Bike Frames 1

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Bike Frames Day 1 Learning objectives

- Identify a force as a push or pull acting on an object, and describe forces acting on a bicycle and rider.
- Recognize the basic physical units needed to talk about mechanics and do some basic conversions.
- Explain the force of gravity on everyday objects using the idea that weight depends on mass $W = mg$
- Draw simple free-body diagrams showing weight, normal force, tension, and applied forces.
- Explain stress and strain conceptually and relate these to strength of bike tubes, tire pressure etc.
- Describe the evolution of bike materials from a materials properties perspective (strength, weight).

Bike Anatomy

https://images.contentstack.io/v3/assets/blt964243cdd7810dea/bltf91ef9d568536952/62140bd6cf85c1619ad89e26/bike-anatomy-bike.jpg

Let's start with units

Concept	Meaning	SI unit	symbol	Other crazy units	Conversion factors
Distance					
Time					
Mass					
Force					
Area					
Velocity					
Acceleration					
Stress (pressure)					

A few bike examples

- A bike is ~1.5 m long
- A pedal stroke lasts ~1 s
- A rider has a mass of 75 kg
- Pedal forces are ~200-600 N
- Gravity on earth is $9.8\ m/s^2$, gravity on mars is only $3.72\ m/s^2$

Let's do a few conversions

- The upcoming Tour de France is 3,333 km. How many miles is this?

- You can ride your bike at 18 mph. What would this be in m/s?

- Danny MacAskill is arguably one of the world's greatest bike trials rider. He weighs ~160 lbs. Convert this to kg.

- Convert a bike frame tube diameter from 2 inches to mm.

- A biker has a 90 rpm stroke cadence. What would this be in radians/s?

What exactly is a Newton???
1 Newton is the force needed to accelerate 1 kg of mass by 1 m/s^2.

So what is the "force of gravity" ?
Gravity creates a "downward" force on everything

1. Gravity gives weight.
2. Weight depends on mass.

$W = mg$

What forces act on a bicycle?

https://www.pinkbike.com/news/fezzari-bicycles-rebrands-to-ari-and-announces-new-lightweight-all-mountain-emtb.html

Free body diagrams
A bike is a complex object made up of dozens of smaller components and forces. A free body diagram let's us simplify the picture, isolate what matters, and ignore what doesn't.

Rules:
1. Replace the object with a dot/box.
2. Draw arrows showing forces
3. Label direction clearly
4. Arrow length is typically proportional to the relative strength

Let's do free body diagrams for three scenarios
1. Bike and rider standing still

2. Pedaling forward on a flat road at a constant velocity

3. Braking hard

The bike slows down, or **decelerates** because there is a **net force** in the opposite direction of the velocity
This is Newton's 2nd Law of Motion!
$F = ma$

We can actually use this to derive the $9.8\ m/s^2$ gravity value for earth!

Universal Gravitation equation

$$F = G\frac{m_1 m_2}{r^2}$$

where G is $6.674 \times 10^{-11} N\frac{m^2}{kg^2}$ and Earth's mass is $5.972 \times 10^{24} kg$ and earth radius is $r = 6.371 \times 10^6 m$

Stress and strain
This allows us to connect the concepts of force to material strength

Stress is an internal pressure caused by forces
When a force is distributed over a larger area, the stress is reduced

$$\sigma = \frac{F}{A}$$

Pressure has the same units!
Let's convert a bike tire at 25psi to Pa.

What would be the stress of our 160 lb biker on the ground below?

Group activity! Let's calculate the stress on the ground as a function of tire pressure
Nice article from University of Wisconsin-Milwaukee and Harley Davidson here.

How much will a material deform under a stress?
Strain (ϵ) is the percent change in physical dimensions when stress is applied

$$\epsilon = \frac{\Delta L}{L_{initial}}$$

The change in length is $L_{final} - L_{initial} = \Delta L$.

What units does strain have??

Elastic modulus
The strain observed is proportional to the stress and the constant of proportionality is the Elastic modulus, E_y
This property is also sometimes called the Young's modulus or the stiffness.

$$E = \frac{\sigma}{\epsilon}$$

or $\sigma = E\epsilon$

Let's assume a 160 lb person is sitting on a bike and 40% of their weight is directed into the seat tube of the frame. If the tube is a hollow, circular cross section of 30 mm outer diameter, 24 mm inner diameter, what would be the stress on the tube frame material?

If the tube was originally 10 cm tall and made of a steel with a modulus of 200 MPa ($1\ MPa = 1 \times 10^6 Pa$) what would be the dimensions when the person sat on the seat to ride?

History of bike frames

1817: - The "Draisine" or "laufmaschine" (precursor to the modern bike) was made of wood.	 https://wide.piaggiogroup.com/articles/products/duecento-anni-in-bicicletta-dalla-draisine-alla-wi-bike/foto1-small.jpg
1820s-1850s: - 3 and 4 wheelers. - Less balance required. - Introduction of pedals, treadles, hand-cranks. - First pedal crank appears in 1853. - "Penny farthing" design with solid rubber tires and high speeds	 https://upload.wikimedia.org/wikipedia/commons/7/70/Bicycle_two_1886.jpg

Late 1800s: - Steel tubing introduced. - Wire spoke tension wheels. - Shift from expensive toy to utilitarian transportation "Safety bicycle." - Diamond frame invented by Isaac R. Johnson. - Step through frames.	 https://upload.wikimedia.org/wikipedia/commons/4/48/Whippet_Safety_Bicycle.jpg
1900 - 1940s: - Aluminum frames become popular. - Single tube with no lugs. - "Lu-Min-Num" bike model out of St. Louis Refrigerator and Gutter Co.	 https://jeffreyrubel.substack.com/p/the-aluminum-bike-frame
1970s: - plastic bikes "Itera" - Plastic everything! Chains, hubs, spokes etc - Claim: "17 lbs and stronger than steel..." - Not a commercial success	 https://upload.wikimedia.org/wikipedia/commons/a/a0/Itera_plastic_bicycle.jpg
1990s: - Titanium frames - Full suspension 1992 Gary Fischer RS-1	

	 https://www.unicorncycles.com/titanium-road-gravel-bike-frames
Modern era: - Carbon fiber dominates high-performance bikes. - 1991 first appears on the Tour de France.