ME250 | Fall 2017 | University of Michigan

HW3: Bike Lab (Transmission and Linkages, Springs and Bearings) and Dynamics

- This is an **Individual Assignment,** although for the lab portion, you may take measurements in a group.
- Due on Thursday, October 5th by 5pm in the ME250 homework box outside the ME250 shop.

This tutorial will guide your team through a hands-on assignment. You are required to disassemble the bicycle as instructed in part A, perform measurements on the disassembled bicycle by following part B, and finally reassembling the bicycle (reverse part A). You will be required to submit a copy of your solutions to the problems described in part B.

Extended ME 250 Shop Hours

- Thursday, September 28th 2:30PM – 4:00PM
- Friday, September 29th 9:00AM-12:00PM; 2:00PM-6:00PM
- Tuesday, October 3rd 10:30AM-12:00PM; 1:30PM-7:30PM

Part A: Bicycle disassembly

In order to start the hands-on assignment, you need the following:

a. Safety glasses
b. A digital camera (cell phone camera is perfect)
c. Suitable clothing (because you can get dirty from bike grease)
d. A copy of this tutorial

Please go through the steps of the assignment in the following order.
Take ample images showing the components before and after disassembly.

1. The GSI will point out the bicycle and bicycle stand that you will be working with and will give you a set of tools that you can use through the session.
2. Take a photo of the bike and the tool set before you start to do any tasks.
3. Ensure that the bike is securely mounted on the bike stand. Your GSI can readjust the mount if necessary.
4. Test the functionality of the brakes and the derailleur (by pedaling and changing gears). Report to the GSI if you notice any malfunction.
5. Begin disconnecting the brakes so that you can take the wheels out. You do not need to disassemble all components of the brake to disconnect it. Please refer to **Figure 1**.

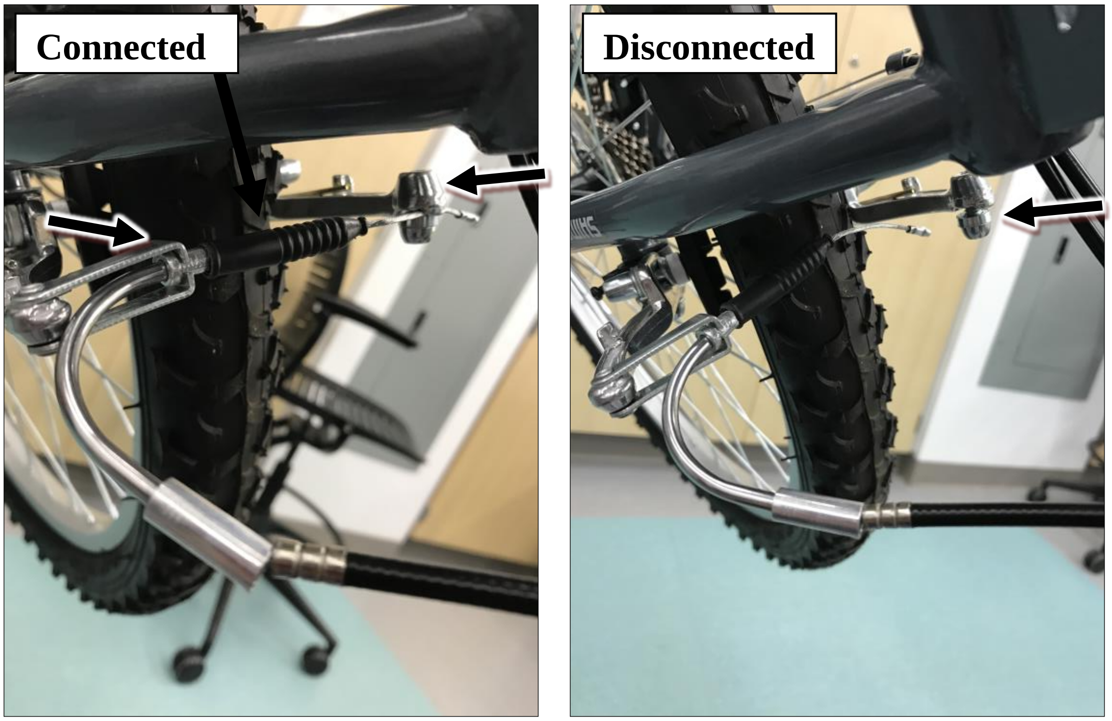


Figure 1: (Left) Connected brake system; (Right) Disconnected brake system

6. Disassemble the wheels (**Figure 2**). You must unscrew two nuts on each wheel. Leave a couple of threads engaged so the nut does not get lost. For the back wheel, you will need to carefully remove the chain from the engaged sprocket. You should not need to take the chain off.

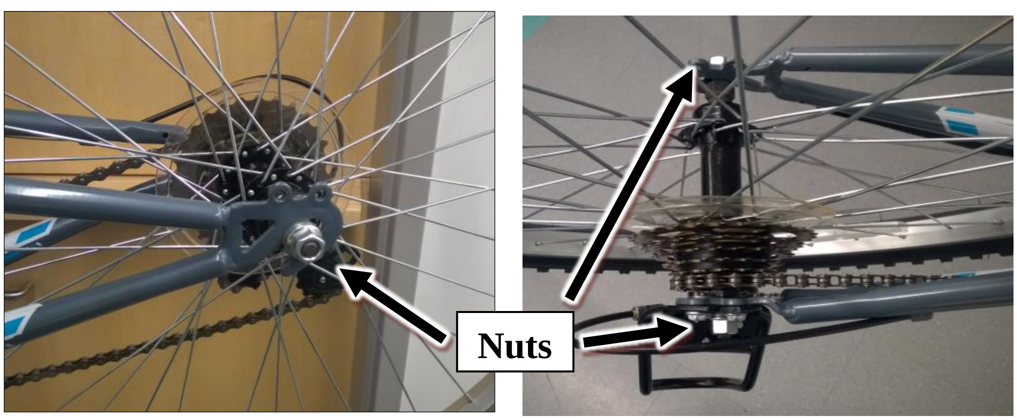


Figure 2: Rear wheel nut

7. Observe the mechanism of the chain and recognize the chain pin and spacer in **Figure 3**.

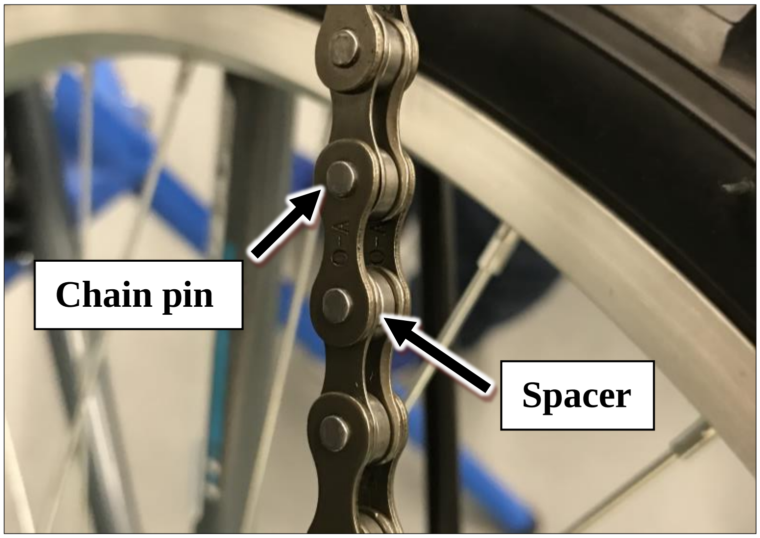


Figure 3: Components of a bike chain

8. Disconnect the back wheel structure from the rear suspension spring as shown in **Figure 4**. For this, you need to unscrew the bolts shown and remove the threaded spacers.

Figure 4: Rear suspension spring

Part B: Measurements and homework problems

For the homework, include the bike model together with your team name (if you do not have one yet, come up with one) and team number. Also, this homework is an **individual** homework and please include your responses to all questions.

1. Transmission (10 points)
   a. (5 points) Count the number of sprockets and the teeth on each sprocket. After open lab hours, identify all possible gear speed ratios and put them in order from smallest to largest ratio, showing which combination of gears you need to achieve each ratio. Report all these values neatly in tables.
   b. (5 points) Measure the diameter of each sprocket and later identify and report the circular pitch of each sprocket.

2. Linkages (10 points)
   Understand how the brake mechanism works. Identify all the links and joints, and measure the lengths of the links such that you can determine the mechanical advantage relating the force that you apply to the brake lever and the force that is applied by the braking pads to the rims. Finally, find the relation between the force applied on the brake lever and the braking torque acting on the wheel. Hint: 1) you will need to estimate the coefficient of friction between the rubber material and the wheel hub; 2) you can assume there is no torque loss during the brake cable transmission.

   For your submission for this part, please report:
   a. Your measurements (these may differ from one bike to the next);
   b. Your methodology and algebra/calculations;
   c. Your final answer for the mechanical advantage of the brake; and
   d. Your final answer for the relation between the braking force and the torque acting on the wheel.

3. Bearings (10 points)

   Identify the bearings used in the bike based on the functionality of each joints on the bike and the characteristics of different types of bearing. These can include radial ball bearings, thrust ball bearings and bushings. Try to identify as many as you can for each type of bearing and clearly indicate the location on the bike, type, and function of each bearing.

4. Springs (Not graded)

   a. (Not graded) Estimate the spring constant by measuring the spring dimensions using the spring theory that you learned from a video and lecture.
   b. (Not graded) Perform a simple experiment to measure the stiffness of the spring, and report the results of your measurements, your calculations, and your final answer.

   First, you need dismount the spring damper assembly from the bike. Refer to **Figure 5** to see how you can extract the spring out of the spring assembly. You need to take out the white plastic spacer using a flat head screw driver. Once it comes out you can take the bushing out of the damper shaft and you can unscrew the nut and take the spring out.

   Warning! When reassembling, be careful not to cross-thread the nut onto the damper!
   To avoid cross-threading, give the nut a couple turns in the opposite direction until you feel the threads click into place.

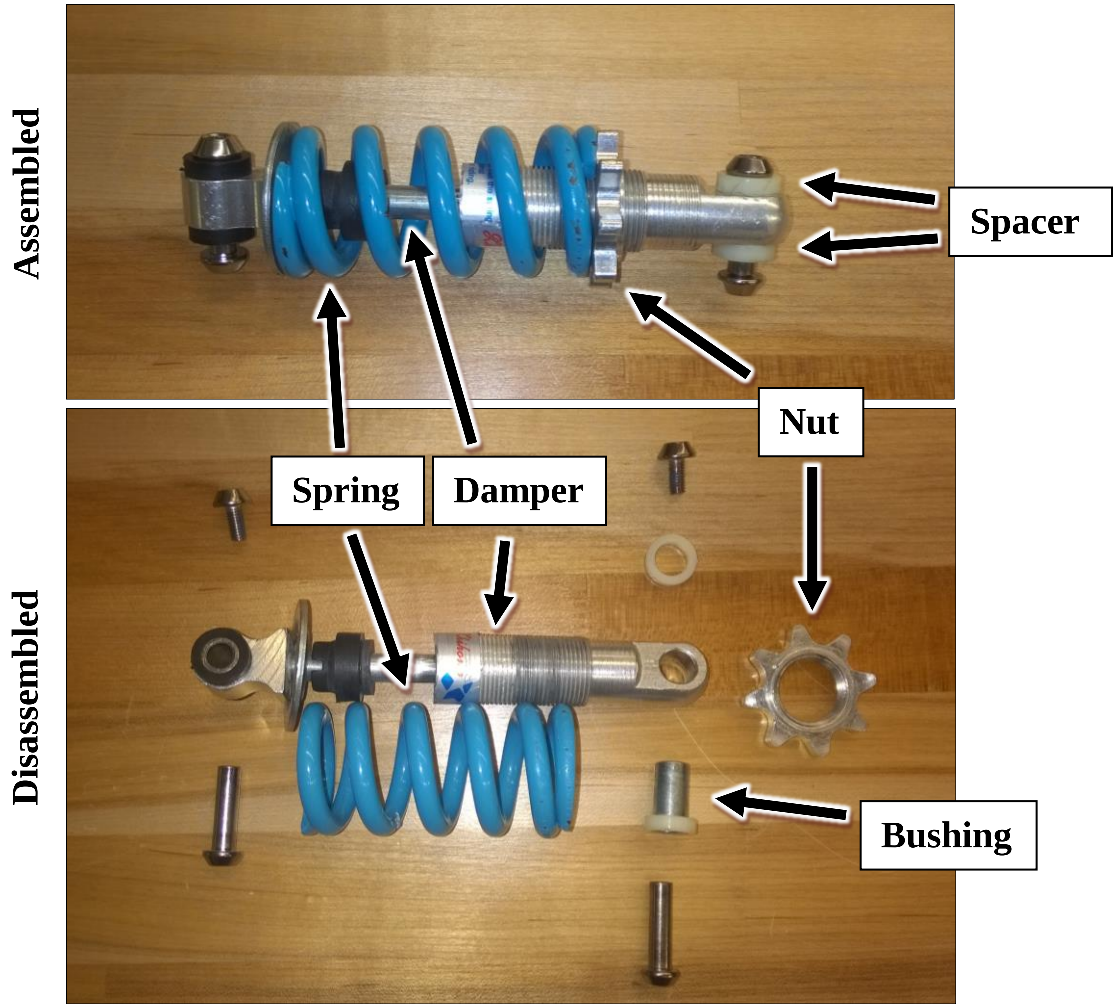
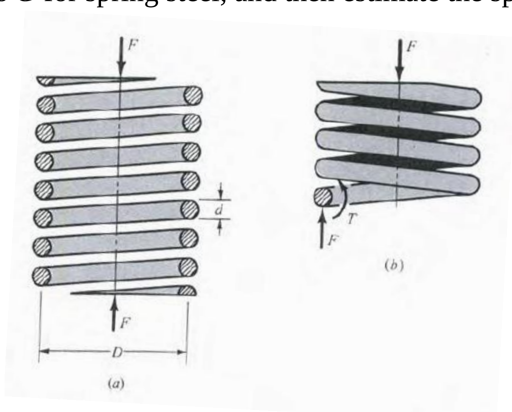


Figure 5: Spring-damper assembly

Next, you will need to take measurements of the spring dimensions: wire and coil diameters, number of turns and end conditions, and the total length. You have to look up the value of shear modulus *G* for spring steel, and then estimate the spring constant using the equation.



$$k = \frac{d^4 G}{8 D_m^{\ 3} N_a}$$

G = Shear modulus
N_a = number of active coils (see the last figure on the final page of this assignment)
D_m = mean diameter of the coil (shown as D in the figure above)

You are now ready to perform an experiment to measure the spring rate (stiffness). You will need to use the parts and tools shown in **Figure 6** and follow the following steps.

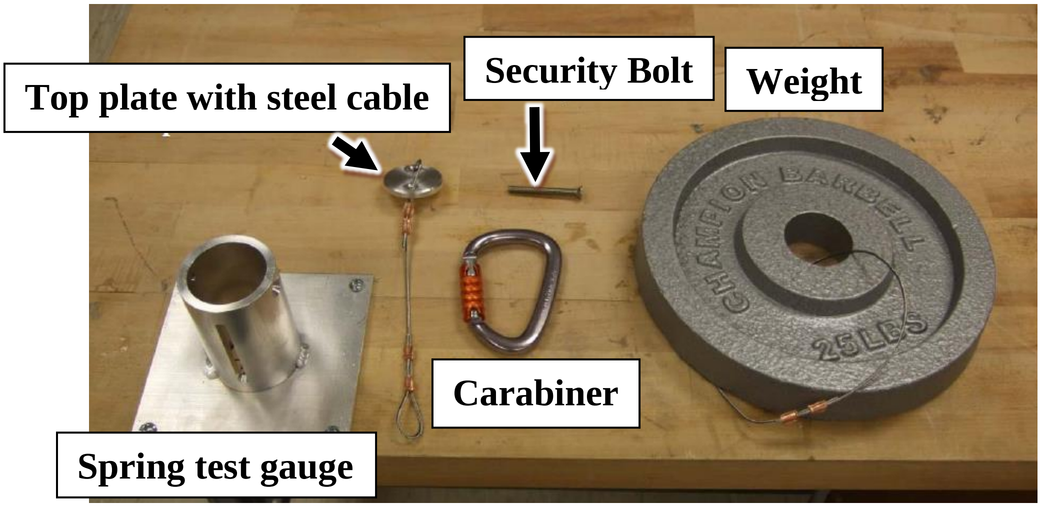


Figure 6: Spring constant measurement

i. Take out the top plate from the gauge and put the spring into it.

ii. Place the top plate on the spring. The steel cable goes through the center of the spring coil as in **Figure 7**.


Figure 7: Spring housed in the gauge

iii. Rethread the security bolt, and make sure it is screwed on the gauge tightly as in **Figure 8**. You are now ready to perform the experiment.

Figure 8: Spring ready for testing

iv. Use the probe of the caliper to touch the top plate and measure the current position of the spring as shown in **Figure 9**. Record the reading in your notebook.

Figure 9: Measuring the spring position using the caliper

v. Hang the carabiner on the steel cable with narrow end up and wide end down. **Figure 10** shows you how to use this type of locking carabiner.

Figure 10: Unlocking the carabiner

vi. Have two people add the 25 lb weights on the carabiner's wide end as shown in **Figure 11**. You should be very careful not to drop the weight, especially on your feet! Perform the depth measurements as in **Figure 9** again in order to record the displacement of the spring. Try to do the depth measurement in the same location each time for measurement consistency.

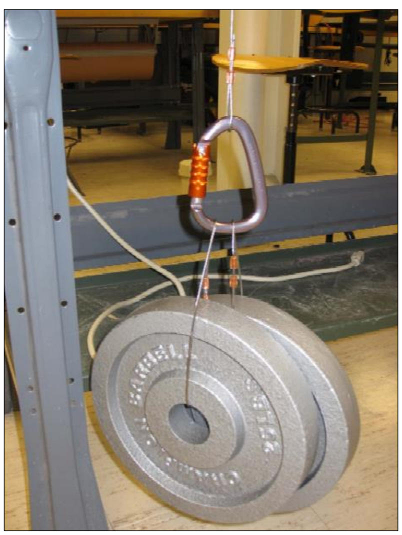


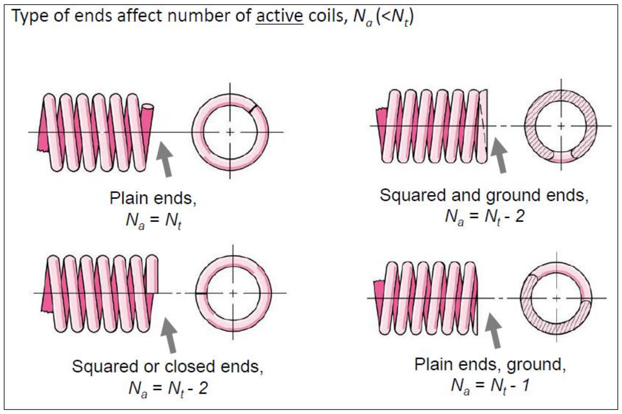
Figure 11: Hanging the weights from the carabiner

vii. Add more weights and do the measurement at each time you increase the load. You can have 4 weights (100lb) maximum.

viii. Unload the weights carefully after you are finished. You should have two people doing this. Be careful to not drop the weights.

You should have at least 3 measurement points to plot the relationship between axial load and the spring displacement. Estimate the spring constant by fitting a straight line to your measurement points and compare the difference between your experiment result and the calculation above.

Reference for the spring calculation:



2) **Analysis Dynamics (20 points)**

Your ME250 team wants to use the planetary gearbox motor, available in you kit, to lift a very small load weighing 1.28oz. You have designed a lifting arm which weighs 0.488oz. Using SolidWorks, you determine that the center of gravity of the arm is 1.5 inches from the shaft. When lifting, the load will be 3 inches from the shaft. Note, the spec for the planetary gearbox motor gives the stall torque/no load speed at 3V, but our battery pack will output 6V, so assume the motor in the problem will be operated at 6 V. Note that due to the large number of gears in mesh, the efficiency of the gearbox can be quite low: use $\gamma = 0.3$ in this case. Show work for each step.

a. Following the procedure for the Lifter calculation, and selecting from only the gear ratios available in the **planetary gearbox motor kit**, find the smallest gear ratio that will lift the load with a safety factor of two. Do your calculation assuming the worst-case orientation of the arm.
b. Continuing to use the Lifter procedure, calculate the speed of the arm in units of RPM, when lifting the load using this gear ratio.
c. If you use the highest available gear ratio to lift the load **instead of** the gear ratio that you selected in part a, what will be the speed of the arm in units of RPM?