Bicycle Dissection Labs

Purpose: To learn more about the most widely used transportation vehicle in the world - how it functions, how it evolved, and how to keep yours in better condition.

Acknowledgement: This module uses as its inspiration materials from ME99: Mechanical Dissection, a 10-week course at Stanford University developed by Sheri Sheppard under the auspices of the NSF Synthesis coalition.

Physical principles involved: Static torque and force analysis, power transmission

Mechanisms involved: Mechanical transmissions (crank, roller chains, sprockets), ball bearings, tubular frames, brakes, free-wheel, shifter (derailleur)

Activities: Dissection, sketching, CAD drawing, force/power analysis

Required tools: Basic toolbox, parts bin, lubricants (30W oil, Teflon lube, white lithium grease), cleaning solution (kerosene), special bike tools:

- Crank Spanner
- Cone Wrenches (9, 11, 13, 15 mm)
- Freewheel removal tool
- Spoke Wrench
- Chain tool

Dissection Deliverables:
1. Assembled, working, well-adjusted bicycle;
2. Computer generated assembly drawing of rear hub unit; and
3. Detailed journal record of activities including:
   a) details of all procedures followed and answers to all questions, and
   b) sketches of parts and assemblies and all other pertinent information.

Bicycle Dissection Schedule:
Some General Guidelines:

1. Follow all instructions.

2. Use the limited lab time wisely. Come prepared and ready to work. Try not to spend too much time on things you can do later, at home.

3. Return all tools to proper place at the end of each session.

4. Put all oil, kerosene, or solvent soaked rags and waste materials in the designated metal container (to avoid causing a fire).
Session 0: Getting the Patient Ready

Readings:  
Chapter 1 - Home Bicycle Repair (BM Guide)  
Chapter 2 - Frames  
Chapter 4 - Wheels and Tires, pp. 38-57

Objectives:  
a) Understanding of shop practices and safety procedures.  
b) Assignment of lab partners, tool boxes and bike.  
c) Perform basic calculations and measurements.

Procedure (record all answers in your journal):

1. Note the manufacturer and model of your bicycle (if available).

2. Identify the type of tubing (material) used in the frame and how the joints are connected.

3. Take your bike out for a ride. Carefully observe its operation and make notes in your journal. Also note any defects in its performance.

4. What is a comfortable "cruising" pedaling rate for you (in RPM of the pedal crank)? Determine it experimentally for one member of your group.

5. Determine:  
a) the weight of your bike, and  
b) the weight distribution (on front and rear wheels) with a rider.

6. What happens to the weight distribution when the brakes are applied (either front or rear)? Why?

7. Record in your journal and on a separate sheet of paper any missing or damaged components that need to be replaced, including flat tubes and tires. Hand in the sheet of paper at the end of class so that replacement parts can be purchased for reassembly.
Session 1: Brakes and Gearing

Readings: Chapter 13 - Brakes  
Chapter 17 - Gears

Objectives: a) Troubleshoot, disassemble and clean front and rear brake systems.  
b) Gain familiarity with transmission basics.

Procedure (record all answers in your journal):

A. Brakes
1. Troubleshoot your brakes (front and rear) as described on pp. 228-229 of the BM Guide.  
Make a list of any necessary replacement parts in your journal and on a separate sheet of paper to be handed in at the end of class.

2. Make a complete sketch of the front and rear brake systems before disassembling them.  
Label all parts and the routing of the cable. This sketch will be very useful when you reassemble the system.

3. What is the cable housing made from? How does the braking system accommodate cable stretch?

4. What type of brake system does your bike use? Are there any springs in the brake system?  
If so, why and how many? Find an alternate brake design on one of the other bikes in class (or in the parking lot) and sketch it.

5. a) Describe the application of braking force on a center-pull brake.  
b) Describe the application of braking force on a side-pull brake.  
c) Which type is better and why?

6. Calculate the mechanical advantage of your rear brake system (ratio of brake force to lever force) using principles of statics. Draw free-body diagrams of the front brake lever and rear brake assembly. Measure and note distances on each drawing as applicable.

7. Disassemble front and rear brakes, cleaning components as described in Chapter 13. Note any missing or damaged components that need replacement. Also, note all cleaning procedures used. Put all components in bin provided.

B. Gears
1. Sketch and describe the "flow" of power through a bike from the point were your foot touches the pedal to the point where the tire meets the road.

2. Determine and list the gear ratios for each speed of your bicycle.

<table>
<thead>
<tr>
<th>#teeth -front</th>
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<tbody>
<tr>
<td># teeth - back</td>
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</table>
3. Troubleshoot the gearing system. Do all the gears work? How well does it shift?

4. What materials are used for the chain and gears? Why?

5. What is the diameter of the rear tire on your bike?

6. What affect would increasing the size of each of the following have on output force and output speed, assuming that the pedal force and velocity are unchanged (i.e., constant input power by the rider)? (Refer to slides from lecture on “Biomechanics of Cycling”.)

<table>
<thead>
<tr>
<th>Increase in:</th>
<th>Effect on Output Force (↑ or ↓)</th>
<th>Effect on Output Speed (↑ or ↓)</th>
</tr>
</thead>
<tbody>
<tr>
<td>front chain ring (# of teeth)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rear cog (# of teeth)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rear wheel (diameter)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>crank arm length</td>
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</tbody>
</table>

7. For your bike, what output force at the rear wheel would result from a 120 pound input force at the pedal for:
   a) the lowest gear ratio?
   b) the highest gear ratio?

8. How many horsepower (average) are needed for you to pedal from the flashing light in Pine Grove Mills to the top of Pine Grove mountain (Route 26) at 10 mph. What gear would you use and why? Does the choice of gear affect the HP required? Why or why not? List all your assumptions. A bicycle power calculator and topo-map (distances and elevations) of the area can be found online: [http://www.mne.psu.edu/simpson/courses/me240/bicycles.html](http://www.mne.psu.edu/simpson/courses/me240/bicycles.html).

9. How much energy (in Milky Way bar equivalents) is needed to climb Pine Grove Mountain?
Session 2: Shifters, Chain

Readings:  Chapter 9 - Gear Shift Levers
           Chapter 8 - Chains

Objectives:  a) Disassemble and clean gear shifters.
             b) Disassemble and clean chain.

Procedure (record all answers in your journal):

A. Rear Shift Lever
1. What type of loading is seen by the shift cable? What kind of loading is seen by the cable housing (i.e. tension or compression)? Why is a cable used instead of a single wire?

2. Disassemble the rear shift lever. How many parts are in it? Why are all these parts needed? Explain how the mechanism works and how it is adjusted.

3. Clean the shift lever and replace any worn parts. Reassemble the unit.

4. Put all components in the bin provided.

B. Chain
1. What is the condition of your chain?

2. Read the instructions for the chain removal tool. Remove the chain by pushing out the master pin (but not all the way, or you will never get it back together!).

3. How many pieces are in a single unit of chain (i.e., the smallest “repeatable” unit from which an entire chain can be assembled)? Make an assembly sketch of a chain unit.

4. What is the pitch and width of the chain?

5. Clean and lubricate the chain as necessary.

6. Put all components in the bin provided.
Session 3: Rear Derailleur, Freewheel, Rear Hub

Readings:  
Chapter 11 - Rear Derailleurs  
Chapter 7 - Freewheels  
Chapter 5 - Hubs

Objectives:  
(a) Remove and clean derailleur.  
(b) Remove and clean freewheel.  
(c) Disassemble, clean, measure and make assembly drawing of rear hub.

Procedure (record all answers in your journal):

A. Rear Derailleur  
1. Remove the rear derailleur, clean and lubricate, but do not disassemble unless necessary.  
2. What is the job of the rear derailleur? Describe its action through words and sketches.  
3. Put all components in bin provided.

B. Freewheel  
1. Remove the freewheel from rear hub but do not disassemble.  
2. What is the purpose of the freewheel? Describe its action through words and sketches.  
3. Put all components in bin provided.

C. Rear Hub  
1. Disassemble the rear hub. Be careful when you access the bearings as they get lost easily.  
2. Make a sketch of the entire hub assembly, labeling all parts.  
3. How does a quick-release mechanism work? Describe its action with words and sketches.  
4. Examine the bearings in the rear hub.  
   a) What type of bearings are in the rear hub? How many bearings are there? How many elements do the bearings have? What size are the rolling elements?  
   b) What types of loads do the bearings support (radial, axial, thrust)? How is the pre-load set in the bearings? What are the dangers of pre-loads that are too high or too low?  
   c) What is the recommended maintenance interval on the rear bearings? What is the recommended lubricant?  
5. What is the significance of the direction in which the freewheel turns in order to be tightened onto the rear hub?  
6. Put all components in the bin provided.
Session 4: Crankset

Readings: Chapter 6 - Crankset

Objectives: Remove and clean crankset.

Procedure (record all answers in your journal):

1. Remove the pedals from the cranks; clean them if necessary. What allows them to rotate within the crank arm? How are the pedals fastened to the crank arms?

2. Remove and clean the left crank arm. How is the crank arm fastened to the axle?

3. Remove and clean the right crank arm and chain ring; do not loosen the chain rings from the spider.

4. Remove and clean the bottom bracket assembly and crankshaft. Sketch the bottom bracket assembly, labeling each part.

5. Why is one cup “fixed” while the other is “adjustable”? (If you have a single-piece crank arm, look at another group’s bike to answer this question.)

6. Examine the threading on both cups; is it the same on both cups? If not, why is one side different from the other? How is it different? (If you have a single-piece crank arm, look at another group’s bike to answer this question.)

7. Count the number of ball bearing elements in each cup. How does this number compare to the number of ball bearing elements found in the rear hub assembly? Are these elements the same size as those used in the rear hub? If not, why not? Finally, what advantages does a sealed bearing cartridge offer over an open, grease-packed set of ball bearings? What are some possible disadvantages of a sealed bearing cartridge?

8. How does the bottom bracket assembly differ from the rear hub assembly? Describe using words and sketches as needed.

8. Put all components in bin provided.
Session 5: Reassembly and Adjustment

Readings:  BM guide, your journal

Objectives:  Put it all back together, *in better shape than when you began!*

Procedure (record all answers in your journal):

1. Reassemble your bike.
2. Lubricate all necessary areas with the appropriate lubricant.
3. Repair, replace, clean, or adjust any other elements of your bicycle as needed.
4. Adjust the seat and handlebar positions to one of your group members as shown in the BM Guide (pp. 266-267, 280-283).
5. Take your "new" bike out for a ride. Have all the problems that you identified before you started the dissection been fixed?
6. Demonstrate your "new" bike in class.
Session 6: Wrap-up and Feedback

Objectives:  a) Reflect on the overall bicycle dissection experience.
             b) Provide feedback for course improvement.

Wrap-up Questions (record all answers in your journal):

1. What criteria must a bicycle designer consider (things like cost, weight, looks, etc)? List as many criteria as you can think of. In real life, you cannot have everything you want; so, tradeoffs and compromises between competing requirements must be made. Comment on the tradeoffs made on your bike and how the other bicycle designs in the room may have made different compromises.

2. How is a mountain bike different from a road (touring) bike? How does the type of bike (its application) change the design tradeoffs?

Bicycle Dissection Feedback:
Please comment on this lab experience by answering the following questions in your journal.

A. Would you rather have seen more/less:

| instructions concerning assembly/dis-assembly | less | about right | more |
| questions relating to the dissection          |      |             |      |
| written assignments                           |      |             |      |
| lectures (if so, on what topics)             |      |             |      |
| time allotted for lab                         |      |             |      |
| open lab time                                 |      |             |      |
| help during open lab time                     |      |             |      |
| other                                        |      |             |      |

B. How would you rate the difficulty of this dissection?
   Trivial                             About right                  Too difficult
   1              2            3             4            5

C. How would you rate the overall value of the bicycle dissection as a learning experience?
   Worthless                     Mediocre             OK                    Good         Excellent
   1                   2                3                  4           5

D. How would you rate the video and student presentations on the evolution of the bicycle?
   Worthless                     Mediocre             OK                    Good         Excellent
   1                   2                3                  4           5

E. How could the learning experience be improved?
Discussion Questions

While watching the 25-minute video, “The Evolution of the Bicycle,” please take notes on the following questions as they will be graded. We will discuss these questions in class afterwards.

1. How were the earliest versions of the bicycle propelled?

2. Identify two disadvantages of the large-wheeled velocipede? What improvements were made to overcome these disadvantages?

3. What principal factor led to the development of the current “diamond frame” design?

4. Identify 3 other factors that helped advance the development of the bicycle.
   
   •
   
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5. Identify 3 factors that hindered the evolution of the bicycle.
   
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   •
   
   •

6. Finally, what do you think the next evolution of the bicycle will entail? What do you envision as the bicycle of the future? What types of components will it have? From what materials will it be constructed? Will it evolve to fulfill a specific function? If so, what?