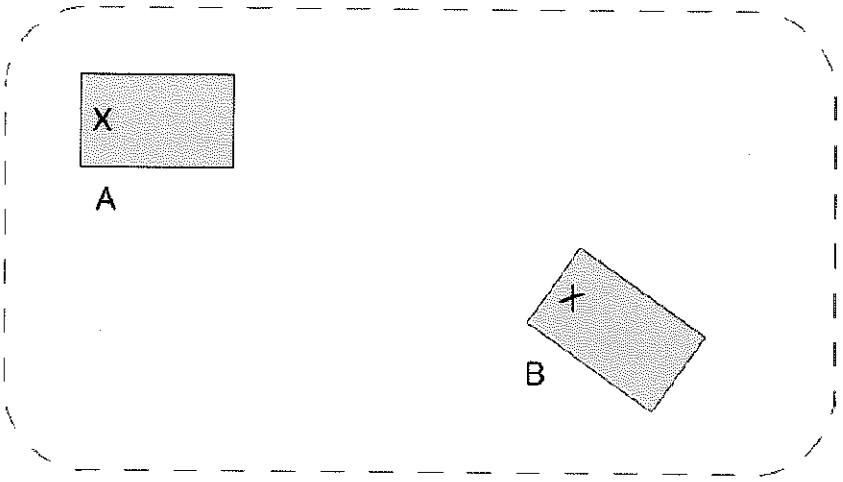
5.1 Worksheet: Robotic Arms and Degrees of Freedom

Name: _____ **Class/Period:** _____ **Date:** _____

In the following scenarios, draw the path that the object must take to get from Position A to Position B and answer the follow up questions.

Note: In each scenario you are shown a view from above (looking down at the tabletop). The object must not leave the table during its trip from point A to B. You also may not move the object outside of the dotted line.

Scenario 1



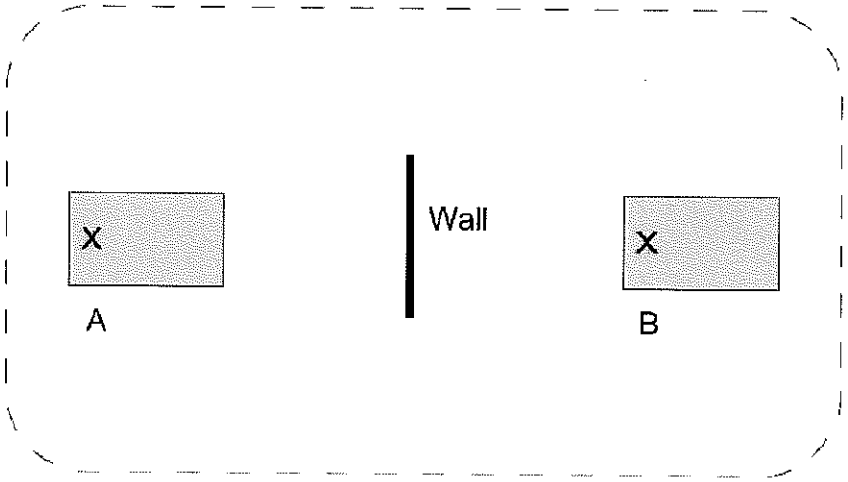
1 How many degrees of freedom did your path use?

_____

2 What is the minimum number of degrees of freedom to move from A to B?

_____

Scenario 2



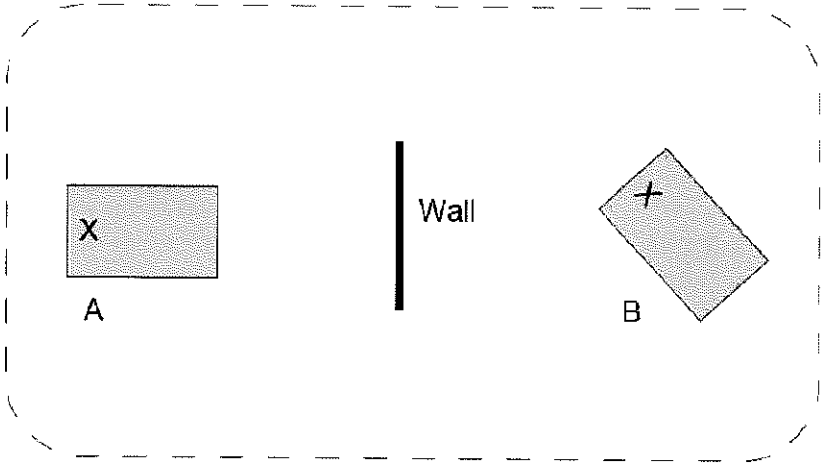
3 How many degrees of freedom did your path use?

_____

4 What is the minimum number of degrees of freedom to move from A to B?

_____

Scenario 3



5 How many degrees of freedom did your path use?

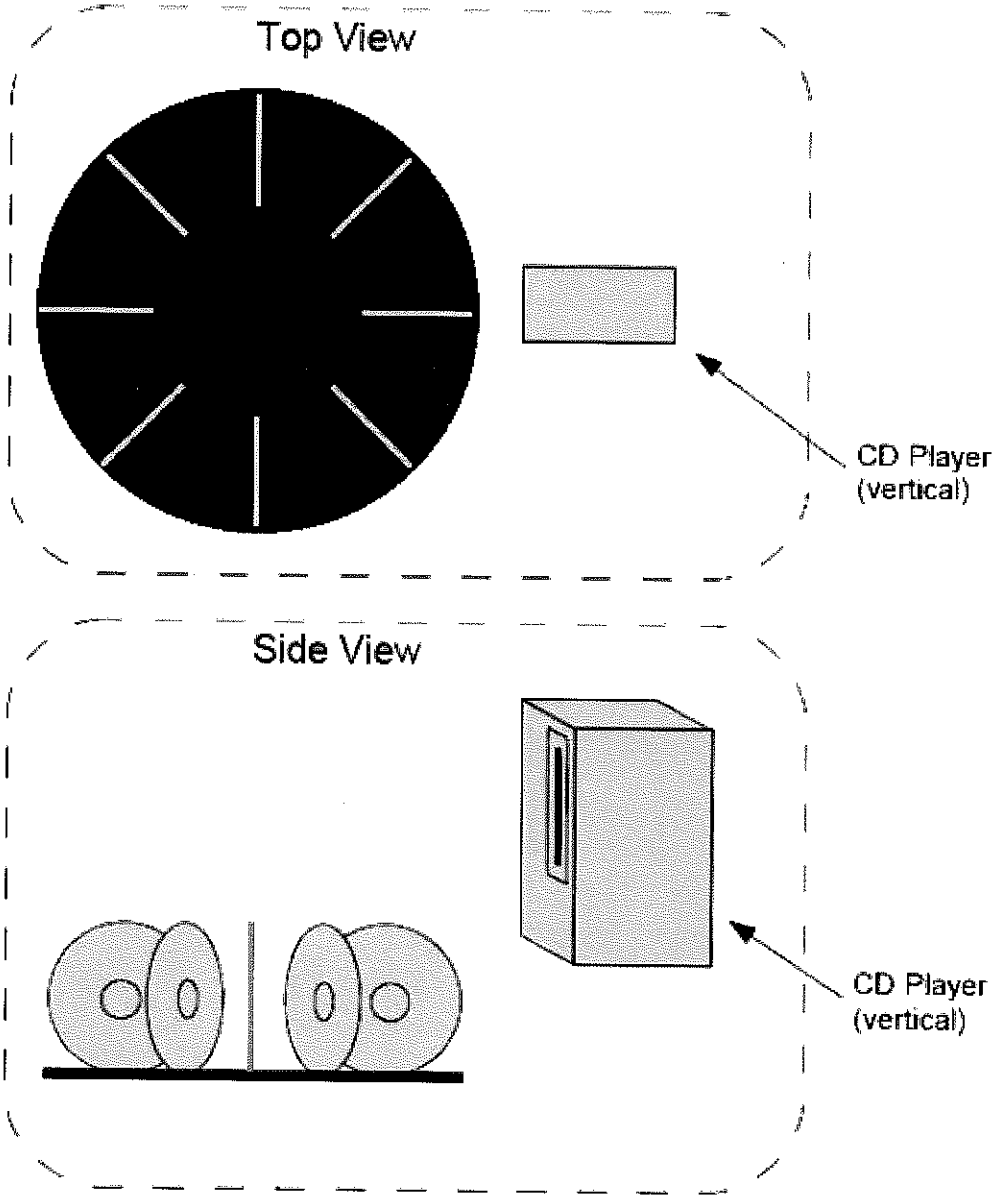
_____

6 What is the minimum number of degrees of freedom to move from A to B?

_____

Robot Design - You are given the following problem:

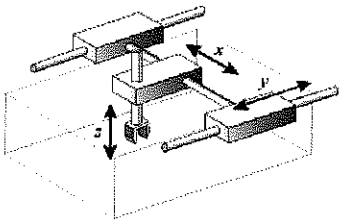
A music DJ wants to have a CD player that is visually appealing for a party. He would like you to design a robotic arm that sits in the middle of the CDs that is capable of picking them up placing them into the CD player automatically.



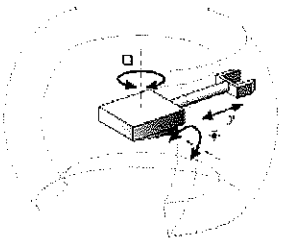
The CD holder has the CDs in a round pattern, the holder does NOT rotate or move in any way. Your task is to design a robotic arm that will automatically load and unload the CD's into the CD player.

The three types of robotic arms that you can use:

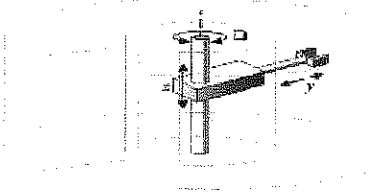
Cartesian Arm



Polar Arm



Cylindrical Arm



Part 1: Problem definition. Answer each question with a short paragraph.

7 Does the CDs orientation need to be rotated as it is moved from the rack to the Player?

8 Are there any obstacles that need to be avoided?

Part 2: Draw the CD path. If it helps, you may use additional paper to draw the individual movements that the CD will take.

Part 3: How many degrees of freedom are required to move the CD? Please label all of the degrees of freedom above on your drawings.

Part 4: Select the arm type that best fits this problem, explain your selection.

5.2 Activity: Construction of a Robotic Arm

Name: _____ **Class/Period:** _____ **Date:** _____

Question Sheet

Question 1 Looking at the arm by itself (i.e., not including the robot chassis), how many degrees of freedom does the arm have? For each degree of freedom, indicate whether it is translational or rotational.

_____

_____

_____

_____

_____

Question 2 Draw the path of the arm, assuming the robot remains stationary.

continued

Question 3 Taking the entire robot into consideration, how many degrees of freedom does the arm have? For each degree of freedom, indicate whether it is translational or rotational.

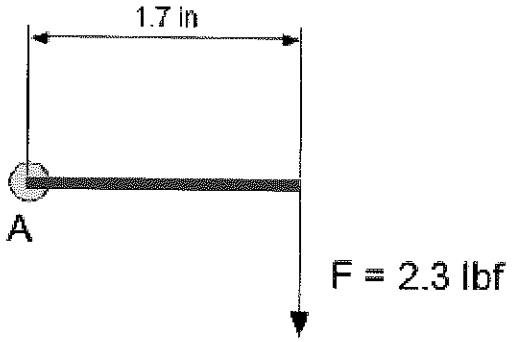
Question 4 Draw the path of the arm, including the robot movement.

5.3 Worksheet: Mass, Weight and Torque

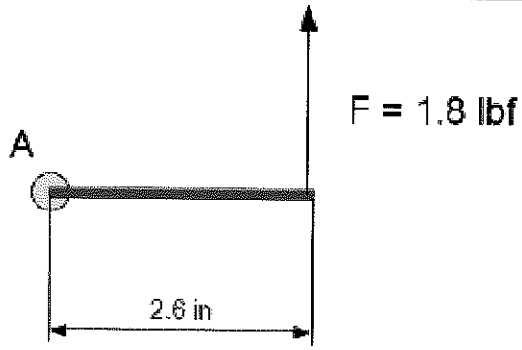
Name: _____ **Class/Period:** _____ **Date:** _____

Problems 1 through 4: Perform a torque sum around point A. Show all of your work.

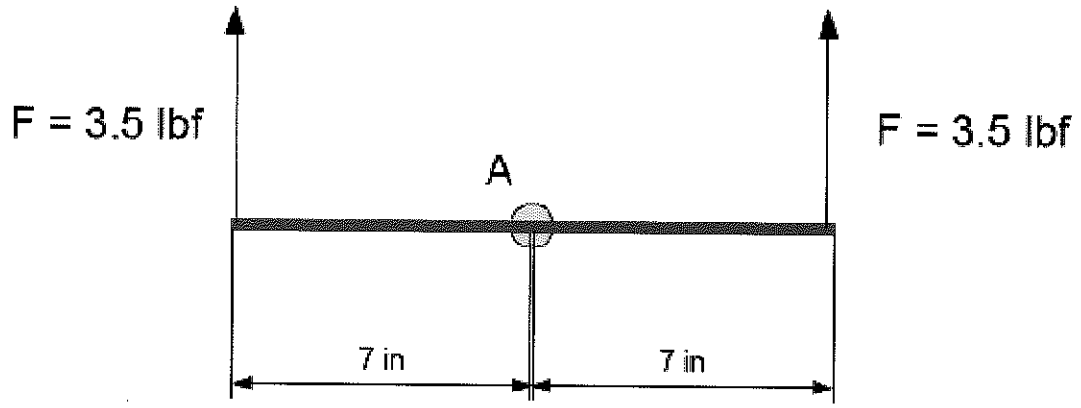
Problem 1.



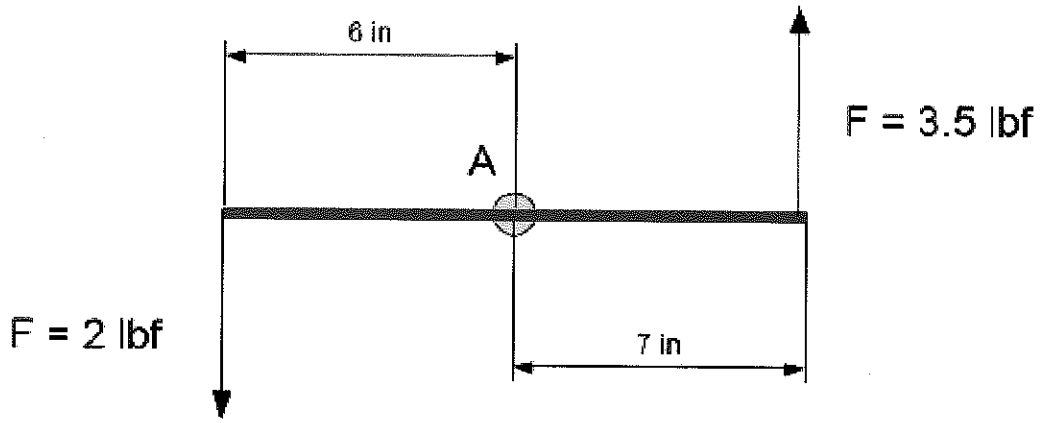
Problem 2.



Problem 3.

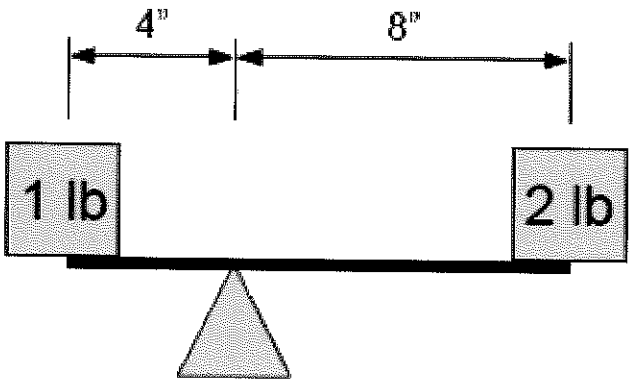


Problem 4.

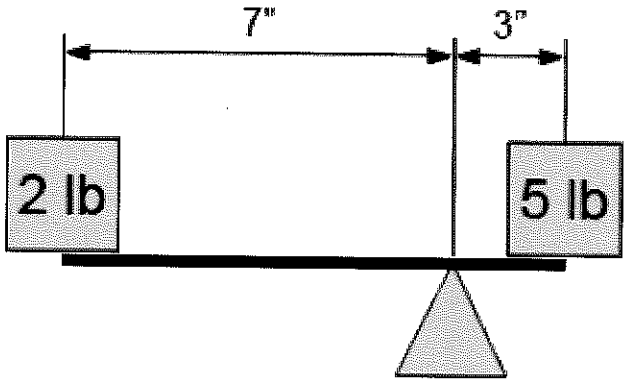


For problems 5 through 7, calculate what will happen to the balance. Explain your answer and show all work.

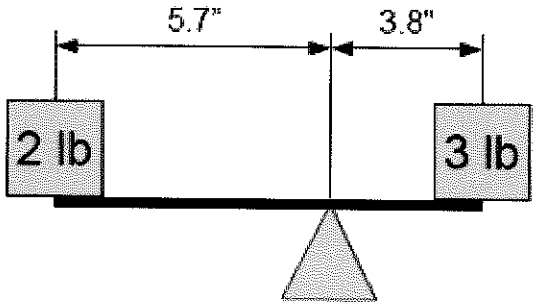
Problem 5.



Problem 6.

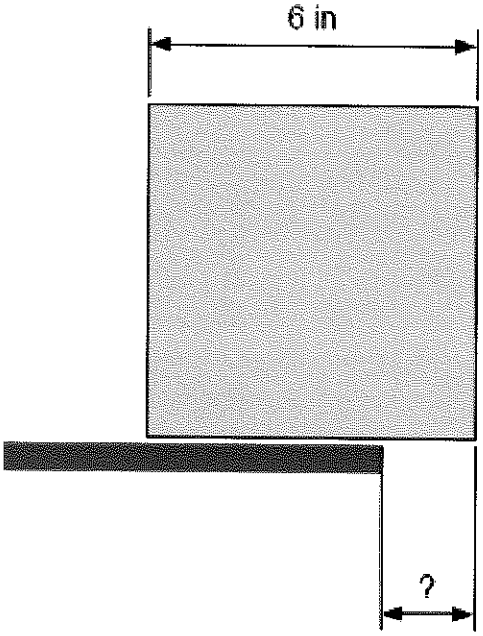


Problem 7.



Problem 8.

Given a block of uniform density, at what distance from the edge will the block start to teeter and begin to fall? Explain why.



5.4F Activity: Center of Weight – Fundamental

Name: _____ **Class/Period:** _____ **Date:** _____

Question Sheet

Question 1 Why do you think it is important to predict how much added weight will cause the robot to tip?

Question 2 Write a short paragraph comparing your observations of the tipping experiment to the mathematical prediction of the weight required to tip the robot.

Question 3 If there was a difference between your calculations and your empirical data, explain why.

5.5 Worksheet: Torque, Gear Ratio, and Payload Weight

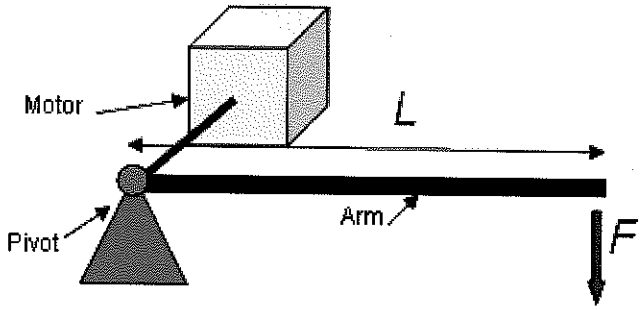
Name: _____ **Class/Period:** _____ **Date:** _____

In the following exercises, a motor is connected to a load as shown in the illustration. In each case, you are to solve for the one bit of information that is not known but can be derived from other bits of data.

Be prepared to hand this in for review at the next class.

1 A motor is directly connected to an arm. The arm is exactly horizontal and has a force applied vertically downward at the very end.

Given the following conditions, calculate the required motor torque (T) to achieve torque equilibrium (ie: counteract the applied load). **Express your answer in units of in-lbf** and show all of your work. If you run out of space, you may use the back of the page.



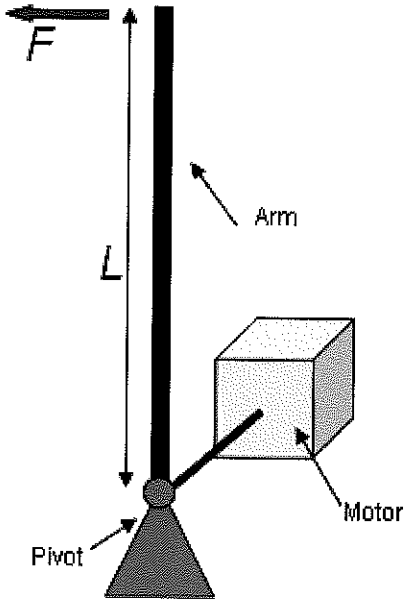
Example:
L = 3 in, F = 6 lbf
Ans-> T = -18 in-lbf

Given: L = 5 in, F = 1 lbf

Calculate *T* = _____*in-lbf*

2 A motor is directly connected to an arm. The arm is exactly vertical and has a force applied horizontally in a counterclockwise direction.

Given the following conditions, calculate the required motor torque (T) to achieve steady state (ie: counteract the applied load). If you run out of space, you may use the back of the page. **Express your answer in units of in-lbf** and show all of your work.



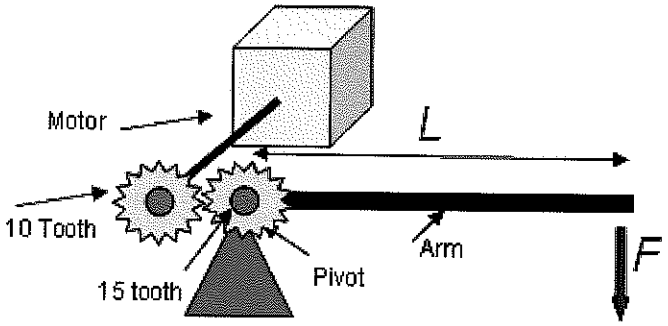
Example:
L = 3 in, F = 6 lbf
Ans-> T = 18 in-lbf

Given: L = 2.7 in, F = 3.2 lbf

Calculate: *T* =_____ *in-lbf*

3 A motor has a gear with 10 teeth. The arm has a 15 tooth gear at its pivot. The arm is exactly horizontal and has a force applied vertically downward at the end of the arm.

Given the following conditions, calculate the required motor torque (T) to achieve steady state (ie: counteract the applied load). If you run out of space, you may use the back of the page. **Express your answer in units of in-lbf** and show all of your work.



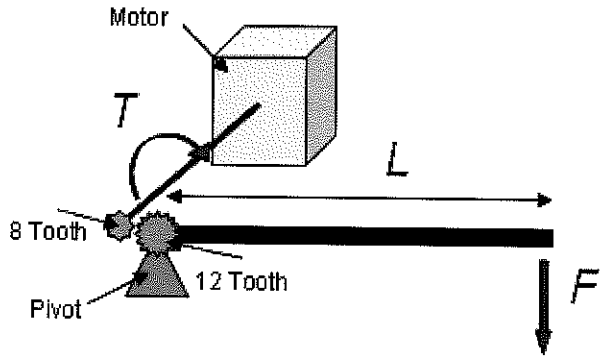
Example:
L = 3 in, F = 6 lbf
Ans-> T = 12 in-lbf (Hint: The gears change the direction or rotation!)

Given: L = 4.9 in, F = 1.7 lbf

Calculate: *T* = _____ *in-lbf*

4 A motor has a gear with 8 teeth. The arm has a 12 tooth gear at its pivot. The arm is exactly horizontal and has a force applied vertically downward at the end of the arm.

Given the following conditions, calculate the force required (F) to achieve steady state (ie: counteract the applied motor torque). If you run out of space, you may use the back of the page. **Express your answer in units of lbf** and show all of your work.



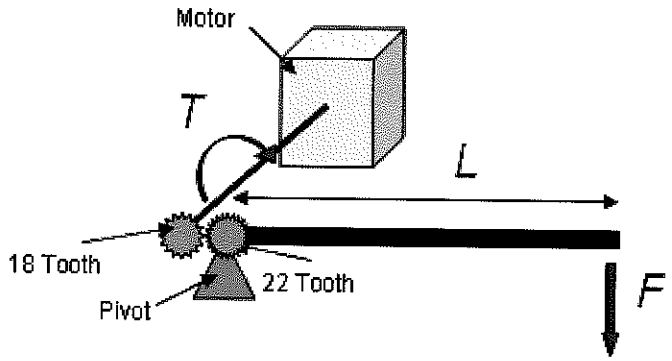
Example:
L = 3 in, T = 6 in-lbf
Ans-> T = 3 lbf

Given: L = 7 in, T = 2 lbf-in,

Calculate: *F* = _____ *lbf*

5 A motor has a gear with 18 teeth. The arm has a 22 tooth gear at its pivot. The arm is exactly horizontal and has a force applied vertically downward at the end of the arm.

Given the following conditions, calculate the length (L) to achieve steady state (ie: counteract the applied motor torque). If you run out of space, you may use the back of the page. **Express your answer in units of in** and show all of your work.



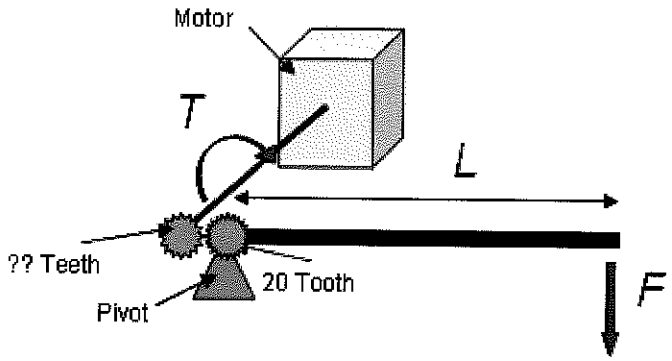
Example:
T = 3 in-lbf, F = 6 lbf
Ans-> L = 0.61 in

Given: T = 2 in-lbf, F = 2 lbf

Calculate: *L* = _____ *in*

6 The arm has a 20 tooth gear at its pivot. The arm is exactly horizontal and has a force applied vertically downward at the end of the arm.

Given the following conditions, calculate the number of teeth (T1) on the motor shaft needed to achieve steady state (ie: counteract the applied motor torque). If you run out of space, you may use the back of the page. **Express your answer in number of teeth** and show all of your work.



Example:

T = 3 in-lbf, F = 6 lbf

Ans-> L = 0.61 in

Given: T = 2 in-lbf, L = 4 in, F = 1 lbf

Calculate: *T1* = _____ *teeth*

5.6 Activity: Stall Torque

Name: _____ **Class/Period:** _____ **Date:** _____

Question Sheet

Question 1 What possible sources of error are present in this experiment?

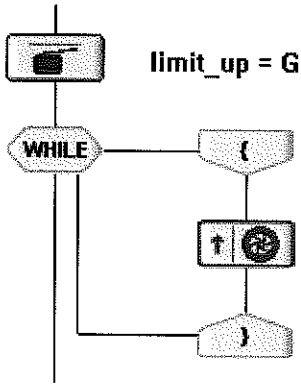
Question 2 How do your results compare to those from Activity 3.15? What factors may have influenced changes? What do you expect remained the same?

5.7 Worksheet: Radio Control and Limit Switches

Name: _____ **Class/Period:** _____ **Date:** _____

Solve the following problems.

1 A fellow student has written the following section of code to control the up movement of an arm with a limit switch:

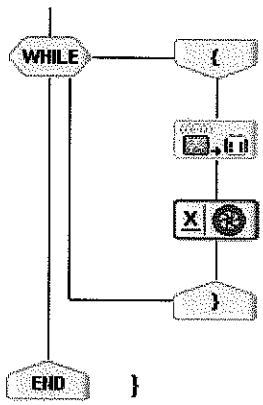



```
limit_up = GetDigitalInput [ 1 ] ; // Get limit switch info

while [ limit_up == 1 ] // Loop until limit switch is pressed
{

SetMotor [ 1 , 255 ] ; // Move the arm motor

}
```

The program does not work right, and you offer to help debug the problem.

- Identify and circle any error(s) in the program above.
- Describe the error(s) in your own words.
- Describe how you would correct the program to eliminate any error(s) found.

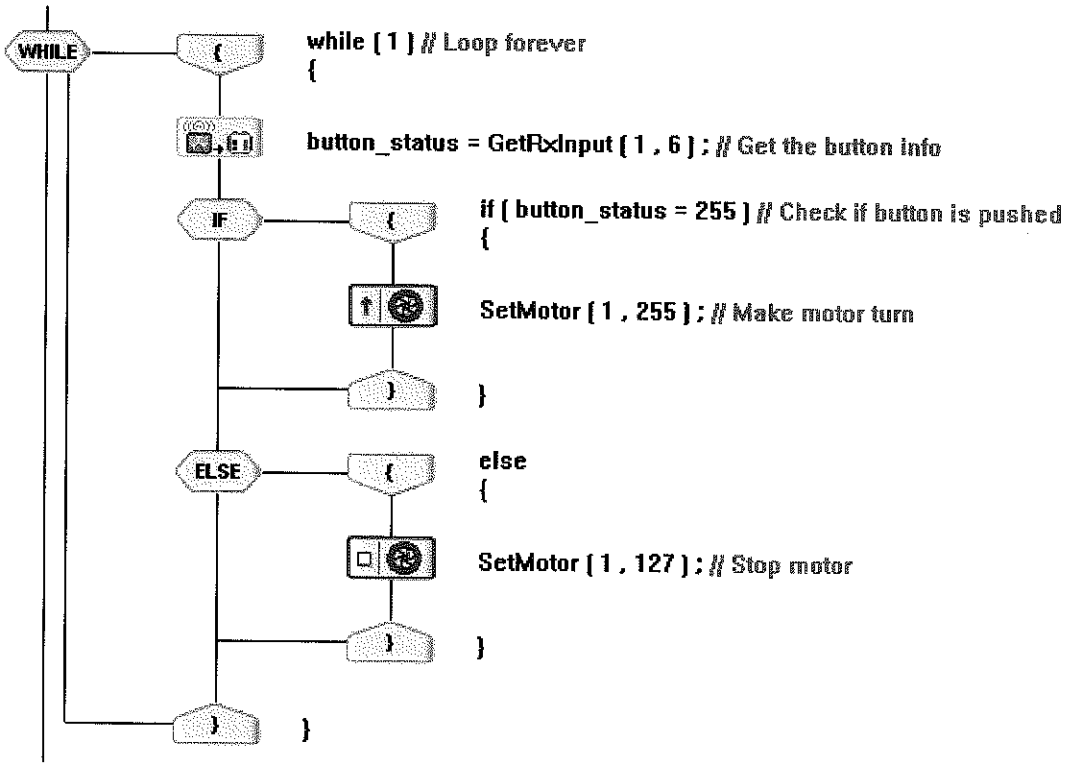
2 Your friend is again having problems with his robotics code. This time he has tried to write a radio control algorithm to control his robot.



Help complete the program.

- Identify and circle any error(s) in the program above.
- Describe the error(s) in your own words.
- Describe how you would correct the program to eliminate any error(s) found.

3 The following program uses a button on the controller.



help debug the problem.

- Identify and circle any error(s) in the program above.
- Describe the error(s) in your own words.
- Describe how you would correct the program to eliminate any error(s) found.

5.8F Activity: Windshield Wiper - Fundamental

Name: _____ **Class/Period:** _____ **Date:** _____

Question Sheet

Question 1 Does your arm bend the switches? If so, what degree of bending occurred?

Question 2 Did your arm bend the lower switch more than the upper one, vise versa, or neither?

Question 3 Explain what steps to take to reduce the amount of bending in the switch.

Question 4 Did your arm move faster in one direction than the other? If so, how would you compensate in your program to make it more consistent?

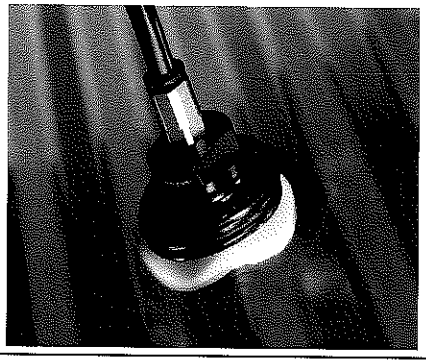
5.9 Worksheet: End Effectors

Name: _____ **Class/Period:** _____ **Date:** _____

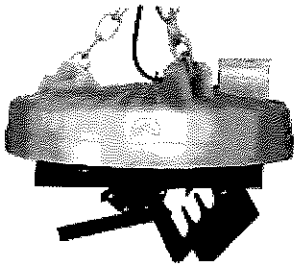
Solve the following problems.

You are given the following end effectors. For each given problem, choose the end effector type that best suits solving the task. Write a paragraph detailing the advantages of your choice and the disadvantages of the remaining end effectors.

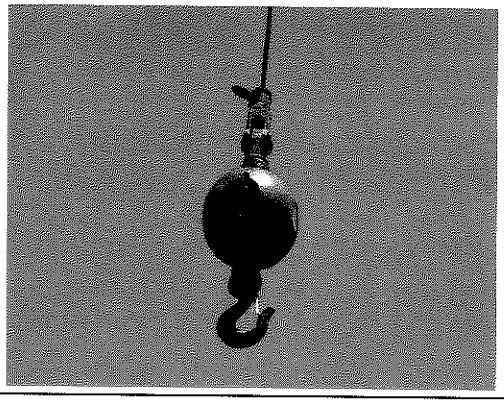
Suction Cup



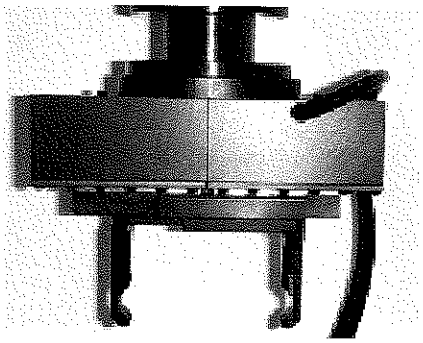
Electromagnet



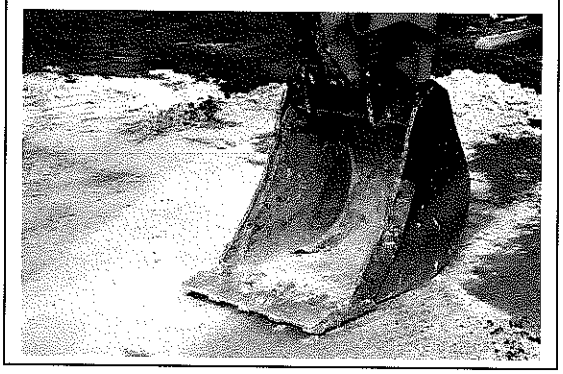
Hook



Mechanical gripper claw



Scoop



Other–an end effector of your choosing. Describe it in detail.

1 In an automated assembly line, an articulated arm must repeatedly pick up picture frames from a conveyor belt and stack them in a box for packaging.

2 A crane in a junkyard must pick up scrap metal from a pile and transfer it to a large compactor.

3 In a metal foundry, a robotic arm must work in a harsh environment to transfer liquid molten metal from a furnace into a mold

5.10F Activity: End Effector - Fundamental

Name: _____ **Class/Period:** _____ **Date:** _____

Question Sheet

Question 1 List the number and type of degrees of freedom of the completed ball-gathering BaseBot.

Question 2 During this activity, there were two different types of control that were explored: Manual Control and Automatic Control. Describe the advantages and disadvantages of each.

Question 3 Using other types of sensors that you have learned about, design and describe a robot that could be used in the class competition, where the behavior of the arm and end effector is totally autonomous, and the human operator only controls the driving of the robot.