Mechanical Engineering: An exciting journey on bicycles

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- Uses principles of physics, mathematics, engineering, material sciences
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- Three main streams:
  - Design
  - Manufacturing
  - Thermal utilization/Energy conversion

Where all is mechanical engineering being used?

- Knowledge dissemination

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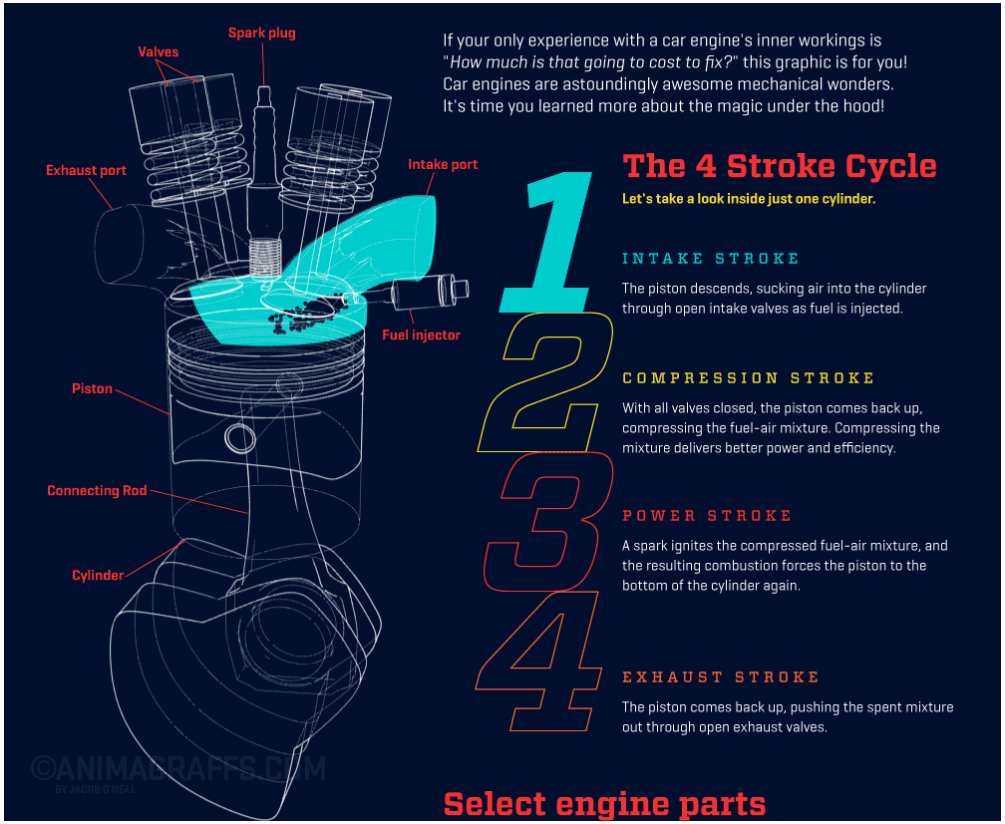

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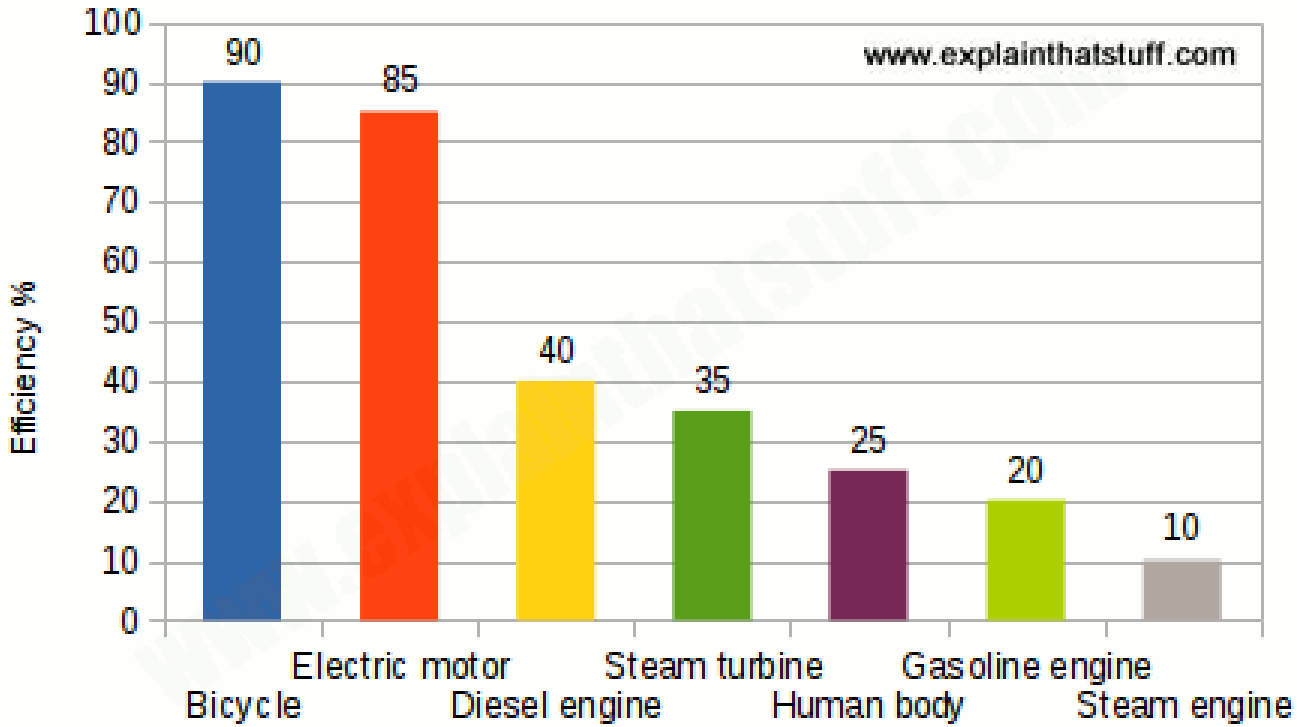
LET US EXPLORE BICYCLES!

1. Why is bicycle exciting?
2. History of bicycles
3. Taking it apart

Why is bicycling exciting?



Most efficient transport machine humans have developed so far!

Why is bicycling exciting?

- Higher efficiency $\Longrightarrow$ you can go further with the same amount of fuel
- You are carrying only a fraction of your weight along
- "A racing bicyclist at 32 km/h could travel more than 574 km/l if there were a liquid food with the energy content of gasoline"

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Bicycle – a machine!

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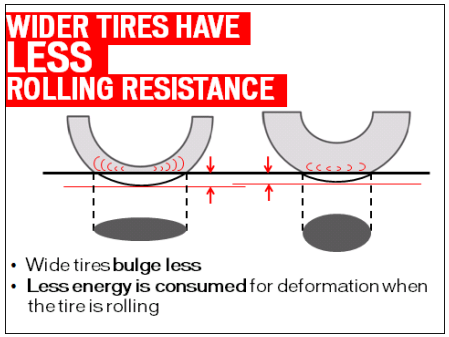

(a) Rolling-resistance

(b) Air-resistance

(c) Uphill against gravity

(d) Cracks/Pot holes

History of bicycles

Velocipede: 1820s

- No pedals! – Foot pushed
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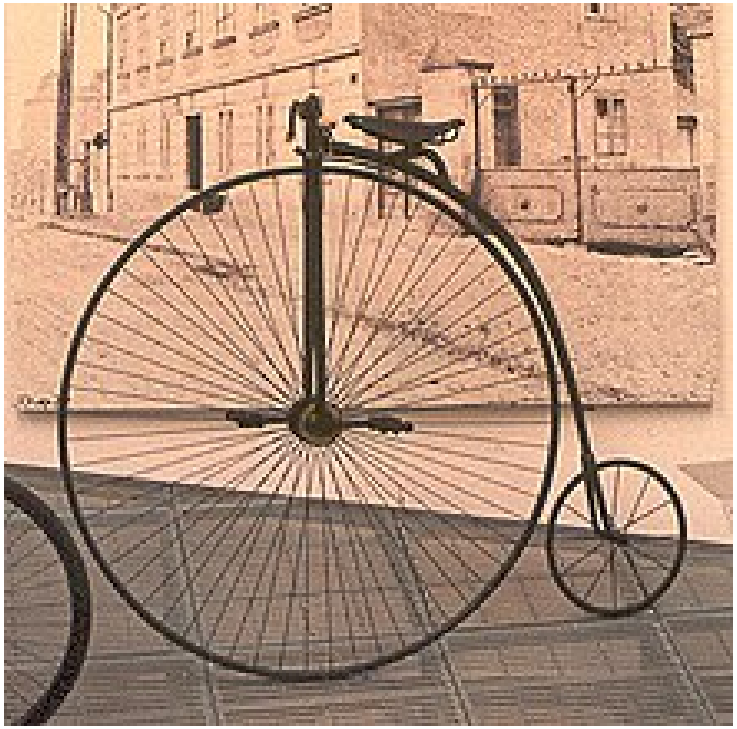
- No pedals! – Foot pushed
- Constructed almost entirely of wood – weighed $\approx$ 22 kg
- Brass bushings within the wheel bearings, iron cased wheels
- Difficult to balance and led to accidents

Bone-shaker: 1860s

- First type of true bicycle with pedals
- Stiff wrought-iron frame
- Wooden wheels surrounded by tires made of iron.
- Nick-named ‘Boneshaker’ for the extremely uncomfortable ride
- Discomfort reduced by a long flat spring that supported the saddle and absorbed many of the shocks from rough road surfaces.

The high-wheel bicycle: 1870s



- Large front wheel $\Longrightarrow$ travel faster
- Solid rubber tires
- Hollow-section steel frames
- Reduced weight, and increased comfort
- Center of gravity: high $\Longrightarrow$ Safety issue
  – High up rider can get thrown over a bad spot in the road.

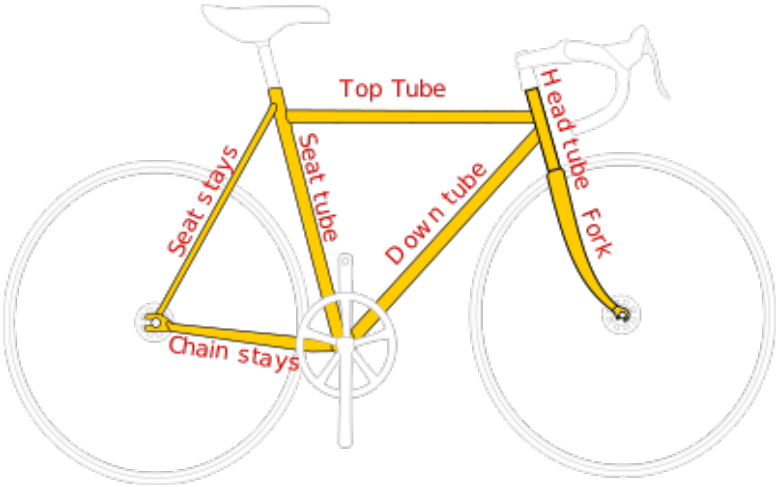
Safety bicycle: 1880–1890s

- Rider's feet within reach of the ground $\Longrightarrow$ easy to stop
- Rider's feet safe and away from front wheel
- Chain drive to transfer power to the rear wheels
- Center of gravity – low and between the wheels – greatly diminished the danger of long fall over the handlebars
- Uncomfortable ride – taken care of by pneumatic/inflatable tires (John Boyd Dunlop, 1887)

Taking it apart

Frame, Wheels, Tires, Gears, Pedals, Brakes

Bicycle frame



(a) Diamond frame

(b) Step-through frame

- Diamond – most common – the main 'triangle' is actually not a triangle
- Inverted A-frame
  – Incredibly strong structure
  – Helps to distribute your weight between the front and back wheels
  – Helps to lean forward or even stand up when you're going uphill so you can apply maximum force to the pedals and keep your balance.

What is the frame made of?

- Bike needs to be strong enough to support the rider's weight and the loads it's likely to experience during different kinds of handling.
- Factors:
  – Density, Stiffness, yield strength, elongation, fatigue limit, and endurance limit

Materials:

- Strong, inexpensive, tubular steel
- Lighter alloys based on steel or aluminum
- Note: Aluminum bikes use tubing with a larger diameter and/or thicker walls than a bike made from steel tubing.
- Carbon-fiber composites in racing bicycles
  – More expensive, but stronger, lighter, and rustproof
  – Can be formed into almost any shape with an aerodynamic profile
  – May have lower impact resistance compared to other materials, and can be prone to damage if crashed or mishandled
  – Vulnerable to fatigue failure

Bicycle wheels

- Turn at the axle $\Longrightarrow$ Speed multiplied at the rim
- Friction to be overcome
  - Rolling friction between wheel and ground – gives grip
  - Between the smooth surfaces of four wheels and their axles – ball-bearings

(a) Wheel and axle

(b) Ball-bearings

- Bicycle wheels are typically over 50 cm in diameter $>$ most car wheels.
- Taller the wheels, the more they multiply your speed when you turn them at the axle.
- Racing bicycles have the tallest wheels (typically 70cmin diameter).

Bicycle wheels

- Wheels = Strong hub + thin rim

- Hub structure – wider than the rim
- About 24 highly tensioned spokes
- Spoked wheels (rather than solid metal) – strong, lighweight, and reduces drag
- Spokes are connected to the rim like strands of a spider's web – criss-crossed
- Strong 3D structure – resists twisting, buckling, bending
- Spokes bear weight unevenly – 'domino' effect

Bicycle tires

(a) Racing bike

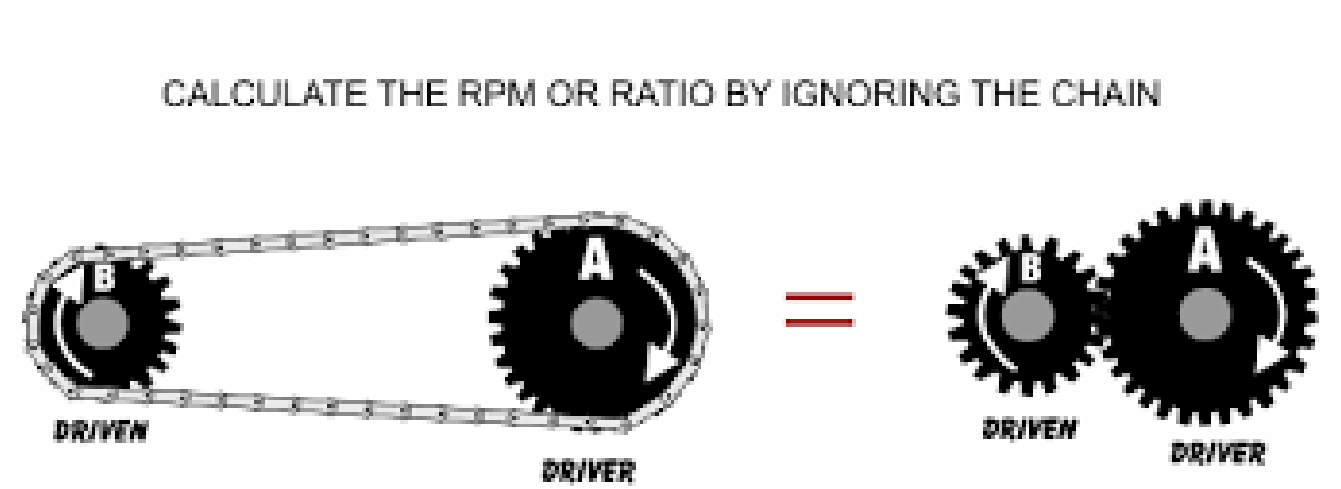
(b) Mountain bike

- Inner tube filled with compressed air $\Longrightarrow$ lighter, more springy, comfortable ride
- Friction is advantageous – gives grip that makes your bike easier to control, especially on wet days
- Racing tire: Narrow, smooth tires, $\sim$ 23 mm width
- Mountain bike: Fatter, Deeper treads, $\sim$ 2 inches

Bicycle gears

- Gear – pair of wheels with teeth that interlock to increase power or speed. In a bicycle, they are linked by a chain
- One end: permanent loop around the main gear wheel
- Other end: shifts between bigger and smaller toothed wheels
- Geared bicycles: 3–30 different gear-wheels

Gear ratio in bicycles



- Gear ratio: the number of teeth on the pedal wheel divided by the number of teeth on the back wheel
- GR = 5:1 for racing bike
  $\Longrightarrow$ Bicycle faster when going along a straight line; A single spin of the pedals will power you about 10 m down the street
- GR = 1:1 for mountain bike
  $\Longrightarrow$ Bicycle easier to pedal when climbing uphill

Bicycle pedals

- Pedals are fastened to the main gear wheel by a pair of cranks: two short levers also magnify the force you can exert with your legs
- Why do have to rotate freely?

Bicycle brakes

- Brakes stop using friction – the rubbing force between two things that slide past one another while they're touching
- Kinetic energy $\rightarrow$ Heat

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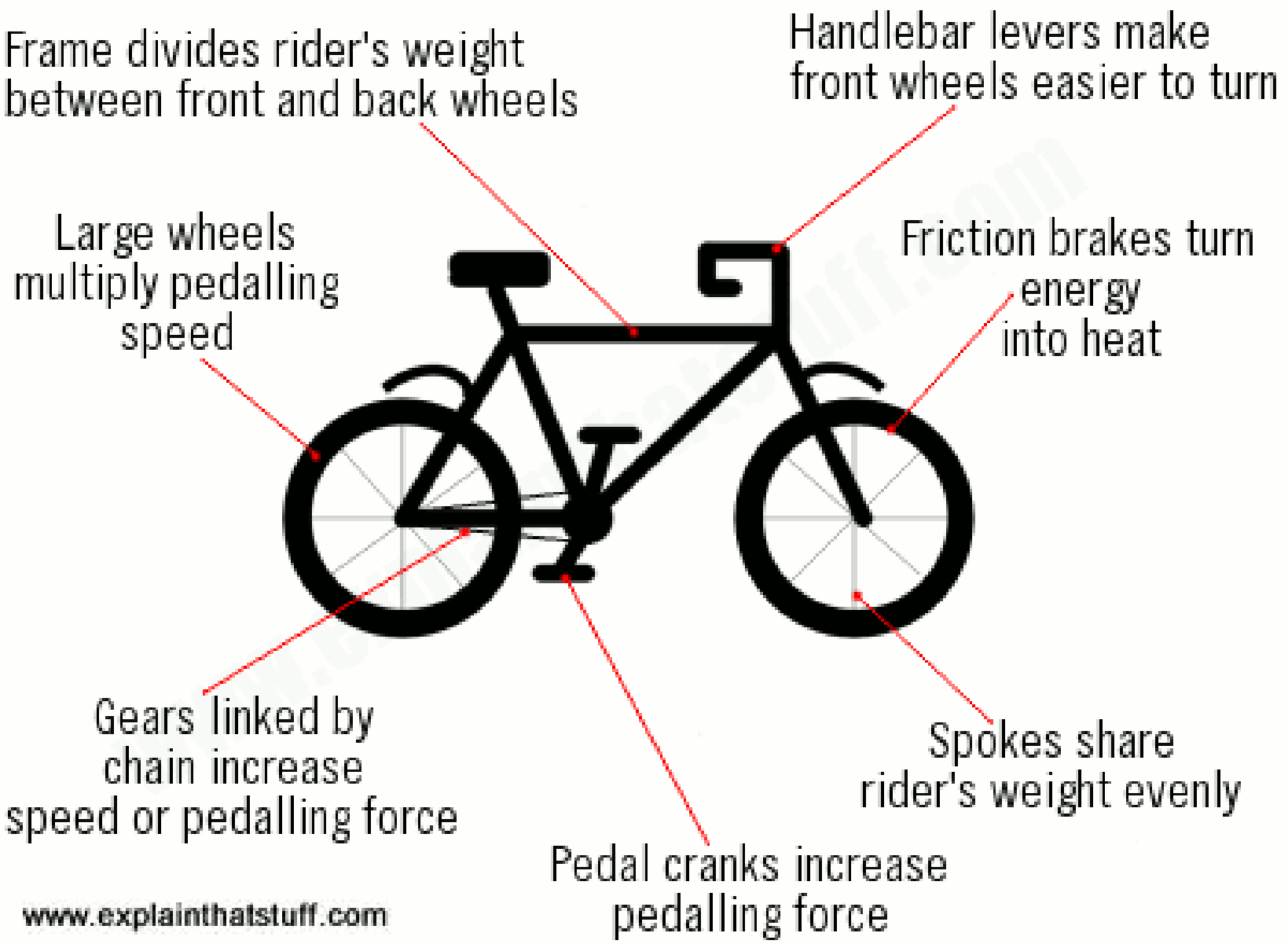
- **Rim brakes:**
  – The rubber shoes (blocks) of the bicycle's brakes clamp the metal rim of the wheel to slow you down.
  – Pushes on the part where the wheel moves fastest
  – Brake shoes rub tightly against the wheels

- **Disc brakes:**
  – Brake discs attached to the wheels
  – Work closer to the hub – can stress spokes
  – Heavy, mechanically complex
  – More effective in wet weather than rim brakes

Bicycling Science



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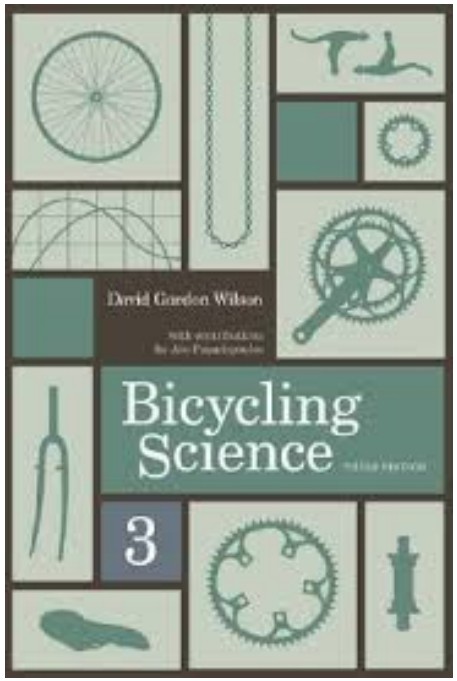
Sources



Bicycling Science – Frank Rowland Whitt and David Gordon Wilson

`https://explainthatstuff.com`