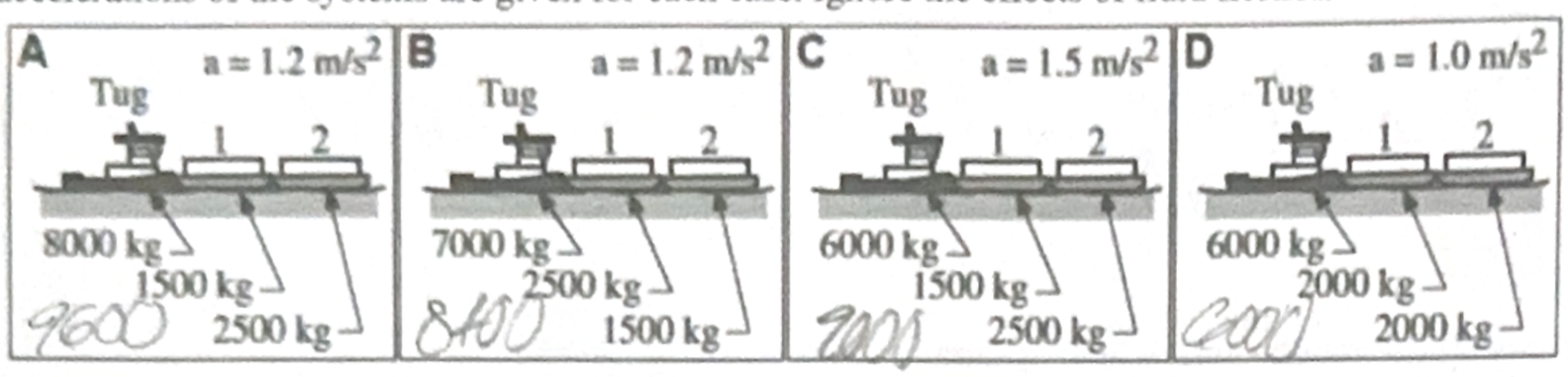
Linear Kinematics

B3-RT24: Tugboat Pushing Barges —Force Tugboat Exerts on First Barge

A tugboat is pushing two barges (labeled 1 and 2) so that they speed up. The masses of the tugboats and barges and the accelerations of the systems are given for each case. Ignore the effects of fluid friction.



$F_{net} = ma$

$a = 0$

Rank the magnitude of the force the tugboat exerts on barge one.

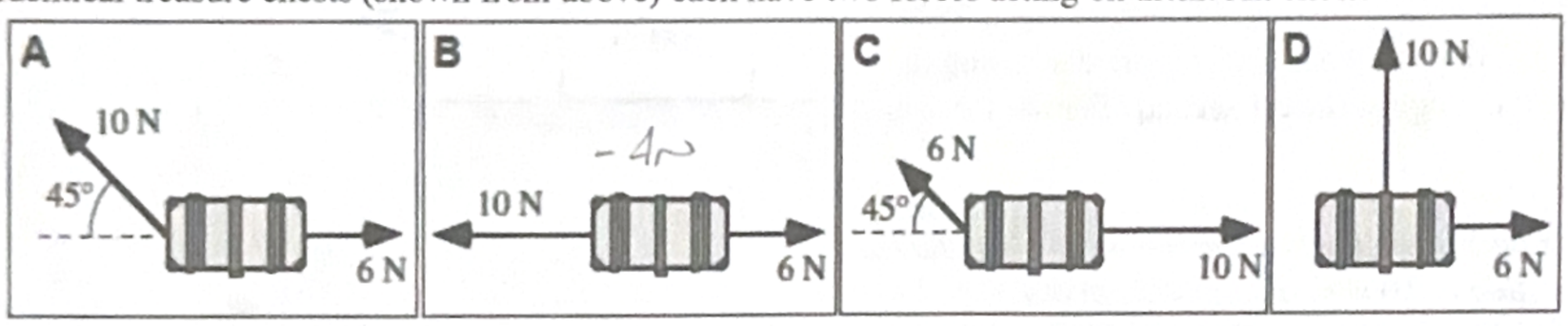
A	B	C D		OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Tugboat A has most mass (12000 kg), B at 11000, and C+D the same/least at 10,000 kg.

B3-RT10: Two -Dimensional Forces on a Treasure Chest —Final Speed

Identical treasure chests (shown from above) each have two forces acting on them. All chests start at rest.



Rank the speed of the treasure chest after 2 seconds.

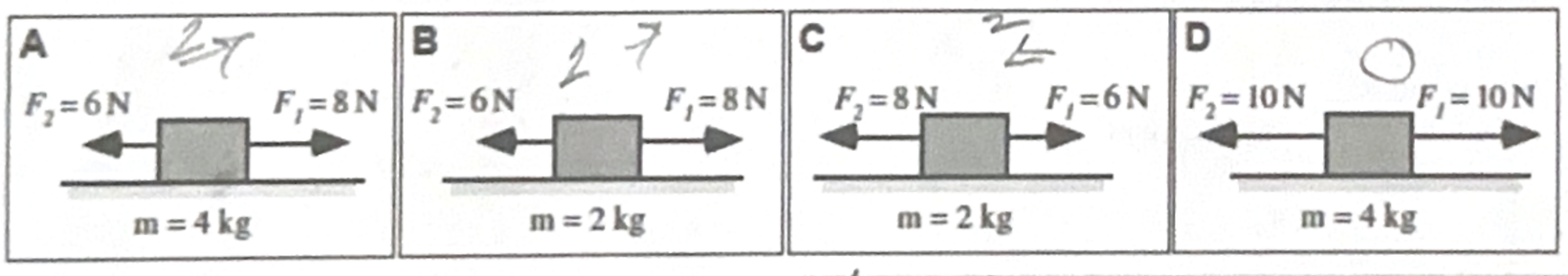
D	CA	B		OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

D → no opposing forces; B slowest because of greatest opp. force

B3-RT25: Forces on Blocks on Smooth Surfaces —Speed

Two forces act on a block that is initially at rest on a frictionless surface.



Rank the speed of the block after 3 seconds.

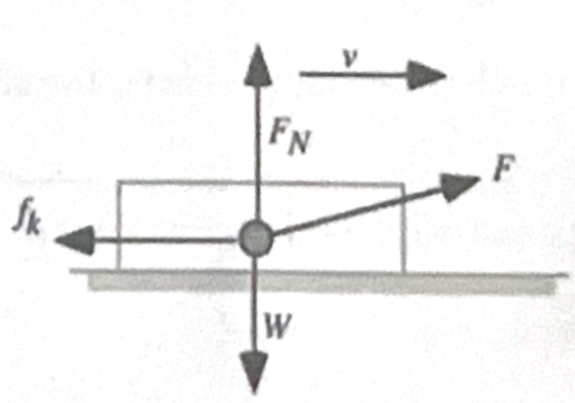
ABC	D			OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

D's forces are equal → speed = 0, ABC have same net force

B3-WWT36: Pulling a Block across a Rough Surface —Force Relationships

A person pulls a block across a rough horizontal surface at a constant speed by applying a force F at a slight angle as shown. A free-body diagram is drawn for the block. The arrows in the diagram correctly indicate the directions but not necessarily the magnitudes of the various forces on the block. A student makes the following claim about this free-body diagram:



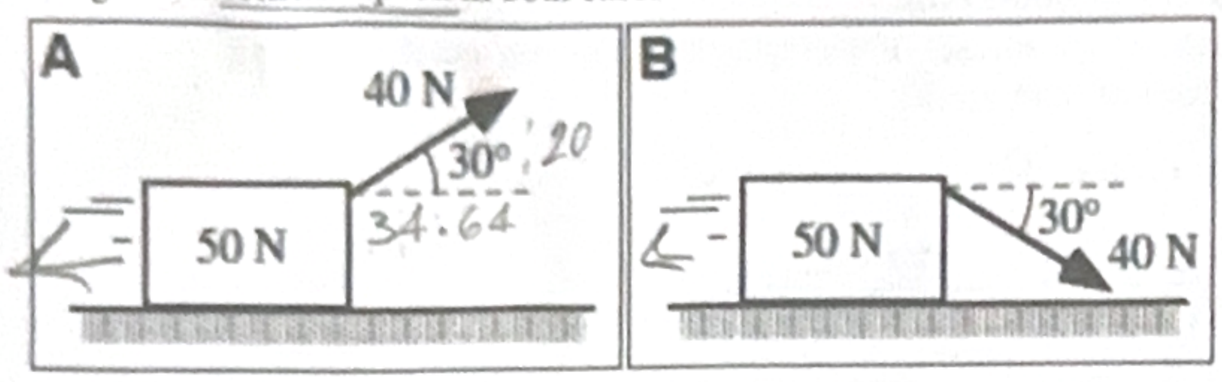
"The velocity of the block is constant, so the net force acting on the block must be zero. Thus the normal force F_N equals the weight W, and the force of friction f_k equals the applied force F."

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

Net force can't be 0 if F isn't horizontal → make F horizontal

B3-CT87: Box Moving over Horizontal Surface —Frictional Force on Box

A 50 N box has an applied force on it of 40 N that makes an angle of 30° with the horizontal. The box is moving to the right at a constant speed in both cases.



$F_f = \mu F_n$

$F_x: -F_f + F_{ax} = ma$ (0)

$F_f = F_{ax}$

$F_f = 34.64$

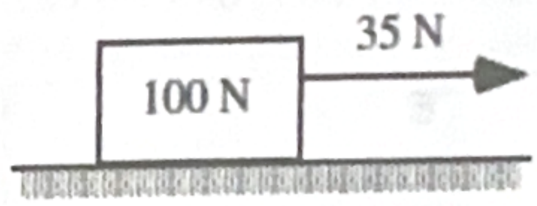
Will the frictional force exerted on the box by the rough surface be (i) greater in Case A, (ii) greater in Case B, or (iii) the same in both cases? i

Explain your reasoning.

B pushing onto the gravel → more friction (↑ normal force)

B3-SCT86: BOX PULLED ON ROUGH , HORIZONTAL SURFACE —FRICTIONAL FORCE ON BOX

A 100 N box is initially at rest on a rough, horizontal surface. The coefficient of static friction is 0.6, and the coefficient of kinetic friction is 0.4. A constant 35 N horizontal force to the right is applied to the box. Four students are discussing the frictional force exerted on the box by the rough surface 1 second after the force is first applied:



Al: *"The frictional force is 60 N since the box will not be moving and the coefficient of static friction is 0.6 with a normal force of 100 N."*

Brianna: *"The frictional force is 40 N since the coefficient of kinetic friction is 0.4 and there is a normal force of 100 N."*

Carlos: *"The frictional force is 35 N since the box will not be moving and the frictional force will cancel out the applied force of 35 N."*

David: *"It is 40 N for the kinetic frictional force and 60 N for the static frictional force. The normal force is 100 N and the coefficient of kinetic friction is 0.4, giving 40 N for the kinetic friction. Similarly, for the static frictional force it is 60 N since it has a coefficient of static friction of 0.6."*

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

Al ✓ Brianna _____ Carlos _____ David _____ None of them _____

Explain your reasoning.

Static friction (starting) → (.6)

and $F_n = 100$ N

↳ $F_f = 60$ N

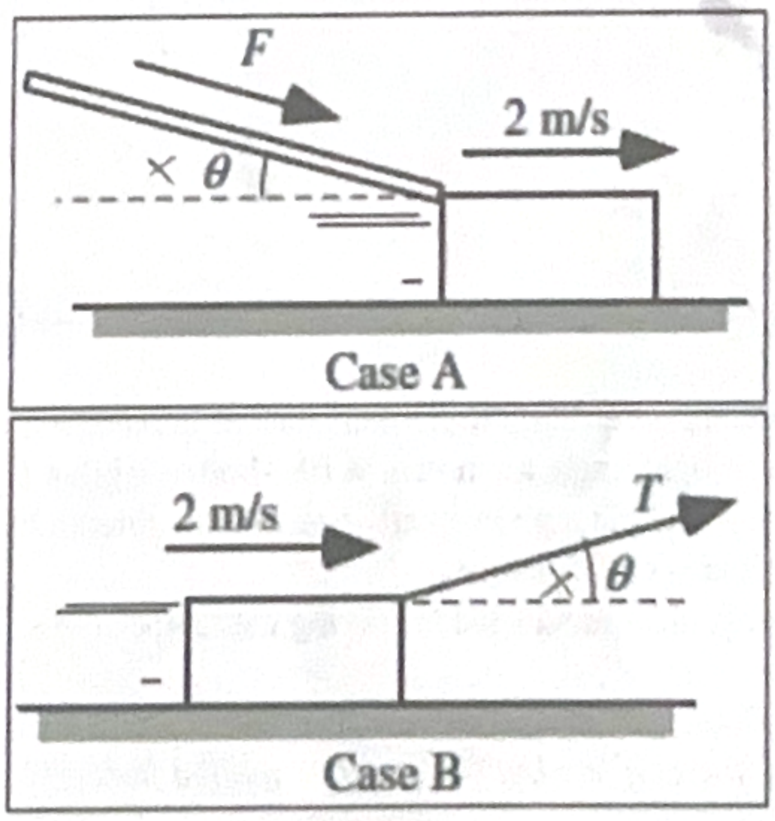
$F_n = 100$

$F_f = F_n$

$(.6)100 = 60$ N

B3-CT35: BLOCKS MOVING AT CONSTANT SPEED —FORCE ON BLOCK

A block is moving to the right across a rough table at a constant speed of 2 m/s. The tables and the blocks are identical in the two cases. In Case A, the block is pushed with a stick and in Case B, the block is pulled with a string. The angle that the applied force makes with the horizontal is the same in both cases.

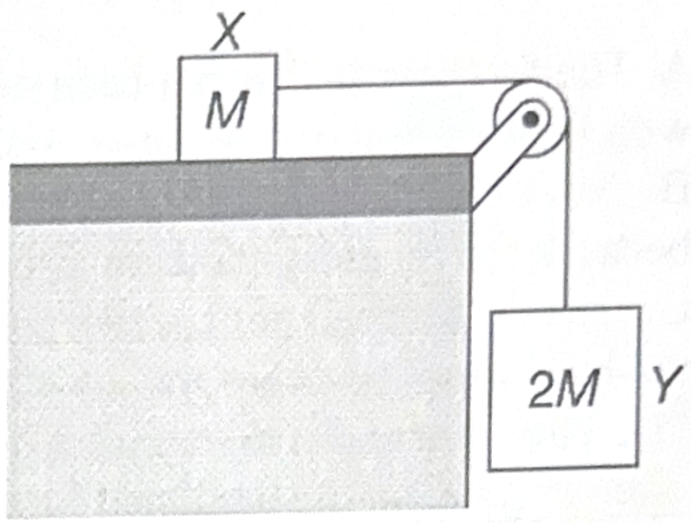


Will the magnitude of the force on the block by the stick in Case A be (i) greater than, (ii) less than, or (iii) equal to the tension on the block by the string in Case B? i

Explain your reasoning. Case A has more friction to overcome ↳ so greater magnitude of force.

Force Review: Name [redacted]

1. Block X of mass M is attached to block Y of mass $2M$ by a light string that passes over a pulley and table of negligible friction and mass, as shown. In which direction will the center of mass (COM) of the two-block system move after it is released from rest, and what is the magnitude of the acceleration a of block X?



	COM	a
A	Down and to the right	$\frac{2}{3}\ -g$
B	Remain at rest	$\frac{2}{3}\ -g$
C	Down and to the right	$\frac{3}{2}\ -g$
D	Remain at rest	$\frac{3}{2}\ -g$

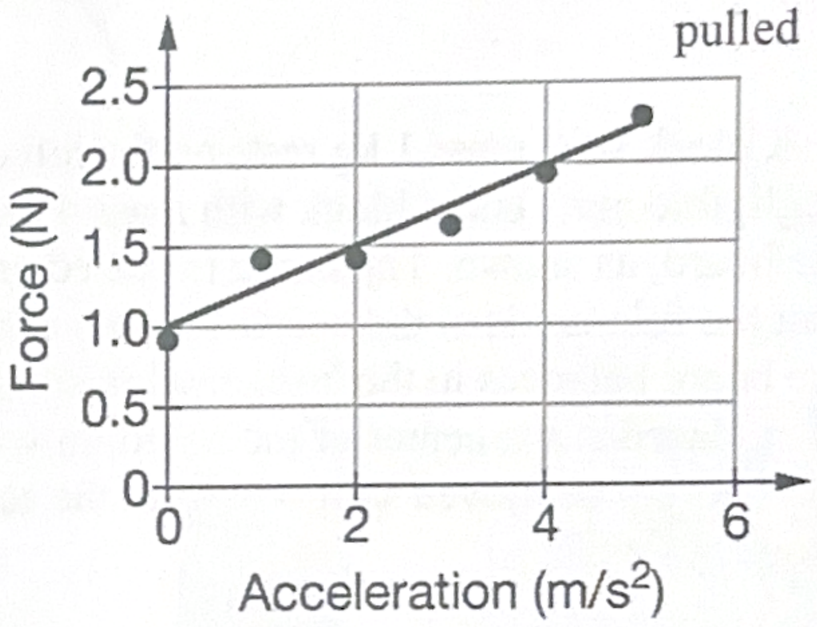
$a = \frac{2}{2+1}g = \frac{2}{3}g$

2. A student must determine the inertial mass of a block that is across a horizontal surface using a force probe and an accelerometer. The student's data are represented in the graph above. What must the student do to determine the inertial mass of the block?

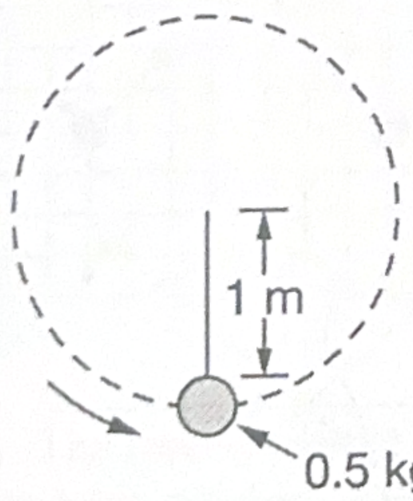
$F = ma$

$\frac{F}{a} = m$

A. Determine the y-intercept.
B. Calculate the slope.
C. Calculate the area under the line.
D. Determine the x-intercept.



3.



Side View

Trial	Tangential Speed (m/s)	Predicted Force of Tension (N)	Actual Force of Tension (N)
1	1	0.5	5.5
2	2	2	7
3	3	4.5	9.5

A student conducts an experiment in which a 0.5 kg ball is spun in a vertical circle from a string of length 1 m, as shown in the figure. The student uses the following equation to predict the force of tension exerted on the ball whenever it reaches the lowest point of its circular path at a known tangential speed for various trials.

$$F_{\text{Tension}} = mv^2/r$$

When the experiment is conducted, the student uses a force probe to measure the actual force of tension exerted on the ball. Why is the predicted force of tension different than the actual force of tension?

A. The force probe has not been calibrated properly because the predicted tension forces are in agreement with their corresponding tangential speeds.
B. Not enough trials were conducted to observe the spread of uncertainty with the collected values because the predicted tension forces are in agreement with their corresponding tangential speeds.
C . The student did not account for the downward centrifugal force that occurs as a result of the inertia of the ball when it reaches the lowest point along its circular path.
D. The student did not account for the downward force due to gravity at the ball's lowest point along its circular path, so the predicted force of tension is the net centripetal force exerted on the ball.

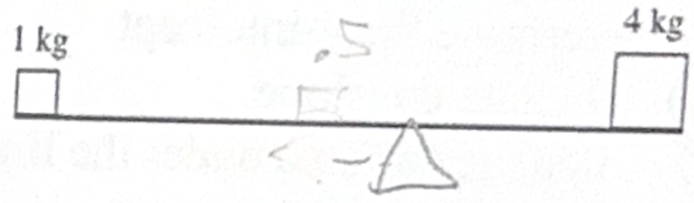
4. A 60 kg person is riding in an elevator. At time t_1, the elevator is accelerating downward with a magnitude of 2 m/s^2. A short time later, at time t_2, the elevator is accelerating upward with a magnitude of 2 m/s^2. The ratio of the normal force exerted by the elevator on the person at time t_1 to that at time t_2 is most nearly

A) 2 : 3 B) 4 : 5 C) 5 : 6 D) 1 : 1

$T = 60(10-2) = 480$ $\frac{2}{3}$
$T = 60(10+2) = 720$

$T = m(g+a)$
$600(10+2)$
$600(8)$
$1:4$ $1.5:6$

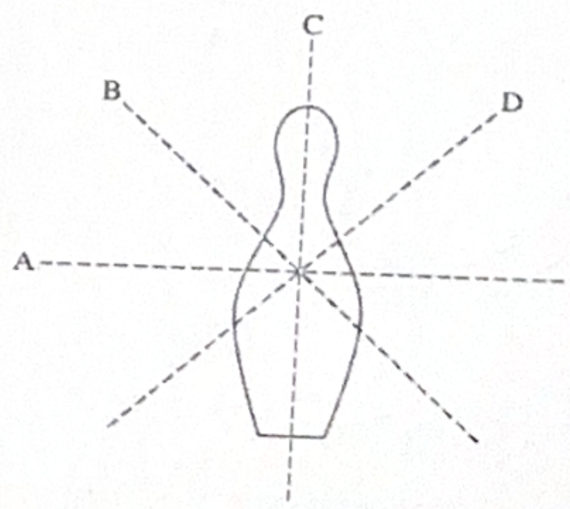
5. A block with mass 1 kg rests on the left end of a board with negligible mass and a block with mass 4 kg rests on the right end of the board, as shown. The board is placed on a fulcrum (not shown) so that the fulcrum is at the center of mass of the two-block system and the board balances in the horizontal position shown. A third block is then placed at the center of the board. In which direction, if any, must the fulcrum be moved so it will be at the center of mass of the three-block system?



A) To the left
B) To the right
C) The fulcrum will not need to be moved.
D) It cannot be determined without knowing the mass of the third block.

6. The bowling pin shown in the figure has uniform density. Based on the symmetry of the bowling pin, along which dashed line must the center of mass be located?

A) A B) B C) C D) D



7. An object of mass m travels in a horizontal circular path of radius r at constant speed. The object's period of T . What is the centripetal acceleration of the object?

(A) Zero B) g C) $\frac{4\pi^2 r}{T^2}$ D) $\frac{2\pi r}{T^2}$

$a = \frac{v^2}{R} = \frac{4\pi^2 R^2}{R T^2}$

$v = \frac{2\pi r}{T}$

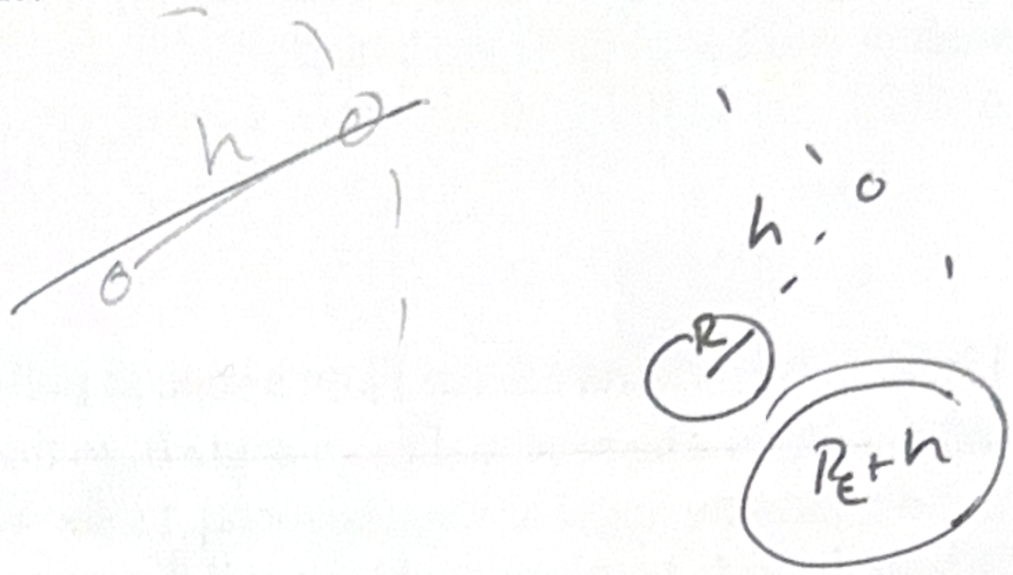
8. A satellite of mass m_s is in a circular orbit at a height h above the surface of Earth, which has a mass M_E and a radius R_E. What is the period of the satellite's orbit?

(A) $2\pi\sqrt{\frac{R_E^3}{Gm_s}}$

(B) $2\pi\sqrt{\frac{R_E^3}{GM_E}}$

(C) $2\pi\sqrt{\frac{(R_E+h)^3}{Gm_s}}$

(D) $2\pi\sqrt{\frac{(R_E+h)^3}{GM_E}}$



9. A student pushes a wall with a force of magnitude $F_{s\text{-}w}$. The wall exerts a force of magnitude $F_{w\text{-}s}$ on the student. The student then pushes harder on the wall, exerting a force of magnitude $2F_{s\text{-}w}$ on the wall. The magnitude of the force that the wall then exerts on the student is

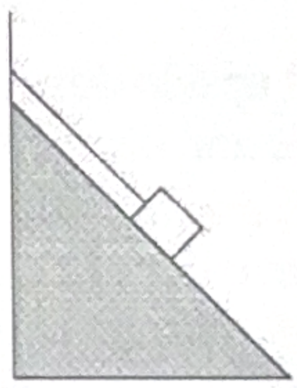
(A) $\frac{F_{w\text{-}s}}{2}$

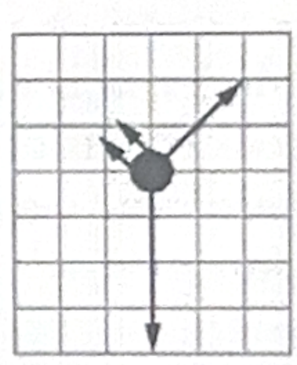
(B) $F_{w\text{-}s}$

(C) $2F_{w\text{-}s}$

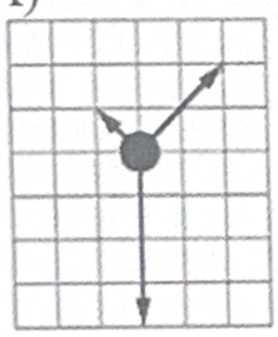
(D) $4F_{w\text{-}s}$

10. The left figure shows a block at rest on a rough inclined surface. The block is attached to a wall by a string of negligible mass. The vector sum of the forces is zero. The right figure shows the free-body diagram for the block. The string is cut and the vector sum of the forces on the block remains zero. Which of the following free-body diagrams could show the forces exerted on the block after the string is cut?

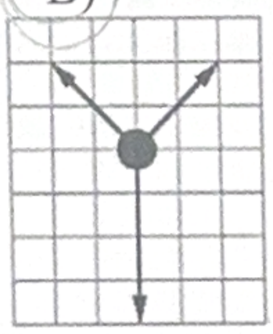




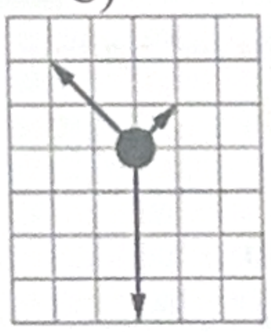
A)



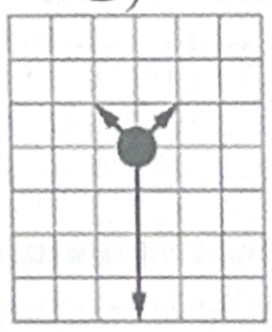
B)



C)



D)



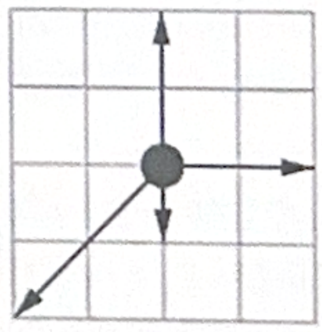
11. The forces exerted on an object at a particular instant are represented in the free-body diagram. The magnitude of each force is drawn to scale. A student claims that the vector sum of the forces on the object is equal to zero. Is the student's claim valid? Why or why not?

A) Yes, because the horizontal components add to zero.

B) Yes, because the vertical components add to zero.

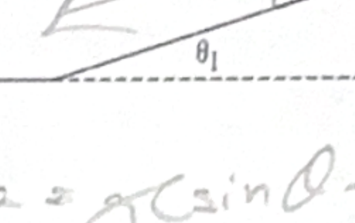
C) No, because the vertical components of the forces do not completely add to zero.

D) No, because the magnitudes of all the forces are not equal

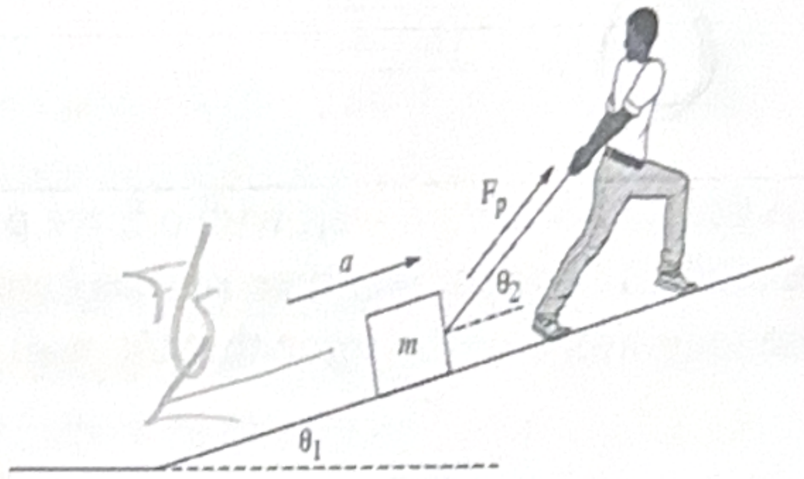


12. A student of mass 45 kg slides down a ramp that is inclined at an angle of 30° above the horizontal. The magnitude of the student's acceleration is 2 m/s^2. The coefficient of kinetic friction between the student and the ramp is most nearly

A) 0.23 B) 0.30 C) 0.35 D) 0.92



13. A person exerts a force F_p on a rope to pull a block of mass m up a ramp. The rope makes an angle θ_1 to the ramp and the ramp makes an angle to the horizontal, as shown. The force of kinetic friction between the block and the ramp has magnitude F_f. Which of the following expressions is equal to the magnitude of the acceleration a of the block?



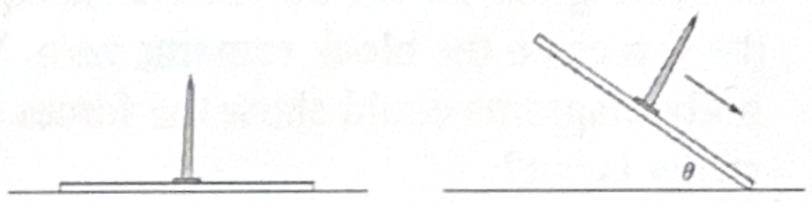
(A) $\dfrac{F_p \cos\theta_2 + F_f}{m} - g\sin\theta_1$

(B) $\dfrac{F_p \cos\theta_2 - F_f}{m} - g\sin\theta_1$

(C) $\dfrac{F_p \cos\theta_2 + F_f}{m} + g\sin\theta_1$

(D) $\dfrac{F_p \cos\theta_2 - F_f}{m} + g\sin\theta_1$

14. A nail is placed upside-down on a board, as shown. The coefficients of static and kinetic friction between the nail and the board are μ_s and μ_k, respectively. The left end of the board is slowly raised so that the board's angle θ with the horizontal increases. As soon as the nail begins to slide down the board without tipping over, the board is held in place at that angle. The nail continues to slide down the board with constant velocity.



Which of the following can be concluded about and μ_s and μ_k based on these observations?

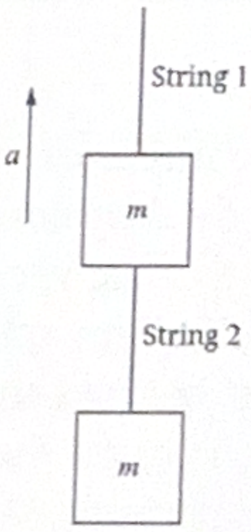
A) μ_k is nearly equal to μ_s

B) μ_k is nearly equal to zero

C) μ_k increases and μ_s decreases as the board's angle is increased

D) μ_k decreases and μ_s increases as the board's angle is increased

15. Two identical crates are connected by heavy strings with non-negligible mass, as shown in the diagram. An upward force is applied to String 1 which causes the blocks-strings system to accelerate upward at a constant acceleration. Which claim is true concerning the tension in String 2 ?



A) The tension in String 2 is greatest where it connects to the upper block because it has to support the weight of the string and Block 2.

B) The tension in String 2 is greatest where it connects to the upper block because String 2 is the bottom string.

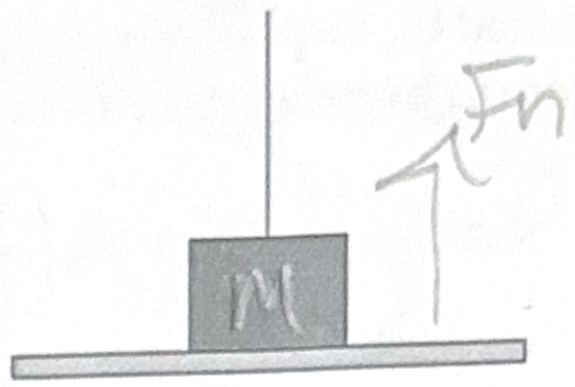
C) The tension in String 2 is equal throughout its length because it is the bottom string.

D) The tension in String 2 is equal throughout its length because tension is always the same through a string. is the bottom string.

16. A string of negligible mass is attached to a box of mass m . With the string taut, the box sits at rest on top of a scale, as shown. Which of the following must be a correct equation for the magnitude F_T of the tension in the string?

(A) $F_T = F_N + mg$
(B) $F_T = F_N$
(C) $F_T = mg$
(D) $F_T = mg - F_N$

$F_T - mg$



$\Sigma F_y : F_n + F_T - mg$

$F_T = mg - F_n$

$F_n + F_T = mg$

17. A student has a calibrated spring scale that measures force with a precision of ± 0.05 N. At sea level, the student holds the scale vertically with a 100 g object attached to it, and the scale reads 1.00 N. The student then brings the scale and the object to the top of a 1000 m high mountain and again holds the scale vertically with the 100g object attached. Which of the following correctly describes the scale's reading, and provides valid justification for the claim?

A) The scale reading is between 0.90 N and 0.99 N, because the scale is not precise enough to read the exact value of the object's weight.
B) The scale reading is between 0.90 N to 0.99 N, because the weight of the object is inversely proportional to the square of the distance to the center of Earth.
C) The scale reading is between 0.95 N and 1.05 N, because the height of the mountain is negligible compared to the radius of the earth.
D) The scale reading is between 0.95 N and 1.05 N, because weight is an intrinsic property of an object which doesn't change even when the gravitational field changes.,

so small

18. A block of mass 2.0 kg is initially at rest on a horizontal surface. The block is pulled a distance of 10 m in 3.0 s by an applied force. The coefficients of static and kinetic friction between the surface and the object are $\mu_s = 0.45$ and $\mu_k = 0.30$, respectively. The magnitude of the applied force is most nearly

A) 6.0 N. B) 9.0 N C) 10.4 N D) 13.4 N



20 N

$F_a = 10.324$ N

$d = vt + \frac{1}{2}at^2$

$10 = \frac{1}{2}a(9)$

$a = \frac{20}{9}\ m/s^2$

$F_f = (.3)(2)(9.8)$

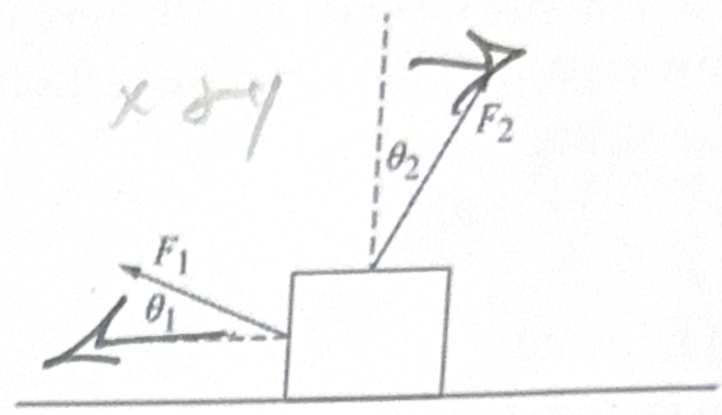
$F_f = 5.88$ N

$ma = F_a - F_f$

$F_a = ma + F_f$

$= (2)\left(\frac{20}{9}\right) + 5.88$

19. A box moves with constant speed to the right along a horizontal surface with negligible friction. Two forces, with magnitudes F_1 and F_2, are exerted on the box at angles θ_1 and θ_2, respectively, as shown. Which of the following is a correct expression for F_1 in terms of F_2?



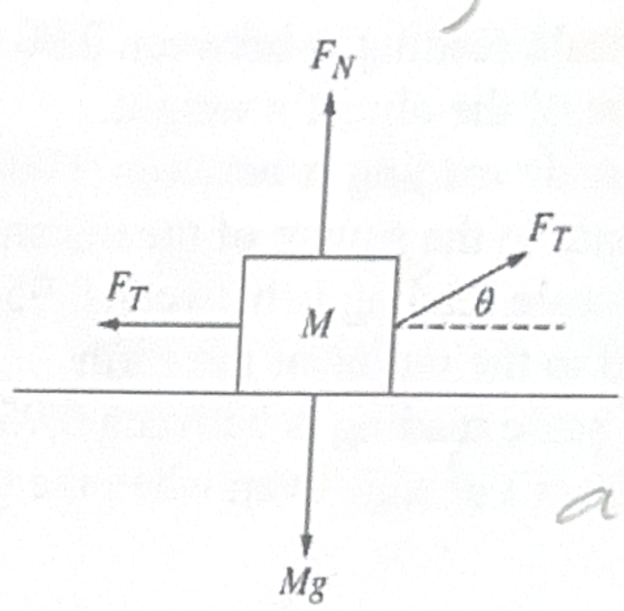
(A) $F_1 = F_2\left(\dfrac{\sin\theta_2}{\cos\theta_1}\right)$

(B) $F_1 = F_2\left(\dfrac{\cos\theta_2}{\sin\theta_1}\right)$

(C) $F_1 = F_2\left(\dfrac{\sin\theta_2}{\sin\theta_1}\right)$

(D) $F_1 = F_2\left(\dfrac{\cos\theta_2}{\cos\theta_1}\right)$

20. A box of mass M slides along a horizontal surface. The forces exerted on the box are indicated in the figure. There is negligible friction between the box and the horizontal surface. Which of the following expressions is equal to the magnitude of the acceleration of the box?



Note: Forces not drawn to scale.

(A) $\dfrac{F_T(1+\cos\theta)}{M}$

(B) $\dfrac{F_T(1-\cos\theta)}{M}$

(C) $\dfrac{F_T(1-\cos\theta)+F_N-Mg}{M}$

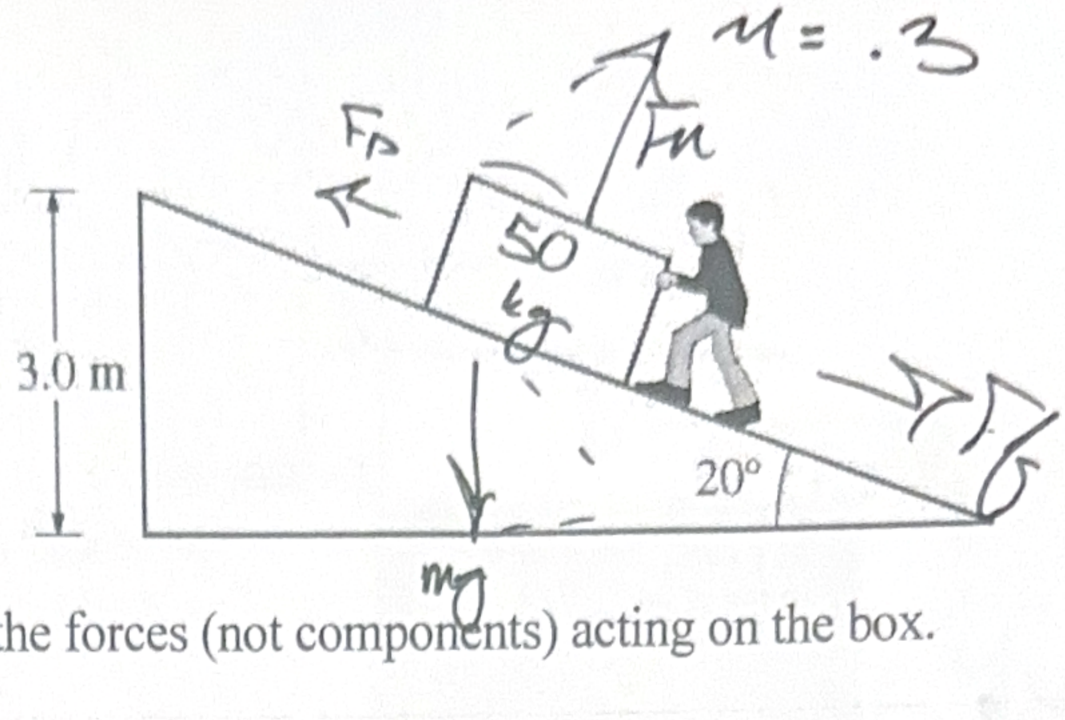
(D) $\dfrac{F_T(1+\cos\theta)+F_N+Mg}{M}$

21. A skydiver is falling through the air attached to a parachute. The mass of the skydiver-parachute system is m. The upward force of air resistance exerted on the system is given by the equation $F_{air} = Av^2$, where A is a constant that depends on the shape of the parachute and v is the speed of the system. After falling a short time, the system reaches a constant speed v_T. Which of the following is a correct expression for v_T?

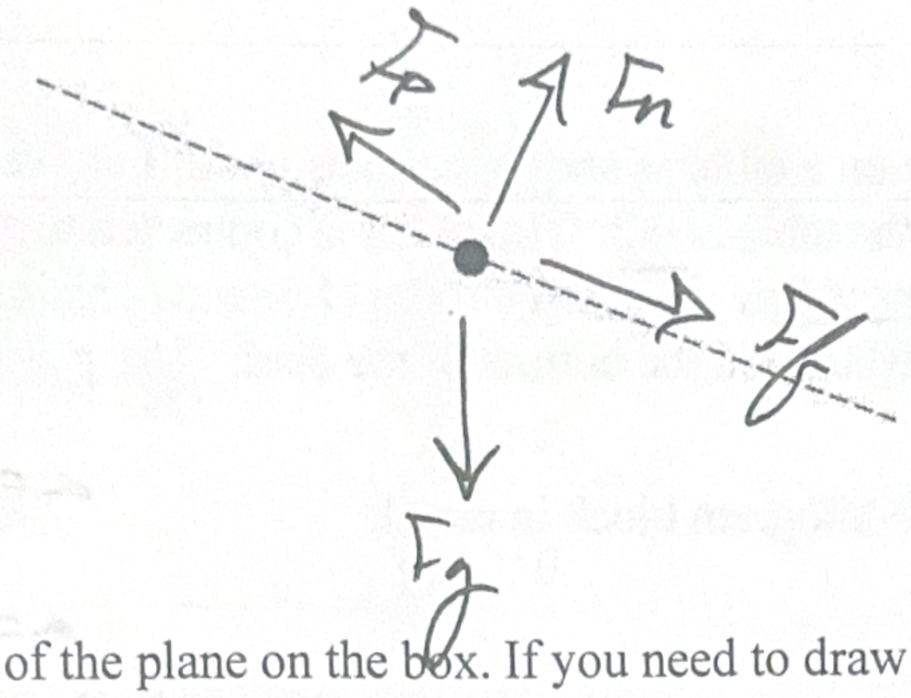
A) 0 B) $\sqrt{\dfrac{g}{A}}$ C) $\sqrt{\dfrac{mg}{A}}$ D). $\sqrt{\dfrac{Ag}{m}}$

g = 10

21. A box is being pushed at constant speed up an inclined plane to a vertical height of 3.0 m above the ground, as shown in the figure above. The person exerts a force parallel to the plane. The mass m of the box is 50 kg, and the coefficient of kinetic friction μ_k between the box and the plane is 0.30.



(a) On the dot below that represents the box, draw and label the forces (not components) acting on the box.



b) Calculate the normal force of the plane on the box. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

$\frac{F_f}{\mu} = F_n$ $\quad \frac{50(10)\sin 20}{.3} = 570.02$

$F_f = mg\cos 20$ $\quad F_n = 469.85$

c) Calculate the component of the force of gravity acting on the box that is parallel to the plane.

$F_{\parallel}: \quad -F_f - mg\sin\theta = ma$

$mg\sin\theta = -ma - F_f$ $\quad mg\sin\theta$

d) Calculate the friction force between the plane and the box.

$F_f = \mu F_n$ $\quad F_f = .2(469.85)$ $\quad F_f = 140.96$

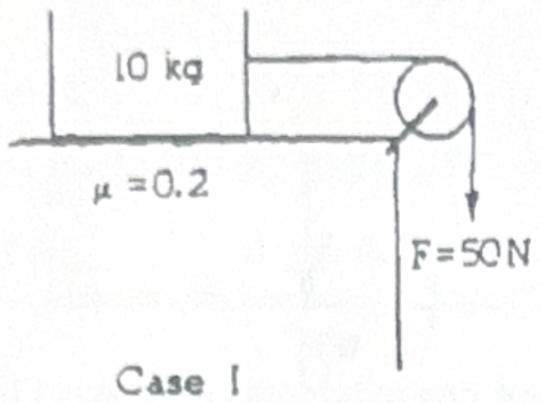
e) Calculate the force applied by the person on the box.

$F_{net} = F_a + mg\sin\theta - F_f$

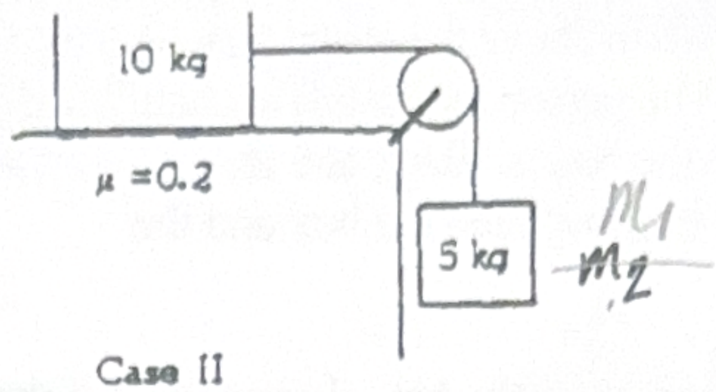
$0 = +F_a - 171.01 - 140.96$

$F_a - mg\sin\theta - F_f = 0$ $\quad F_a = 311.97$ N

$F_a = (171.01)(140.96)$



Case I



Case II

$\mu = .2$

22. A 10-kilogram block rests initially on a table as shown in cases I and II above. The coefficient of sliding friction between the block and the table is 0.2. The block is connected to a cord of negligible mass, which hangs over a massless frictionless pulley. In case I a force of 50 newtons is applied to the cord. In case II an object of mass 5 kilograms is hung on the bottom of the cord. Use g = 10 meters per second squared.

a. Calculate the acceleration of the 10-kilogram block in case I.

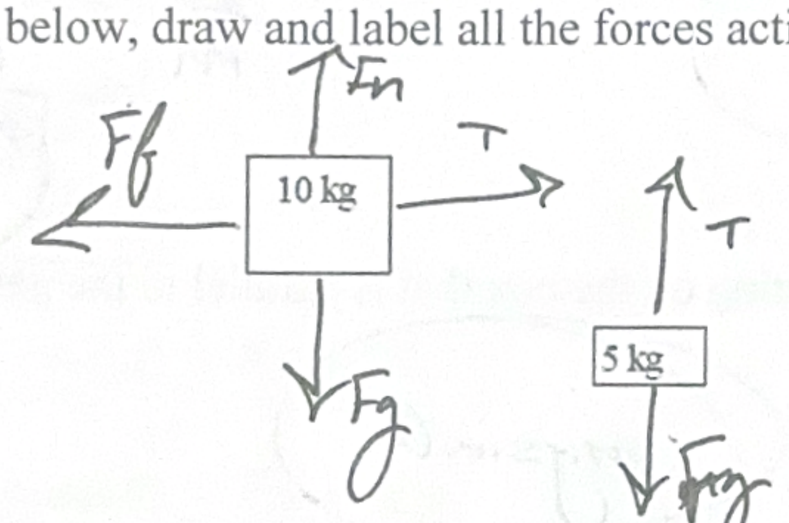
$a = g\left(\frac{m_1 - \mu m_2}{m_2 + m_1}\right)$

$a = 10\left(\frac{10 - .2(5)}{15}\right)$

$a = 10\left(\frac{5 - .2(10)}{15}\right)$

$a = 2\ m/s^2$

b. On the diagrams below, draw and label all the forces acting on each block in case II.



c. Derive the formula for the acceleration of the modified Atwood in case II.

$\Sigma F_{y_1} = m_1 g - T = m_1 a$

$m_1 g - m_1 a = T$

$\Sigma F_{x_2} = -Ff + T = m_2 a$

$= -(\mu m_2 g) + T = m_2 a$

$T = m_2 a + (\mu m_2 g)$

$m_1 g - (\mu m_2 g) = m_2 a + m_1 a$

$a = \frac{g(m_1 - \mu m_2)}{m_2 + m_1}$

d. Calculate the acceleration of the 10-kilogram block in case II using your derived formula.

$a = \frac{g(m_1 - \mu m_2)}{m_2 + m_1}$

$\frac{10(5 - (.2)(10))}{15} = 2\ m/s^2$

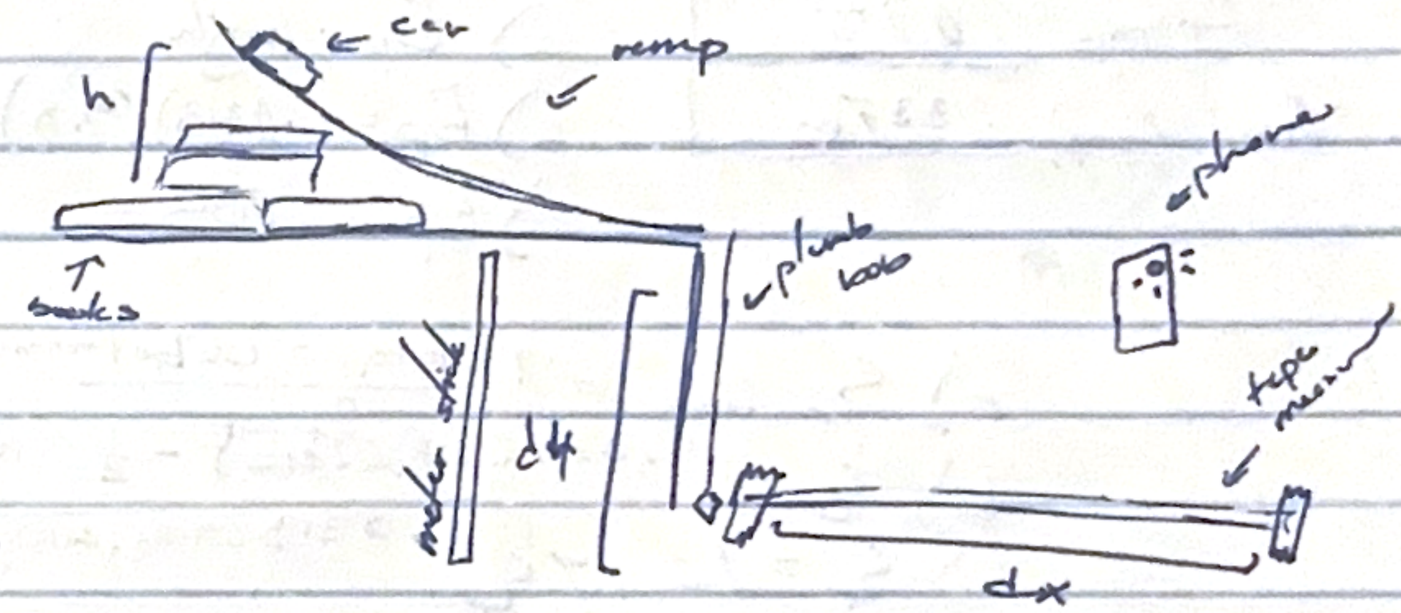
[redacted] 2

What is the % of energy lost 11/4
of a car down a ramp?

2. To find not only the average percent of energy loss of a car going down a ramp, but to test the minimum velocity and height that the car needs to start from to complete the trunk.

3. We hypothesize that the percent of energy lost to other forms will be around 20%.

4. - meterstick
- type measure
- matchbox car
- ramp / track
- textbooks
- phone - plumb bob



5. - Set up ramp and use plumb bob to check for exit position of the car and place measuring tape on the floor & make sure to weigh car + where it hits the floor
- Measure the height of the ramp from the front of the car and then record where the car hits on the tape on the floor three times
- From these values, determine the initial velocity, time, potential & kinetic energy, and finally the percent of lost energy

e.	m	d_y	t	d_x	v_{ix}	E_p	E_k	ξ_{lost}	h
t1	.0313kg	.94m	.438s	1.155m	2.637m/s	.127J	.109J	14.17 ξ	.415m
t2	.0313kg	.94m	.438s	1.175m	2.683m/s	.127J	.115J	11.02 ξ	.415m
t3	.0313kg	.94m	.438s	1.155m	2.637m/s	.127J	.109J	14.17 ξ	.415m

R	.1175m
v_{min}	1.07m/s
$E_{k\,TOP}$	.0179J
$E_{P\,TOP}$	.0721J
$E_{T\,TOP}$	.09J
$h_{min\,(ramp)}$	.337m

c) $d_y = \frac{1}{2} g t^2$

b) $.94 = \frac{1}{2}(9.8) t^2$

c) $t = .438s$

c) $v_{ix} = \frac{dx}{t}$

b) $v_{ix} = 1.155/.438$

c) $v_{ix} = 2.637 m/s$

a) $E_p = mgh$

b) $E_p = (.0313)(7.8)(.415)$

c) $E_p = .135J$

c) $E_k = \frac{1}{2} m v^2$

b) $E_k = \frac{1}{2}(.0313)(2.637)^2$

c) $E_k = .109J$

c) $\xi_{loss} = \left| \frac{E_{ptop} - E_{kbottom}}{E_{ptop}} \right| \times 100$

b) $\xi_e = \left| \frac{.0313(9.8)(.415) - \frac{1}{2}(.0312)(2.637)^2}{.0313(7.8)(.415)} \right| \times 100$

c) $\xi_e = 14.17 \xi_e$

c) $v_{min} = \sqrt{Rg}$

b) $v_{min} = \sqrt{.1175(7.8)}$

c) $v_{min} = 1.07$

a) $E_{T\,TOP} = mgh - (\text{org.} \cdot \xi_{loss})\, mgh$

b) ~~$E_{T\,TOP}$~~ $.09 = (.0313)(9.8)(h) - .1312(.313)(7.8)h$

c) $h = .337m$

7. The data relatively supported my hypothesis as the average ξ ~~lost~~ was about 13 ξ_e, not too far from my predicted value of twenty percent. The results were very surprising, the determined values of kinetic and potential were a little smaller than expected, but the mass of the cup in kg was small and so was the height. Uncertainties and error could have stemmed from measuring / determining mass + lengths incorrectly, yet we had partners to verify.

end of ramp: 100 cm mass: 31.3g .0313kg
height of ramp: 41.5 cm .415 m
height of table/ramps: 94 cm .94m

#1: 115.5 cm 2.637 m/s
#2: 117.5 cm 2.683 m/s
#3: 115.5 cm 2.637 m/s

2.5 m/s $gh = \frac{1}{2}v^2$ $9.8(.415) = \frac{1}{2}v^2$

.138 = t

$E_p = mgh$ $9.8(.0313)(.415) = .135$
$E_k = \frac{1}{2}mv^2$ $\frac{1}{2}(.0313)$
#1: $\frac{1}{2}(.0313)(2.637)^2 = .109$
#2: $\frac{1}{2}(.0313)(2.68)^2 = .113$
#3: $\frac{1}{2}(.0313)(2.637)^2 = .107$

#1 or #3: $\left|\frac{.135 - .107}{.135}\right| = 19.26$
#2: $\frac{|.135 - .1131|}{.135} = 16.30$

d: .235m
r: .1175m

$v_{min} = \sqrt{Rg} = \sqrt{9.8(.1175)} = 1.07$

$\frac{1}{2}mv^2 = .0179$
$mgh = .0721$

$.0313(9.8)h - .1312(.0313)(9.8)h = .09$
$= .337m$

	m	d_y	t	d_x	v_{ix}	E_P	E_k	$\theta_{e\,lost}$	h
#1:	.0313 kg	.94 m	.138 s	1.155 m	2.637 m/s	.127 J	.104 J	14.17°	.415 m
#2:	.0313 kg	.94 m	.138 s	1.175 m	2.683 m/s	.127 J	.115 J	11.02°	.415 m
#3:	.0313 kg	.94 m	.138 s	1.155 m	2.637 m/s	.127 J	.104 J	14.17°	.415 m

Avg θ_e: 13.12°

R	.1175 m
V_{min}	1.07 m/s
$E_{k\,TOP}$	.0179 J
$E_{P\,TOP}$	0.0721 J
$E_{T\,TOP}$	.09 J
$h_{min\,(real)}$	.337 m