are balanced or unbalanced.



    c. Sketch acceleration vs. time, velocity vs. time, and displacement vs. time graphs of the student during the elevator ride.



24. Two objects with masses of $m_1 = 6$ kg and $m_2 = 10$ kg are connected by a massless wire. They are pulled upward by an applied force F. The result is a constant acceleration of 3 m/s^2 downward for the two objects, because the force F is smaller than the total weight of the objects. The tension in the wire between the objects is labeled T.



Identify from choices (1)-(5) how each change described below will affect the magnitude of the tension (T) in the wire between the objects.

Compared to the case above, this change will:

(1) *increase* the magnitude of the tension in the wire.
(2) *decrease* the magnitude of the tension in the wire but not to zero.
(3) *decrease* the magnitude of the tension in the wire to zero.
(4) *have no effect* on the magnitude of the tension in the wire.
(5) *have an indeterminate* effect on the magnitude of the tension in the wire.

All of these modifications are the only changes to the initial situation shown in the diagram.

a) The mass of m_1 is decreased to 5 kg and the mass of m_2 is increased to 11 kg. 1
Explain.

b) The mass of m_1 is increased to 7 kg and the mass of m_2 is decreased to 9 kg. 2
Explain.

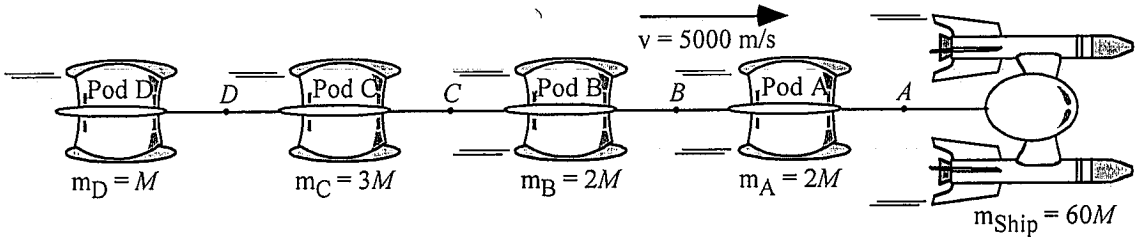
c) The applied force F is increased and the acceleration is 2 m/s^2 downward. 1
Explain.

d) The applied force F is increased and the acceleration is 4 m/s^2 upward. 1
Explain.

e) The applied force F is decreased and the acceleration is 4 m/s^2 downward. 2
Explain.

f) The applied force F is decreased and the mass of m_1 is decreased. _____
Explain.

25. Shown is a spaceship pulling four cargo pods at a constant velocity. The pods are connected to each other by rods, and a rod connects Pod A to the spaceship. The velocity of the spaceship and of the pods is 5000 m/s. All masses are given in the diagram in terms of *M*, the mass of an empty pod. (Since this is in space, we can ignore any resistive forces.)



Rank the magnitude of the tension at the labeled points in the rods.

Greatest 1 _____ 2 _____ 3 _____ 4 _____ Least

OR, The magnitude of the tension in all the rods is the same but not zero. ___

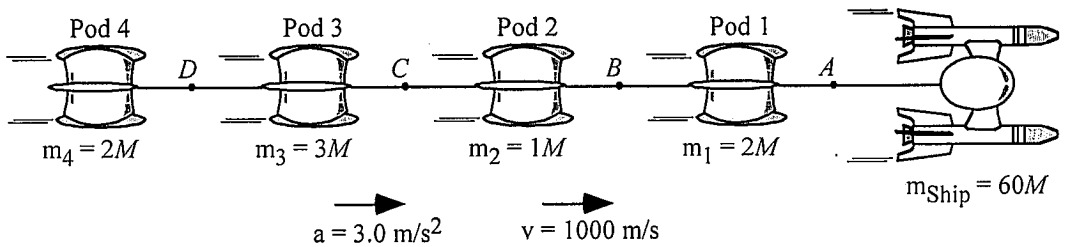
OR, The magnitude of the tension in all the rods is zero. X

OR, The ranking for the tensions in the rods cannot be determined. ___

Explain your reasoning.

They are moving at a constant speed so there is no force.

Now the spaceship is accelerating at 3.0 m/s^2



Rank the magnitude of the tension in the tow rods at the labeled points.

Greatest 1 A 2 B 3 C 4 D Least

OR, The magnitude of the tension in all the tow rods is the same but not zero. ___

OR, The magnitude of the tension in all the tow rods is zero. ___

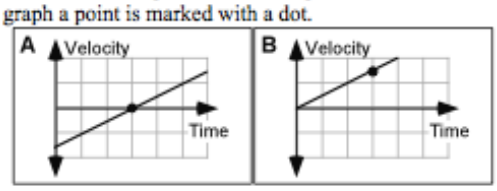
OR, The ranking for the tensions in the tow rods cannot be determined. ___

Explain your reasoning.

The tension in rope A has to pull m_1, m_2, m_3, m_4 B only has to pull $m_2, m_3, \& m_4$ & so on.

Forces and motion graphs

26. These graphs below show the velocity versus time for two identical train engines on a straight track. A positive velocity indicates that the engine was traveling east. The scales on both axes are the same for the graphs. On each graph a point is marked with a dot.



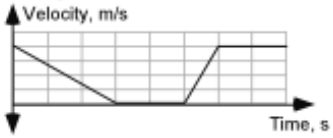
A student who is asked how the net force acting on the engine in graph A at the identified point compares to the net force acting on the engine in graph B states:

"I think that B has the larger net force since the net force on A at the identified point is zero."

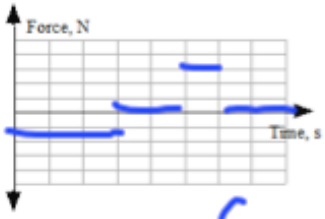
What, if anything, is wrong with this statement? If something is wrong, identify it, and explain how to correct it. If the statement is correct, explain why.

Slope → accekration → net force.
Since slopes are same, and masses are same forces are same.

27. Shown is the velocity versus time graph for an object that is moving in one dimension under the (perhaps intermittent) action of a single horizontal force.



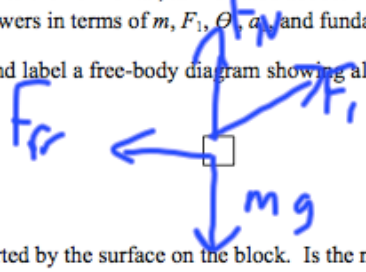
On the axes below draw the horizontal force acting on this object as a function of time.



Explain. Acceleration & force are proportional to each other, when vel. changes, must have a force.

28. A block of mass m is pulled along a rough horizontal surface by a constant applied force of magnitude F_1 that acts at an angle Θ to the horizontal, as indicated above. The acceleration of the block is a_1. Express all algebraic answers in terms of m, F_1, Θ, a_1, and fundamental constants.

a. On the figure below, draw and label a free-body diagram showing all the forces on the block.



b. Determine normal force exerted by the surface on the block. Is the normal force greater than or less than mg and why?

$\Sigma F_y = ma_y$ (0)

$= 0 = F_N + F_1 \sin\theta - mg$

$F_n = mg - F_1 \sin\theta$

less than mg, $F_1 \sin\theta$ pull helps support block.

c. Derive an expression for the coefficient of kinetic friction μ between the block and the surface.

$\mu F_N = F_{fr}$

$\Sigma F_x = ma_x$

$F_1 \cos\theta - \mu F_N = ma$

$\mu = \frac{F_1 \cos\theta - ma}{mg - F_1 \sin\theta}$

d. On the axes below, sketch graphs of the speed v and displacement x of the block as functions of time t if the block started from rest at $x = 0$ and $t = 0$.