

Unit 2 ~ Learning Guide Name: _____**Instructions:**

Using a pencil, complete the following notes as you work through the related lessons. Show ALL work as is explained in the lessons. You are required to have this package completed BEFORE you write your unit test. Do your best and ask questions if you don't understand anything!

Dynamics Review:

1. If an object is in equilibrium, it means that $F_{\text{net}} =$ _____, the acceleration = _____, velocity = _____, and displacement = _____.
2. Explain how you can recognize F_{net} based on the size of the force vectors.
3. If an object was in equilibrium, what would we know about the forces (no matter how many forces were involved).
4. Can an object be moving at 100 km/hr and be in equilibrium? Explain.
5. Can an object have an unbalanced force and have a velocity of zero? Explain.
6. The previous questions can be confusing to someone who is learning to understand motion, as it keeps relating to the current instantaneous velocity. When we study forces, the current velocity is not important – it's the _____ in velocity (or acceleration) that is important.
7. A 4500 kg helicopter accelerates upward at 2.0 m/s^2 . What lift force is exerted by the air on the propellers? Make sure you draw a FBD and write $F_{\text{net}} = ma$ to begin this solution.
8. Describe a situation where the normal force on an object is NOT equal to the gravitational force.

9. Sketch or describe three situations in the boxes on the left. In the boxes to the right of each situation, draw the appropriate FBD.

Situation		Free Body Diagram
<i>Situation description</i>	$v = 0, a = 0$	<i>FBD of situation on left</i>
<i>Situation description</i>	$v \neq 0, a = 0$	<i>FBD of situation on left</i>
<i>Situation description</i>	$v \neq 0, a \neq 0$	<i>FBD of situation on left</i>

10. If you put a 1200 kg car on a scale (reading Newtons), what would it say? ie. what is the normal force supporting a 1200 kg car? Make sure you draw a FBD and write $F_{\text{net}} = ma$ to begin this solution.

11. What is the normal force supporting a 1200 kg car with a 75 kg person sitting in it and a 50 kg luggage rack on its roof?

12. What is the normal force supporting a 1200 kg car when a crane above it is pulling up on the car with a force of 500N?

13. What is the normal force supporting a 900 kg car in a mechanic's garage on a lift when the lift is accelerating the car up at an acceleration of 1.6 m/s^2 ?

14. The brakes are applied to a 750 kg car traveling 30 m/s and the car skids to a stop. The coefficient of sliding friction between rubber tires and wet pavement is 0.50.
 - a) What is the size and direction of the force of friction that the road exerts on the car?

 - b) What would be the acceleration of the car?

 - c) How far does it travel before it comes to a stop?

15. What is the force of friction between the dragster's tires and the track if the dragster has a mass of 300 kg and the coefficient of friction between the tires and the asphalt is 0.80?
16. _____ Law describes forces related to springs.
17. A steel spring is stretched from length 3.0 cm to a length of 8.0 cm. If the spring constant is 200 N/m, what force is required? Make sure you draw a FBD and write $F_{\text{net}} = ma$ to begin this solution.
18. A spring scale hangs from the ceiling of an elevator. Attached to the scale is a 25N weight.
- a) What is the scale reading when the elevator is still?
- b) What is the scale reading when the elevator is accelerating up at 1.5 m/s^2 ?
- c) How far does the spring compress/stretch in each situation if $k = 12 \text{ N/cm}$?
19. To slide a metal puck across a greased sheet of metal at constant speed requires a force of 0.525 N. If the force of gravity on the puck is 5.00 N, what is the coefficient of friction between the puck and the greased metal? Start by drawing a FBD (free-body-diagram). **Show your work** as shown in the lessons.

20. A car is travelling at 120 km/hr when it slams on the brakes.
- How long is the skid mark if the coefficient of friction is 0.62? (hint: convert km/hr to m/s)
Show your work as shown in the lessons.
 - Explain why a more massive car does not take longer to stop, given that Newton's 2nd Law tells us that a bigger force is required to slow down a bigger mass. Hint: mass also impacts _____. Explain:
21. A tow-truck is trying to pull a 1.4×10^3 kg car out of some mud. The coefficient of static friction is 0.76. What force will the tow truck have to apply to the car before it will start to move? **Show your work** as shown in the lessons.
22. The space shuttle has a mass of 2.0×10^6 kg. At lift-off, the engines generate an upward force of 3.0×10^7 N.
- What is the acceleration of the shuttle? **Show your work** as shown in the lessons.
 - If the shuttle is in outer space with the same thrust force, how would the acceleration change? Explain why this is so using Newton's Laws

23. The maximum force that the handles on a grocery bag can withstand and not rip is 250 N.
- If 20 kg of groceries are lifted from the floor to the table with an acceleration of 5 m/s^2 , will the bag hold? **Show your work** as shown in the lessons. (*ans. No - as proven*)
 - If the bag was lowered with the same acceleration would it be able to hold more or less mass? Prove with equations.

2D Force Problems:

- Bob pulls on a 10 kg mass with a force of 40.0 N North. Sally pulls at the same time on the mass with a force of 30.0 N West. What will be the resulting acceleration if the mass is on a frictionless surface?
- What is the net force on a mass if the force of 100 N at 53° AND a force of 120 N at 135° act on it at the same time?

3. A 25 kg box is pulled across a wooden floor with a rope. The rope makes an angle of 30° with the floor. The coefficient of friction between the box and floor is 0.21. A force of 75 N is exerted on the rope. How fast does the box accelerate along the floor?

4. A 50-N applied force (pulling 30 degrees up from the horizontal) accelerates a 5 kg box across a horizontal floor.
 - a. What is the normal force on the box?

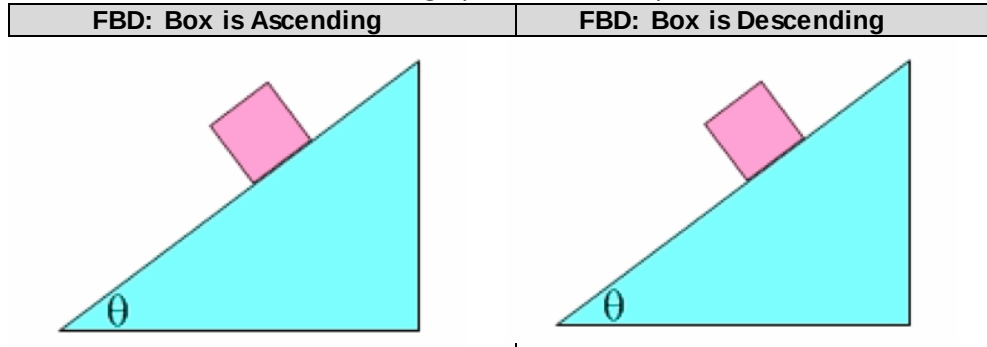
 - b. If the coefficient of friction between the floor and box is 0.15, what is the acceleration of the box?

Ramp Problems:

1. A 10 kg object rests on a 30° ramp which has a coefficient of friction of 0.20.
 - a) What will the object do?
 - b) What would a 50 kg mass do?

2. A box is pushed up a rough ramp (i.e. friction) with an initial velocity, v . As it ascends the ramp it slows to a stop after a distance, d . On the way down it accelerates over the same distance d . It is observed that the time it takes to climb up the ramp is significantly shorter than the time to return back down.

- i. Add the forces on the box in each of graphic below to represent FBD's in each case.



- ii. Starting with $F_{NET} = ma$, determine an expression for " a " (in terms of g, θ, μ).

a. Up the ramp:

b. Down the ramp

- iii. Using the answers above explain why the time is longer on the way down.

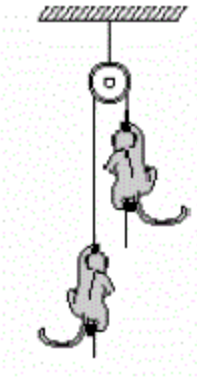
3. A 9.6 kg box slides down a ramp inclined at 32° to the horizontal. At what rate will it accelerate if the coefficient of kinetic friction is 0.28? Lay out your work as shown in the lessons.

Pulley Problems:

1. In order to solve pulley problems, you need to recognize that:
 - a. The _____ in the cable/rope is the same throughout.
 - b. The acceleration of the entire _____ is the same.
 - c. We can “cut the rope” to consider any part of the system, replacing the rope with a _____ in our FBD.

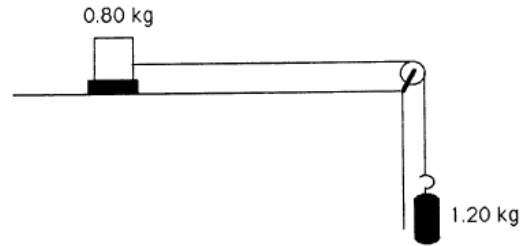
2. A pulley system involves two masses (8.0 kg and 3.0 kg) connected by a cable over a frictionless pulley. What is the acceleration of the system? What will be the rope's tension in this system, once released?

3. Two monkeys are connected by a rope of negligible mass, which passes over a pulley. Friction in the pulley is negligible. One monkey has a mass of 20.0 kg while the other has a mass of 22.0 kg.



- a. At what rate will the monkeys **accelerate**? **Draw a FBD and show your work** as shown in the lessons.
- b. Draw a FBD for each monkey. What will be the tension in the rope connecting the monkeys in the original system? **Show your work** as shown in the lessons.

4. Consider the system on the right.



a) What would be the acceleration and rope tension of the system if there was no friction? **Draw a FBD and show your work** as shown in the lessons.

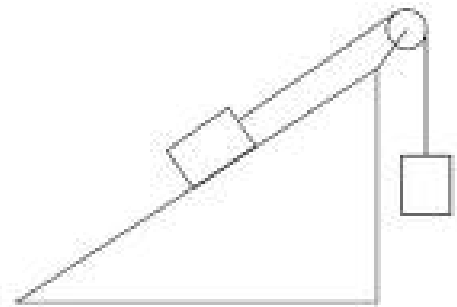
b) Repeat the above question assume that the coefficient of friction between the 0.80 kg mass and the table is 0.2. **Draw a FBD and show your work** as shown in the lessons.

c) From part a) what two forces are responsible for the motion entire system? What would we need to **increase** if we want the system to stop moving (2 answers)?

5. Two masses are connected with a rope and pulley as shown:

a. If the mass on the ramp is m_1 and the hanging mass is m_2 **carefully complete the free-body diagram for the system**. Be sure that forces include the subscript "1" if they are associated with mass 1 and "2" if they are associated with mass 2. Assume frictionless for now.

b. What forces (or components of forces) must we compare to determine if the box on the ramp goes up or down? Identify these forces below then circle these forces on the free-body diagram.



- c. Why must we do part "b" before we label any friction forces?

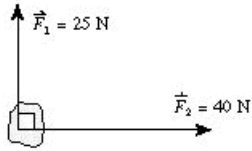
- d. If $m_1 = 7 \text{ kg}$, $m_2 = 6 \text{ kg}$, and the angle between the ramp and the floor is 40° , which way does the block on the ramp accelerate? Show any calculations below.

- e. If the coefficient of friction between the ramp and the block is $\mu = 0.1$, what is the acceleration of the system?

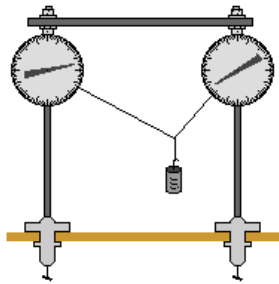
- f. What is the tension in the rope?

Translational Equilibrium:

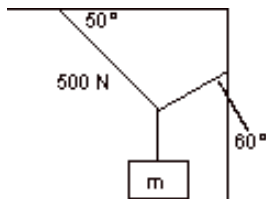
1. The picture below shows a top view of two forces acting on a mass. What is the value of the third force necessary to achieve translational equilibrium? Show all work and state both magnitude and direction.



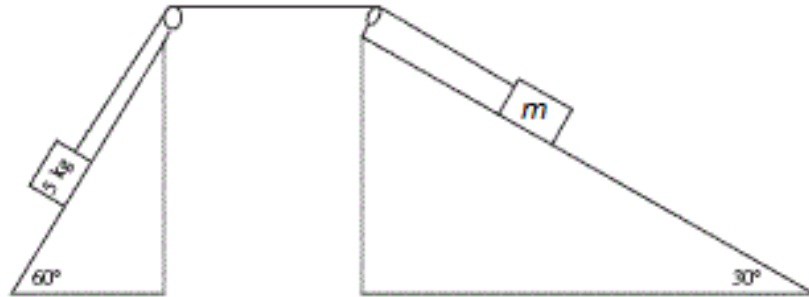
2. The experiment below shows two spring scales attached to a hanging mass. The system is in translational equilibrium. With the help of a good free-body diagram and/or any equations justify why the tension on the right hand cable is larger.



3. Determine the magnitude of the hanging mass, m . Show all work and construct a vector diagram labeling any forces clearly. The tension in the left-hand cable is 500N and the angle between this cable and the ceiling is 50° . The angle between the right-hand cable and the wall is 60° .

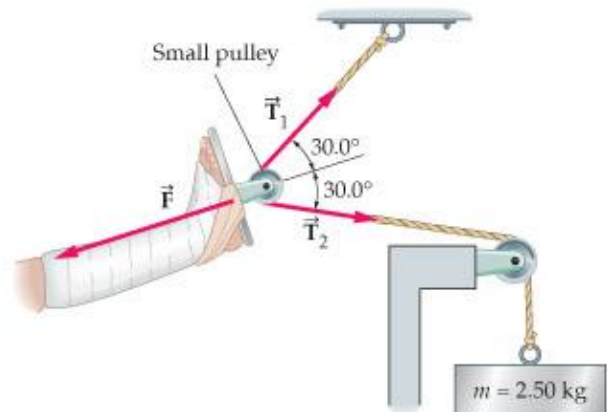


4. Two masses are placed on different smooth (frictionless) ramps and connected together with a rope (of negligible mass) as shown below.



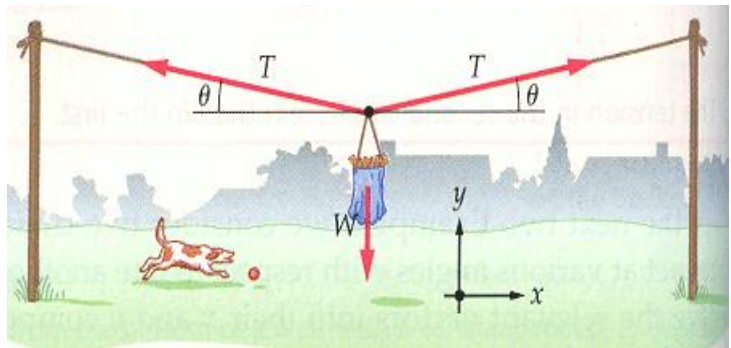
- i. Label all of the forces present on this diagram. Ultimately what two forces must balance each other to keep these masses from moving (the answer may be a component(s) of a force).
 - ii. Determine the mass of the box on the right to keep this system in translational equilibrium.
5. A leg is placed in traction to keep it elevated and prevent it from moving as shown:

- i. What is the tension in the rope (recall: one rope gliding through pulleys will have the same tension throughout)?

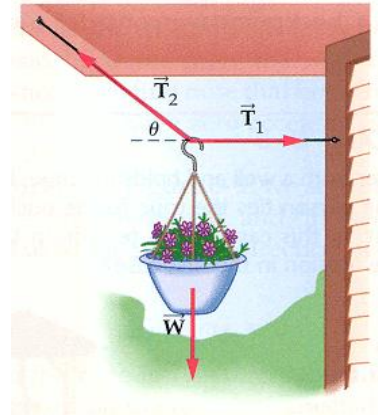


- ii. With what is force, F , that is acting to pull on the foot and keep the leg under tension?
Construct a vector diagram to assist with your solution.

6. Note the situation where the clothes hanging on the line may be too low.
If the weight of the clothes does not change, would raising the line create more or less tension, T ? To answer this, consider the required vertical component of T , then the horizontal. Why is an angle of 0° impossible?



7. To hang a 6.20 kg pot of flowers, a gardener uses two wires—one attached horizontally to a wall, the other sloping upward at an angle of $\theta = 40^\circ$ and attached to the ceiling.
- i. Which wire will have the most tension? Justify your answer (no math required – just a sound explanation).

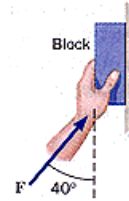


- ii. Find the tension in each wire using the two methods:

Method 1: Component method

Method 2: Vector diagram and trig method

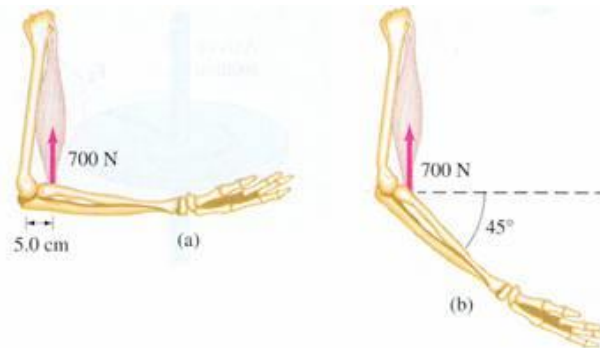
8. A block is prevented from sliding down a wall with a force, F as shown below. The coefficient of static friction between the block and the wall is $\mu_s = 0.2$.



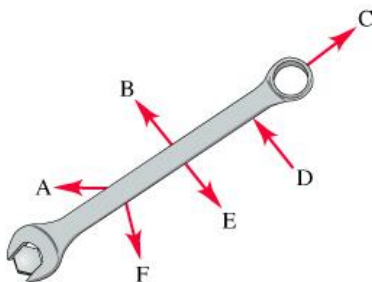
- a. Draw the FBD for this block.
- b. What force(s) are responsible for holding the block up? (you may use components of a force in your response)
- c. Describe how the friction force is generated (recall $F_f = \mu_s F_N$). You may use equations to help with your answer.
- d. If the mass of the block is 5kg, what is the **minimum** force, F , required to prevent the block from sliding down the wall?
- e. Describe how your free-body diagram would change if the question was rewritten as "What is the **maximum** force, F , required to prevent the block from slipping up the wall?" How would your answer change?

Rotational Equilibrium (Torque):

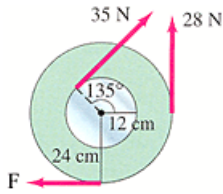
1. Your forearm can be considered a lever that can generate torques. The bicep muscle attaches to the forearm near the elbow as show. The bicep is capable of producing a force, $F = 700\text{N}$.



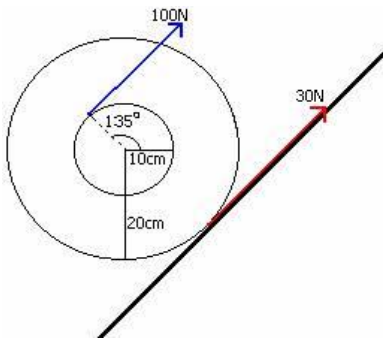
- a. Using the definition of torque, which position will the bicep generate the most torque on the forearm?
 - b. Calculate the torque produced by the bicep about the elbow in each position.
2. Forces of the same magnitude act on a wrench depicted below. Some of the locations and orientations are more effective than others in loosening the nut. Rank the forces according to their ability to generate a torque on the nut. Rank them from maximum torque to minimum and justify your rankings according to the definition of torque.



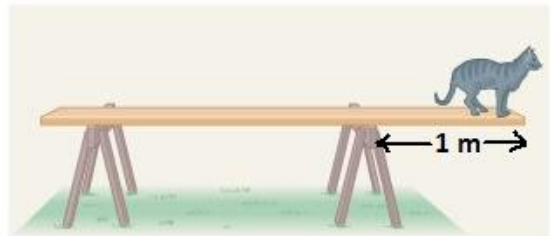
3. If the net torque is zero, what is F ? **Show your work.**



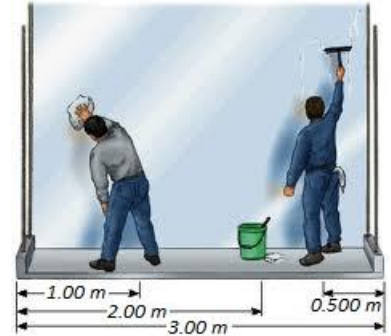
4. Only two forces act on the wheel below. A string is attached to the inner axel generating a force of 100N up the ramp. A friction force of 30N acts between the outer wheel and the ramp (up the ramp) preventing the wheel from slipping. What is the net torque on the wheel?



5. A 7kg cat walks to the end of a 15 kg board resting on two saw horses as shown below. When the cat is at the 1m position as shown, the board "just" lifts off of the left hand support. How long is the board?

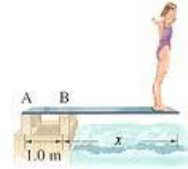


6. Two painters each of mass 75kg are positioned on a scaffold of mass 30kg as shown below. A paint can of mass 5kg is also on the scaffold.



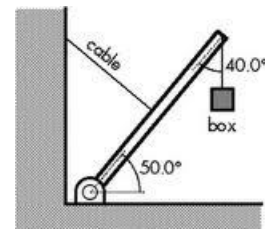
- a. Assuming the left rope has a tension of F_{T1} and the right rope has a tension of F_{T2} , which rope will have the greater tension acting on it? Justify your answer (*no math required – only an explanation*).
- b. Label all of the forces acting on the scaffold directly on the diagram above. What forces are unknown?
- c. The board is not rotating or accelerating. What two equilibrium conditions must be satisfied for this to be true? Write the formulas below.
- d. Since the board is not accelerating we may assume that $F_{\text{NET}} = 0$. Use this equilibrium condition to determine the magnitude of the sum of $F_{T1} + F_{T2}$? State the equation first, then solve.
- e. Starting with your net torque equilibrium condition (τ_{NET}), determine the tension in each rope. Show all work below.
- f. At some time during the day the workers get a call from their supervisor from the ground. He is in a panic. Apparently the ropes on the scaffold are dangerously old and need to be replaced. Each rope can only handle 925N of force. Fortunately our workers know their physics and reposition themselves quickly. What did they do to remain safe?

7. A diver of mass 50 kg is positioned at the end of a 4 m long diving board as shown below. The mass of the uniform board is 20 kg.



- a. The diving board is bolted down at only one of the supports. Which of the supports makes the most sense (A or B)? Answer by considering the removal of the bolts, and then discuss the solution.
- b. Construct a free-body diagram showing all of the forces acting on the board. Use this diagram to determine the magnitude and direction of the forces acting on support A and B.

8. A 20 kg uniform beam 10m long is attached to a wall with a cable. The cable is attached to the middle of the beam at 90° to the beam. A box of mass 50 kg is suspended from the beam as shown.

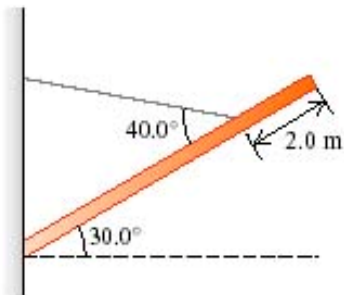


- a. Draw a free body diagram labelling all the forces acting on the beam (include the forces acting on the floor hinge). Choose and label an appropriate pivot point "P". Label all distances from this point.

b. Determine the tension in the cable.

c. Determine the force acting on the hinge at the bottom.

9. An 8m long beam of mass 30kg is supported at an angle of 30° above the horizontal with a cable as shown. Determine the tension in the cable. Show all work and label all forces on the diagram above.



Answers:

Dynamics Review:

- 1) 0,0,anything,anything 2) what cancels what? 3) all cancel 4) yes 5) yes(momentarily) 6)change
 7) $5.3 \times 10^4 \text{ N}$ 9) $F_{\text{net}}=0$, $F_{\text{net}}=0$, $F_{\text{net}} \neq 0$ 10) 12000N 11) 12985N 12) 11260 N 13) 10260 N
 14) a) -3675 N b) -4.9 m/s² c) 91.8 m 15) 2352N 17) 10N 18) a) 25 N b) 28.8 N c) 2.08m, 2.4cm
 19) 0.105 20) 91 m 21) $1.0 \times 10^4 \text{ N}$ 22) a) 5.2 m/s² b) increase, air, gravity 23) a) No, 296N b) Yes, 96 N

2D Force Problems:

- 1) $5.0 \text{ m/s}^2 @ 37^\circ \text{ W of N}$ 2) 167 N @ 82° N of W 3) 0.86 m/s^2 4) 24N, 7.9 m/s^2

Ramp Problems:

- 1) 3.2 m/s^2 [down], same 2) $a = g \sin \theta + \mu g \cos \theta$ $a = g \sin \theta - \mu g \cos \theta$ 3) 2.9 m/s^2

Pulley Problems:

- 1) tension(force), system, force 2) 4.5 m/s^2 , 42.8 N 3) a) 0.47 m/s^2 b) 205 N 4) a) 5.88 m/s^2 , 4.7 N
 b) 5.1 m/s^2 , 5.8 N 5) b) F_{g1x} , F_{g2} c) direction of F_f d) up e) 0.73 m/s^2 f) 54N

Translational Equilibrium:

- 1) $47 \text{ N} @ 32^\circ \text{ S of W}$ 3) 57kg 4) $F_{g1x} = F_{g2x}$, 8.7kg 5) 24.5N, 42.4N 7) $T_1 y = 0$, $T_1 = 72.4 \text{ N}$, $T_2 = 94.5 \text{ N}$ 8) b) F_y & F_f
 c) $F_f = \mu F_N$ where $F_N = F_x$ d) 54.8N

Rotational Equilibrium (Torque):

- 1a) first b) 35Nm, 24.7Nm 2) D, BE, F, A, C 3) 10.5N 4) 4Nm [rolling up] 5) 2.93m 6) a) T_2 b) T_1 , T_2
 c) $F_{\text{NET}} = 0$, $T_{\text{NET}} = 0$ d) $T_1 + T_2 = 1813 \text{ N}$ e) $T_1 = 776 \text{ N}$, $T_2 = 1037 \text{ N}$ f) symmetry 7) a) F_A b) $F_A = 1670 \text{ N}$ [down],
 $F_B = 2350 \text{ N}$ [up] 8) b) 756N c) 613N 9) 264N