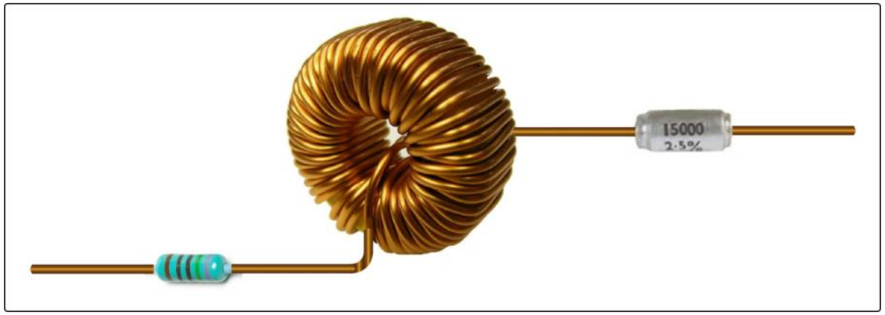
ECE 10C
Fall 2020
Instructor: Galan Moody

Slide Set 0
Course Info
TA: Kamyar Parto

What We'll Cover in 10C

This class is about understanding how to analyze the transient (*i.e.* time) response of electrical circuits. Developing an intuitive understanding of how capacitance, inductance, and/or resistance impact high-speed circuit response is arguably the most important skill for electrical and computer engineers

resistor capacitor



inductor

Chapters 10, 12-14

- Review of Thevenin equivalent circuits, node method, KVL/KCL
- Review of 1st-order ODEs + power and energy
- Undriven 2nd-order LC/RLC circuits
- Driven RLC circuits + an intuitive analysis
- Transient analysis + the impedance method
- Frequency domain analysis + transfer functions
- Frequency response + filter design
- Resonance in 2nd-order circuits

Course Information

Instructor:
Galan Moody
moody@ucsb.edu

Office Hours: TBD

Lectures:
Virtual, synchronous

TA/Lab Instructor:
Kamyar Parto
kamyar00@ucsb.edu

Office Hours: Kamyar will email

Labs:
Remote/virtual

Text Book:
Agarwal and Lang: Foundations of Analog and Digital Electronic Circuits

Zoom:
Don't be shy in asking questions! If you can, please turn on your cameras so we can communicate better. **IMPORTANT**: Sign in to zoom

Poll for Lecture Office Hours

Course Information

Lectures will be a combination of:

- Slides and notes that will be on Gauchospace
- Derivations and examples (in slides, review sessions)
- Quizzes at the beginning of most lectures
  - Promptly at start of class, ~ 5 minutes
  - Based on reading material for upcoming lecture
  - Won't negatively impact your grade
  - Counts for up to 10% credit on your final exam (100% max)

Grading: 20% HW + 35% Midterm + 45% Final Exam

To incentivize you to first solve your on your HW sets on your own, if your total grade is better based only on your exams, I'll drop the weight of the HW score to 0%. Your exam grade will include up to the 10% bonus from in-class quizzes.

Homework Assignments

- 6 assignments, posted Tuesdays, due Thursday of following week
- Upload onto Gauchospace by Thursday due date, start of class
- Collaboration is allowed, but I don't recommend solving HWs together without first working on it yourself. List on your HW who you've worked with.
- Each student must work out the problems and write their own answers in their own words
- **No extensions**, but <u>lowest HW grade will be dropped</u>

**** First HW posted next week, Due October 15th ****

Lab Projects and Reports

- **Labs can be done independently of the designated lab hours for the course, also with assistance from Kamyar during his office hours. The week they are due, upload onto Gauchospace on Thursdays by beginning of lecture, 5 pm PST**
- **First Lab Due:** October 15th
- Encourage you to find virtual lab partners to work through labs. Reports must be your own though.
- Kamyar will notify you of the lab report format and will be posting details for this as well as his zoom link on Gauchospace

Lab Projects and Reports

Poll for Labs

Exams

- **Midterm**: Thursday, November 5th ("take home")
  - Will post in AM, host office hours during class to answer any critical questions, due at end of class
- **Final**: Wednesday, December 16th ("take home")
  - Will do same as the midterm for answering questions (but keeping the regular exam schedule, 7:30-10:30PM)
- Open notes, open book.

Tentative Course Schedule

first HW due and first lab

Midterm

Final

Week #	Date	Topics	Homework	Labs
Week 0	10/1	**10:** Class introduction	• None	• NO LAB
Week 1	10/6	**10:** Review of Thevenin equivalent circuits + review of chapter 10 (first-order RC/LC circuits)	• HW 1 posted	• NO LAB
	10/8	**11:** Finish chapter 10 review + power and energy in 1st order circuits and digital logic		
Week 2	10/13 10/15	**12.1-12.3:** Undriven second-order LC/RLC circuits + stored energy	• HW 1 (10/15) • HW 2 posted	• Lab 1 due
Week 3	10/20 10/22	**12.5-12.9:** Driven RLC circuits + an intuitive analysis	• HW 2 (10/22)	• Lab 2 due
Week 4	10/27 10/29	**13.1-13.3** Transient analysis + the impedance method	• HW 3 posted	
Week 5	11/3	Review (if time allows)	• HW 3 (11/5) • Study Session	• Lab 3 due
	11/5	Midterm (in class)		
Week 6	11/10 11/12	**13.4:** Frequency domain analysis + transfer functions	• HW 4 posted	
Week 7	11/17 11/19	**13.5-13.7:** Frequency response review + filter design	• HW 4 (11/12) • HW 5 posted	• Lab 4 due
Week 8	11/24	Review (if time allows)	•	• Lab 5 due
Week 9	12/1 12/3	**14:** Resonance in second-order circuits	• HW 5 (11/21) • HW 6 posted	
Week 10	12/8 12/10	**Final Topics TBD (possibly final exam review)**	• HW 6 (12/3) • Study Session	• Lab 6 due

Other Important Information

- Complete syllabus including course information including schedule, and policies + resources are on Gauchospace (e.g. check out Gaucho Goals)
  - Individual differences and accommodations
  - Academic integrity policy
  - Religious observances policy
  - Copyright and course recording policy
  - Discrimination and sexual harassment policy
  - Distressed students
- **If you have any concerns or questions about any of these, don't hesitate to speak with me and I'll help where I can or point you in the right direction to available resources**

Poll for Course Content

ECE 10C: What's it good for?

Why should you care about what you're learning in this class?

Will you ever use what you learn in this class again?

Let's go through some examples.

Example 1

TESLA MODEL S

Electric cars are nothing new. In fact, they've been around for just about as long as cars with internal combustion engines (ICE's). Tesla however, is the first company to make a modern electric car practical. In 2008, they introduced a small electric sports car called the Roadster to a limited enthusiast audience, then in 2012, the model S was released for the general consumer. The Model S is priced as a luxury car starting out in the 70 thousand dollar range. The version seen here is the P85D; it is the second most expensive version incorporating a larger battery and a dual motor

Zero to 60

The P85D variant of the Model S is one of the quickest cars on the road. Its 0-60 mph time of 3.2 seconds puts it among much more expensive high end cars like Lambourghinis and Ferraris.

Topping It Off

Charging your Model S at home is as simple as plugging it into the wall. When you're on a road trip, however, sometimes that's not so easy. Tesla has your back though with an extensive network of free charging stations along many highways. Simply back your car up to the charger, grab lunch for 30 minutes, and your car will be back up to 50 percent charge.

Double Efficiency

Some might think that having two motors would mean a decrease in efficiency. The dual motor design in P85D however, actually makes the car more efficient, increasing it's overall range while also making it quicker.

Junk in the Frunk

Without an engine taking up a large volume of space in the front, the Model S features two trunks. The rear trunk has two extra seats allowing a maximum of seven people to travel in the car at once. The trunk in the front has large storage space and is lovingly referred to by Tesla owners as the "frunk."

Look Ma, No Hands!

Every Model S ever released has had the necessary sensors on board for the car to have a working highway autopilot. It wasn't until 2015, though, that Tesla released an over-the-air firmware update that enabled the system. Because Teslas automatically update, owners literally woke up one morning to find their cars could drive themselves.

Drive Safe

The Model S is one of the safest cars on the road. It received the highest safety score ever given by the National Highway Traffic Safety Administration. Due to its battery pack being in the floorboard it has an extremely low center of gravity, which can prevent rollovers. And, because it doesn't have an engine in the front, the 'frunk' acts as a huge crumple zone.

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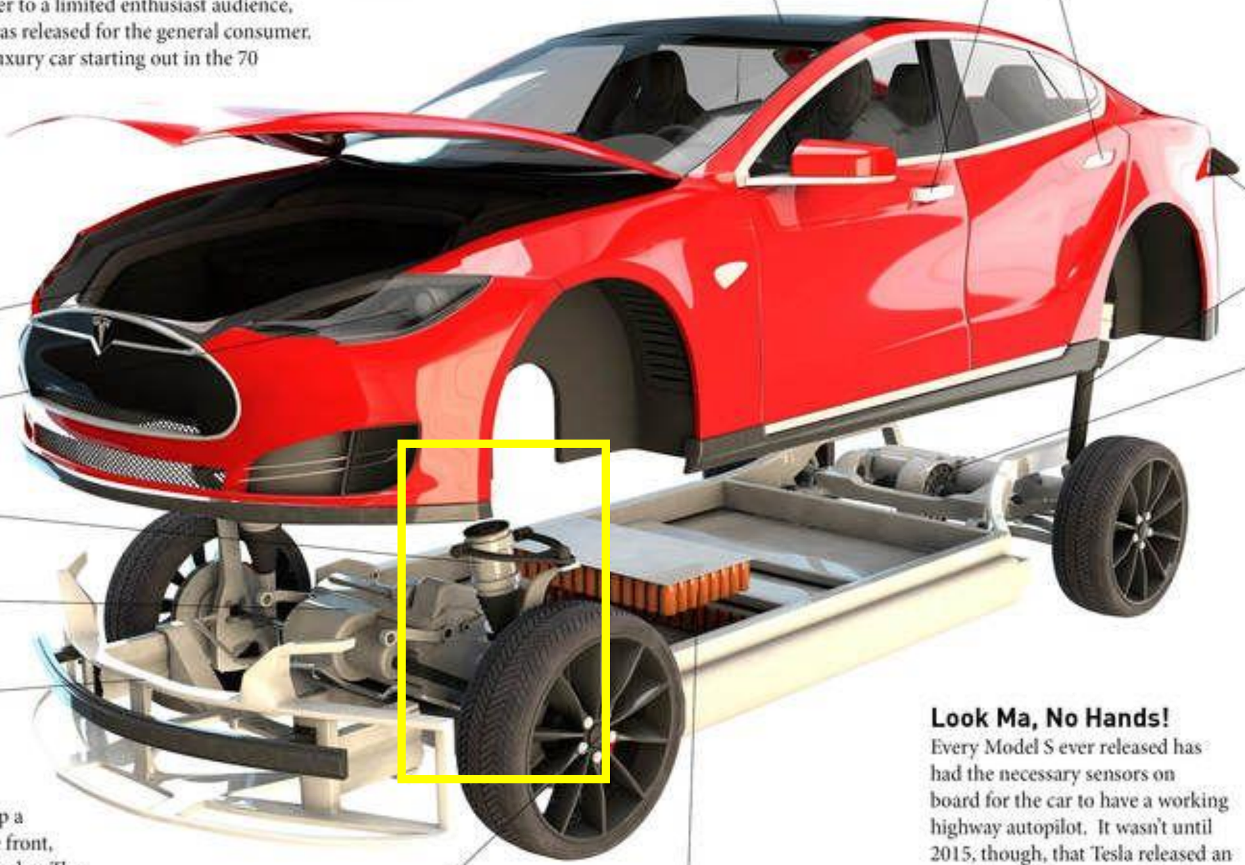

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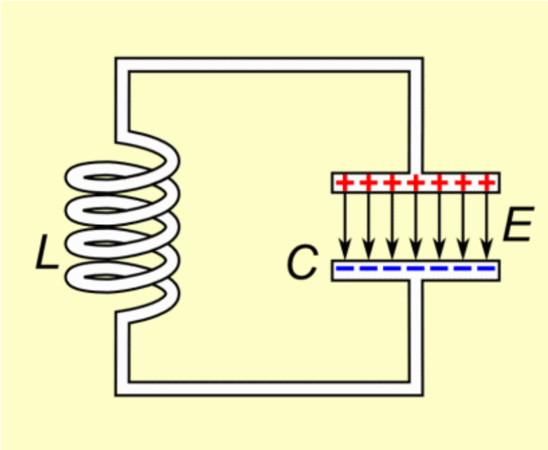
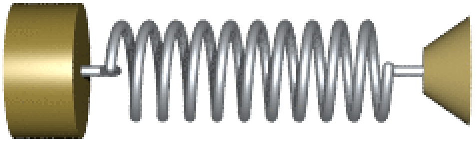
RLC Circuits: Electronics vs. Mechanics

RL Circuit



Mass on a Spring



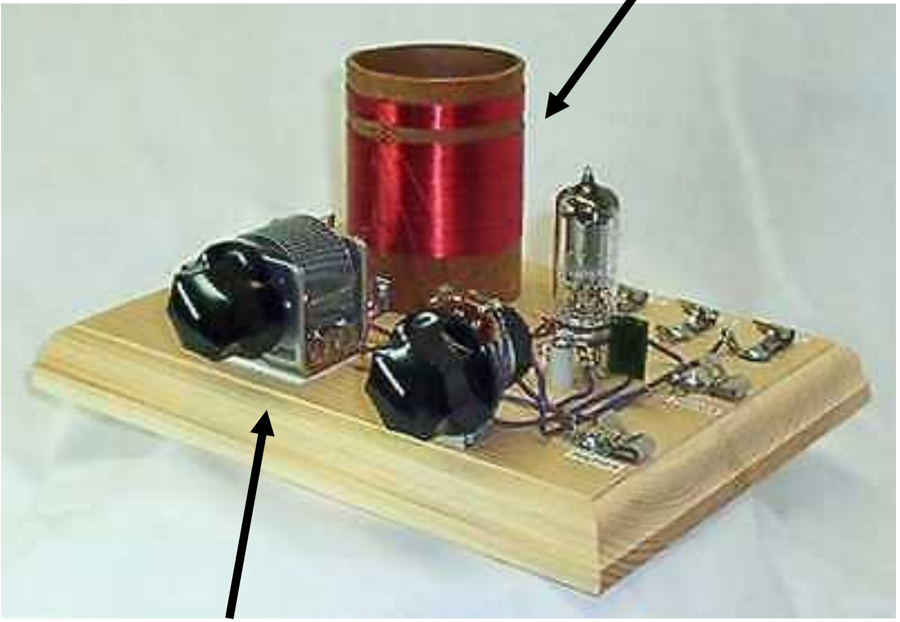
capacitor ⟷ spring

inductor (magnetic energy) ⟷ mass (kinetic energy)

RLC Circuits: Electronics vs. Mechanics

RL Circuit

inductor



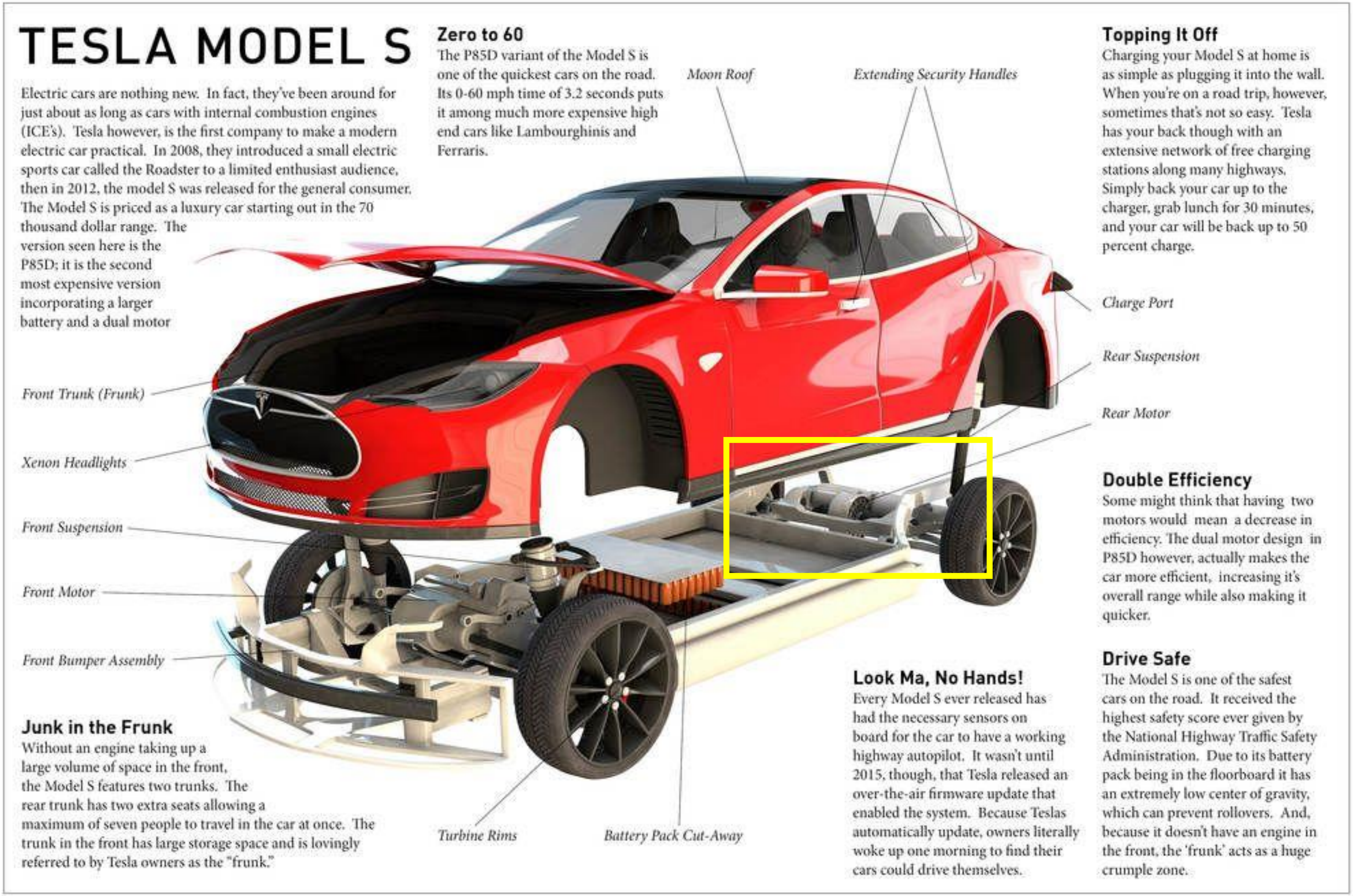
variable capacitor

Mass on a Spring

balance wheel

spring

Example 1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Moon Roof
Extending Security Handles
Topping It Off
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Charge Port
Rear Suspension
Rear Motor
Front Trunk (Frunk)
Xenon Headlights
Front Suspension
Front Motor
Front Bumper Assembly
Double Efficiency
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Turbine Rims
Battery Pack Cut-Away
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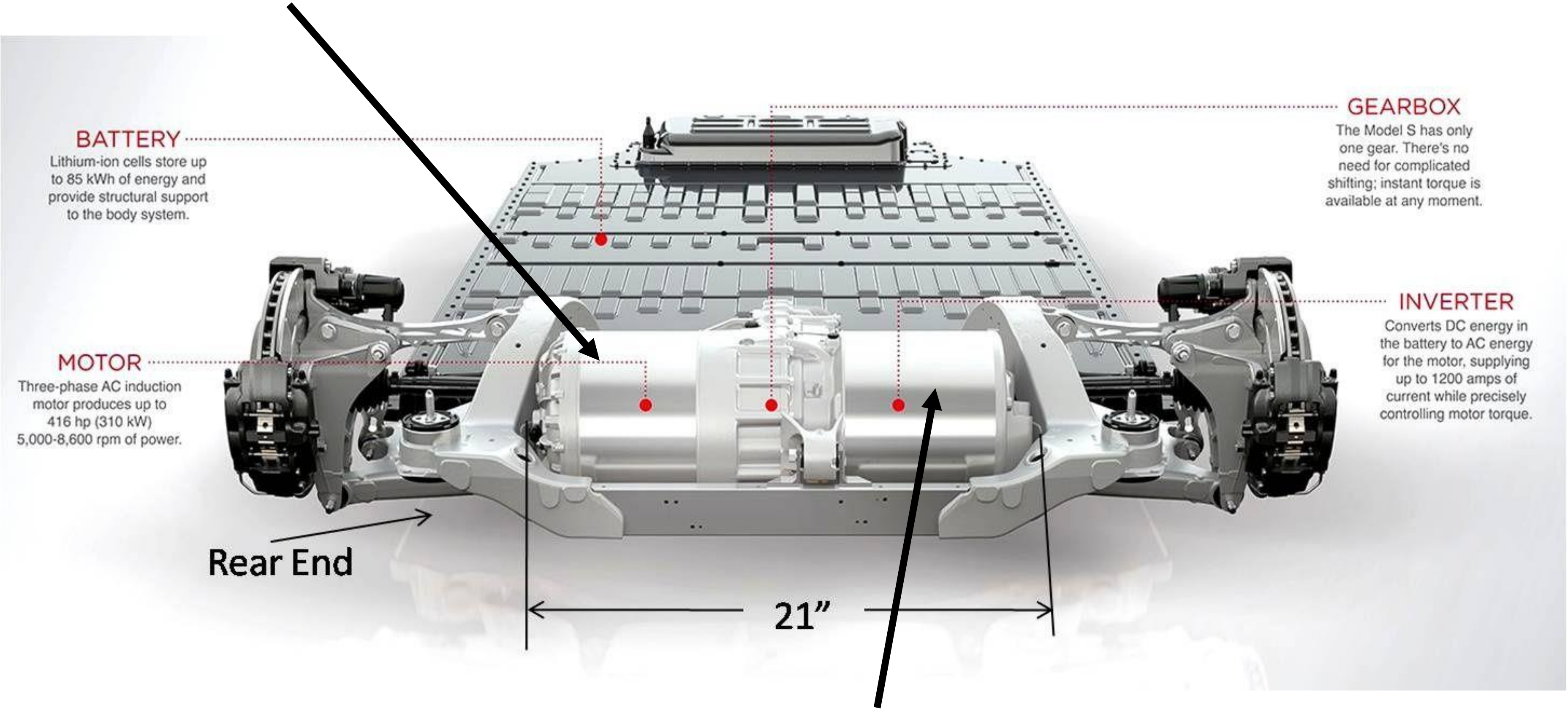
Example 1

Induction motor requires no permanent magnetic, takes 3-phase AC input current to create rotating magnetic field, which turns the rotor (drive shaft)



Inverter = transformer + switches to convert DC to AC.
Problem: ?

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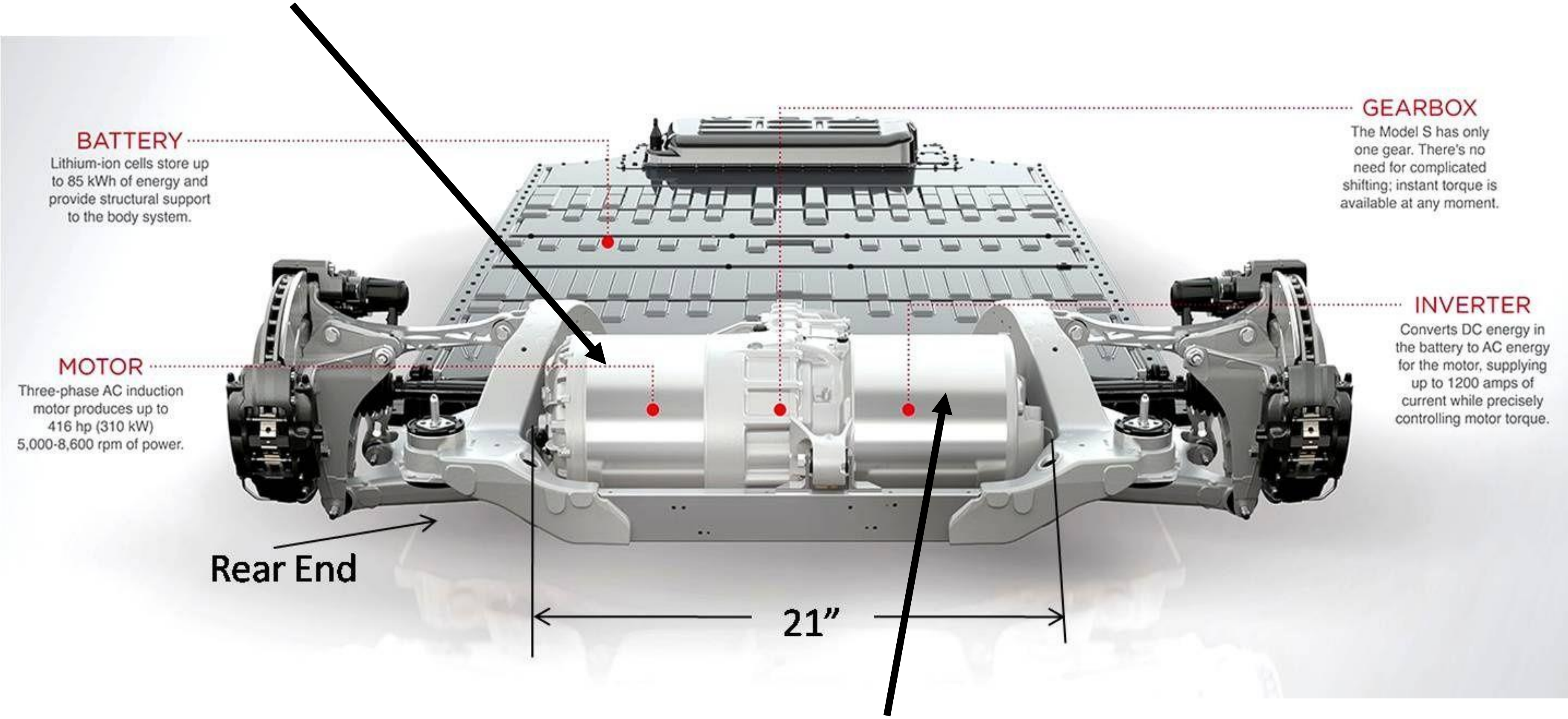

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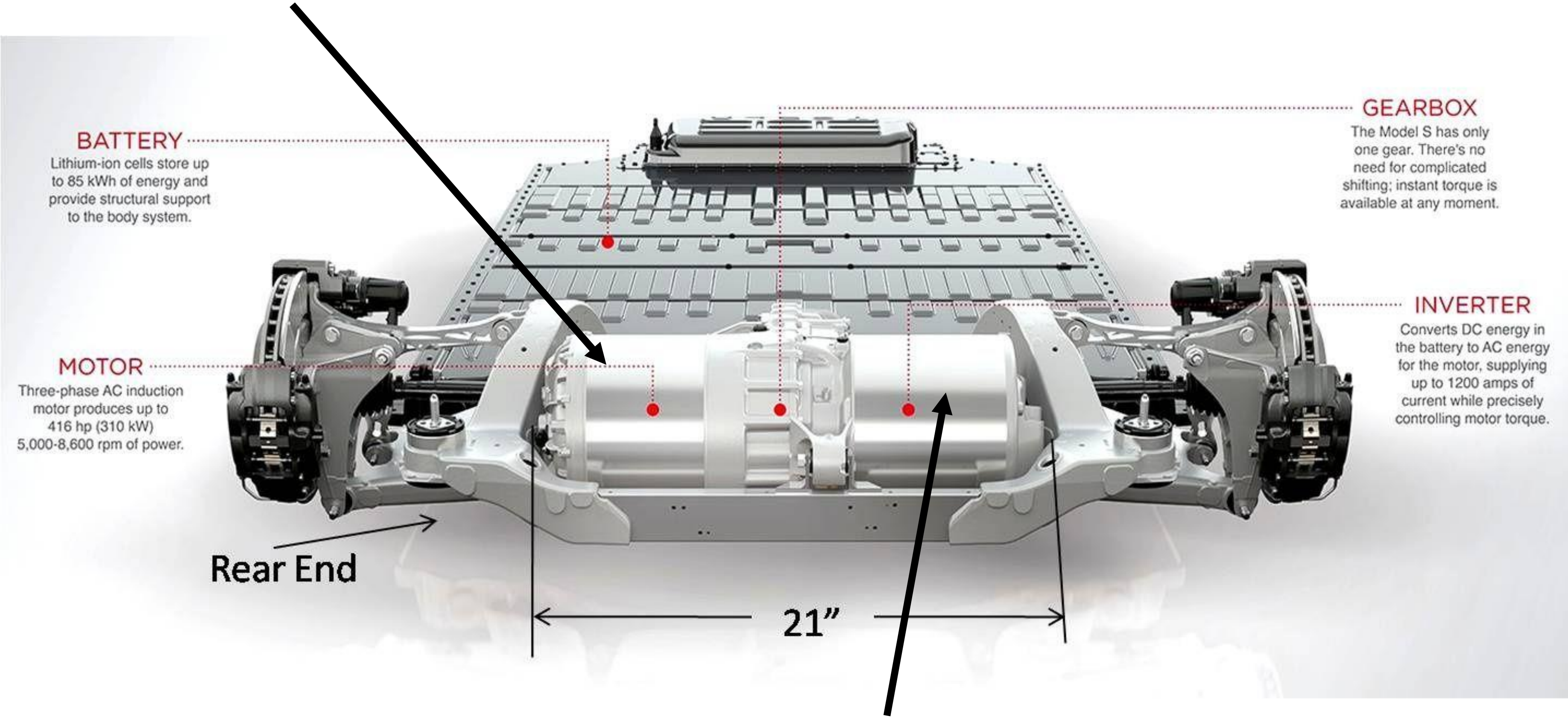
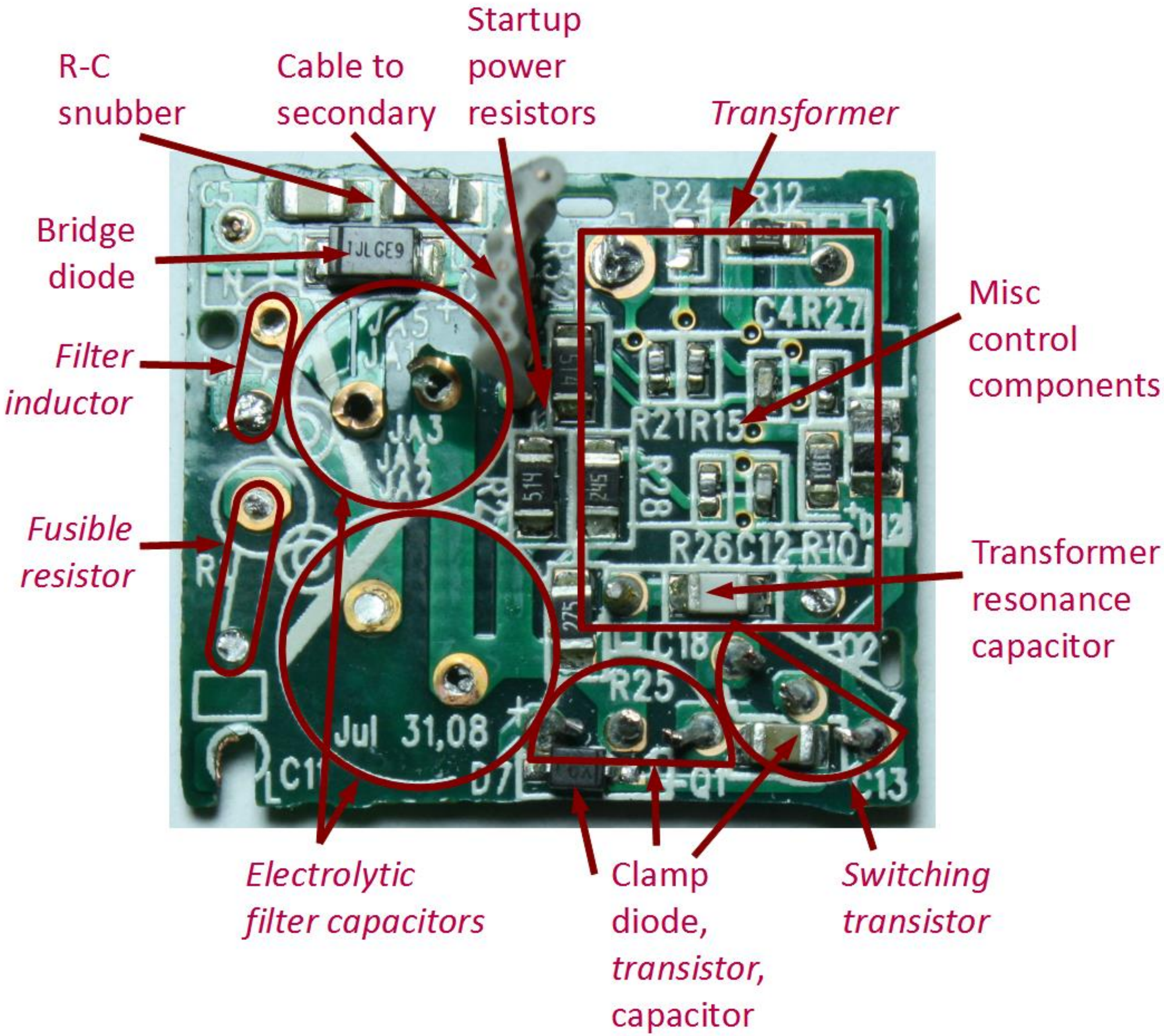
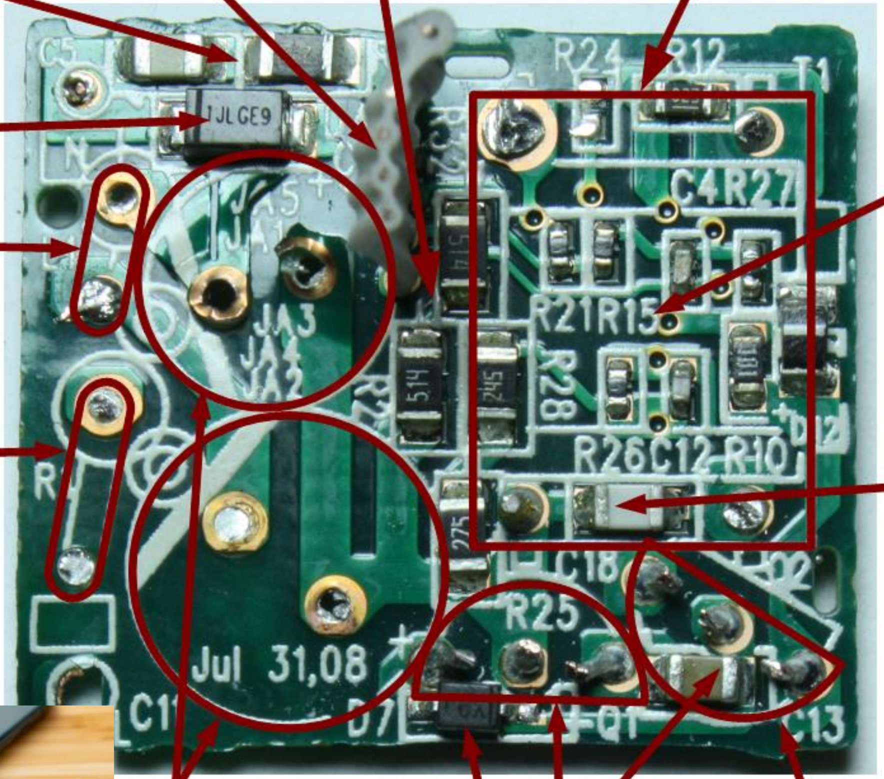


Inverter = transformer + switches to convert DC to AC.
Problem: Produces square wave with many frequency components – induction motor wants single frequency
Solution: RLC circuits to filter out a single frequency!

Example 2


R-C snubber
Cable to secondary
Startup power resistors
Transformer
Bridge diode
Filter inductor
Fusible resistor
Misc control components
Transformer resonance capacitor
Electrolytic filter capacitors
Clamp diode, *transistor*, capacitor
Switching transistor

Example 2



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Jul 31,08

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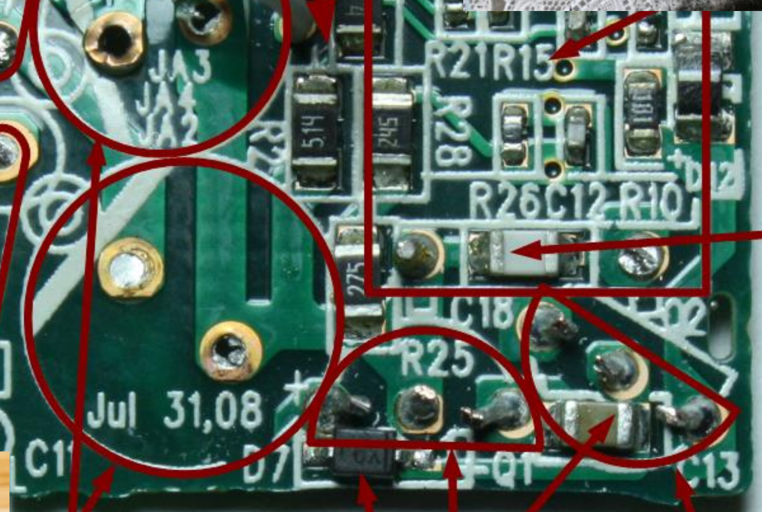
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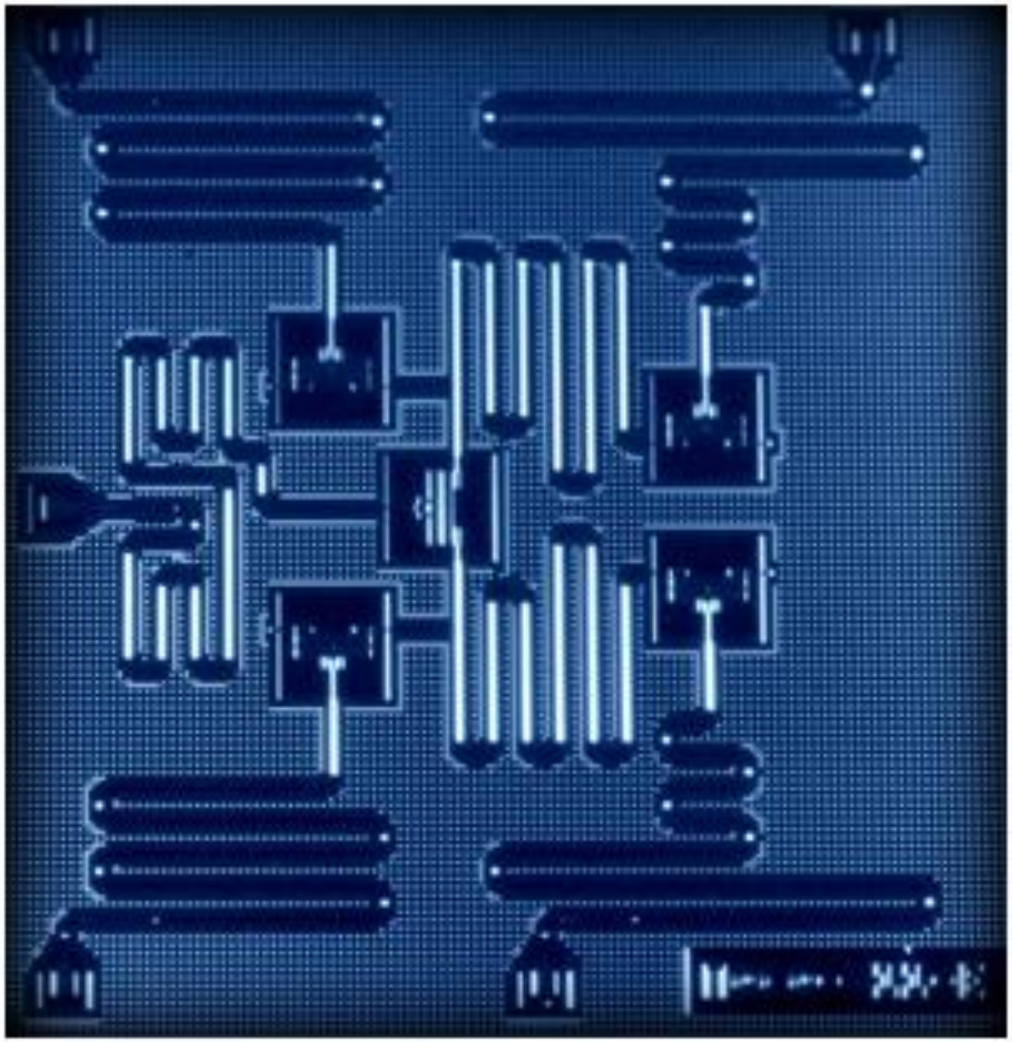
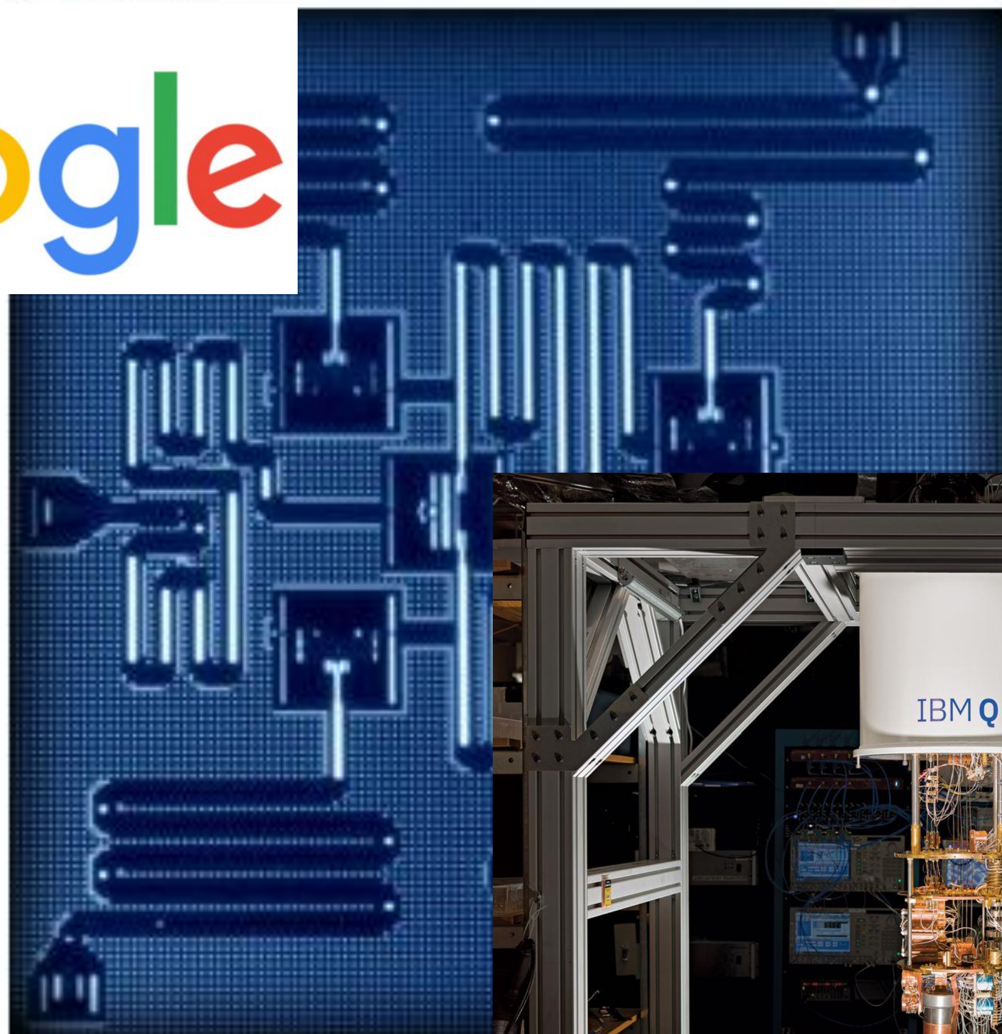
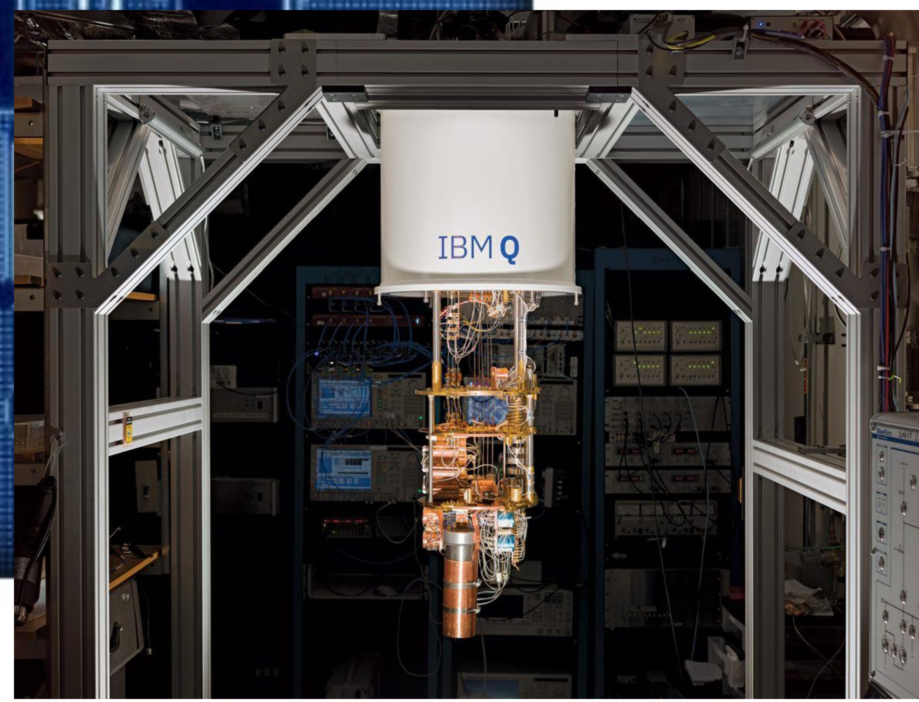
Example 3



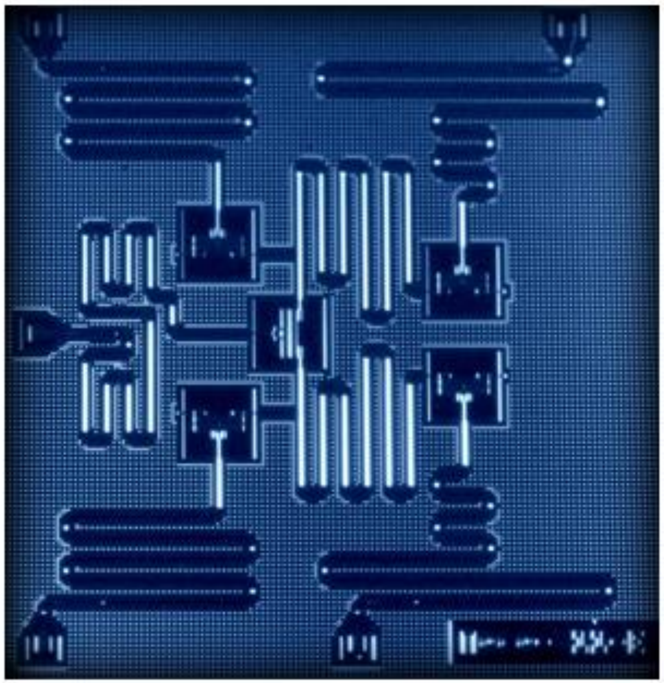
Example 3

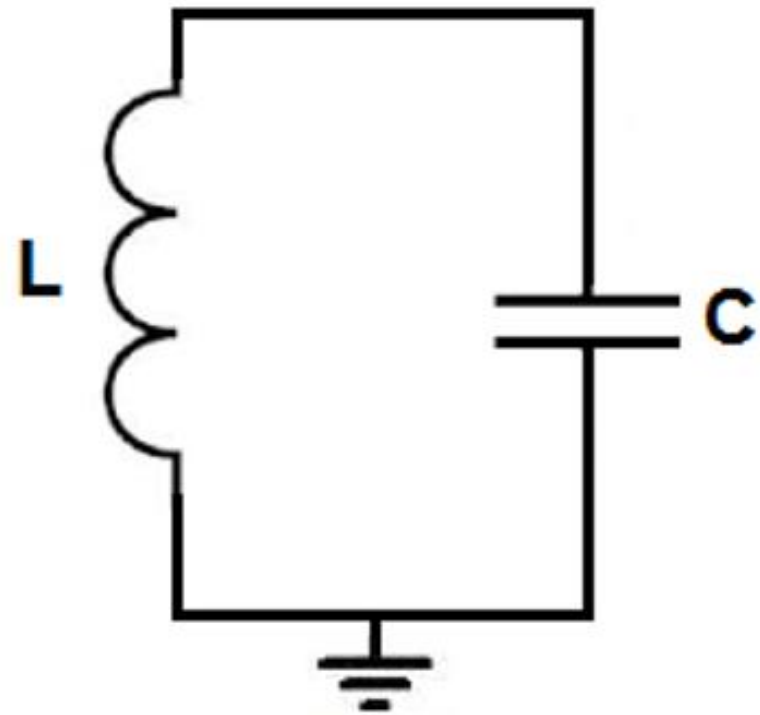




Example 3

- Harmonic oscillator: mass-on-a-spring, LC circuit
- Superconducting qubit similar to an LC circuit (but not your ordinary inductor)

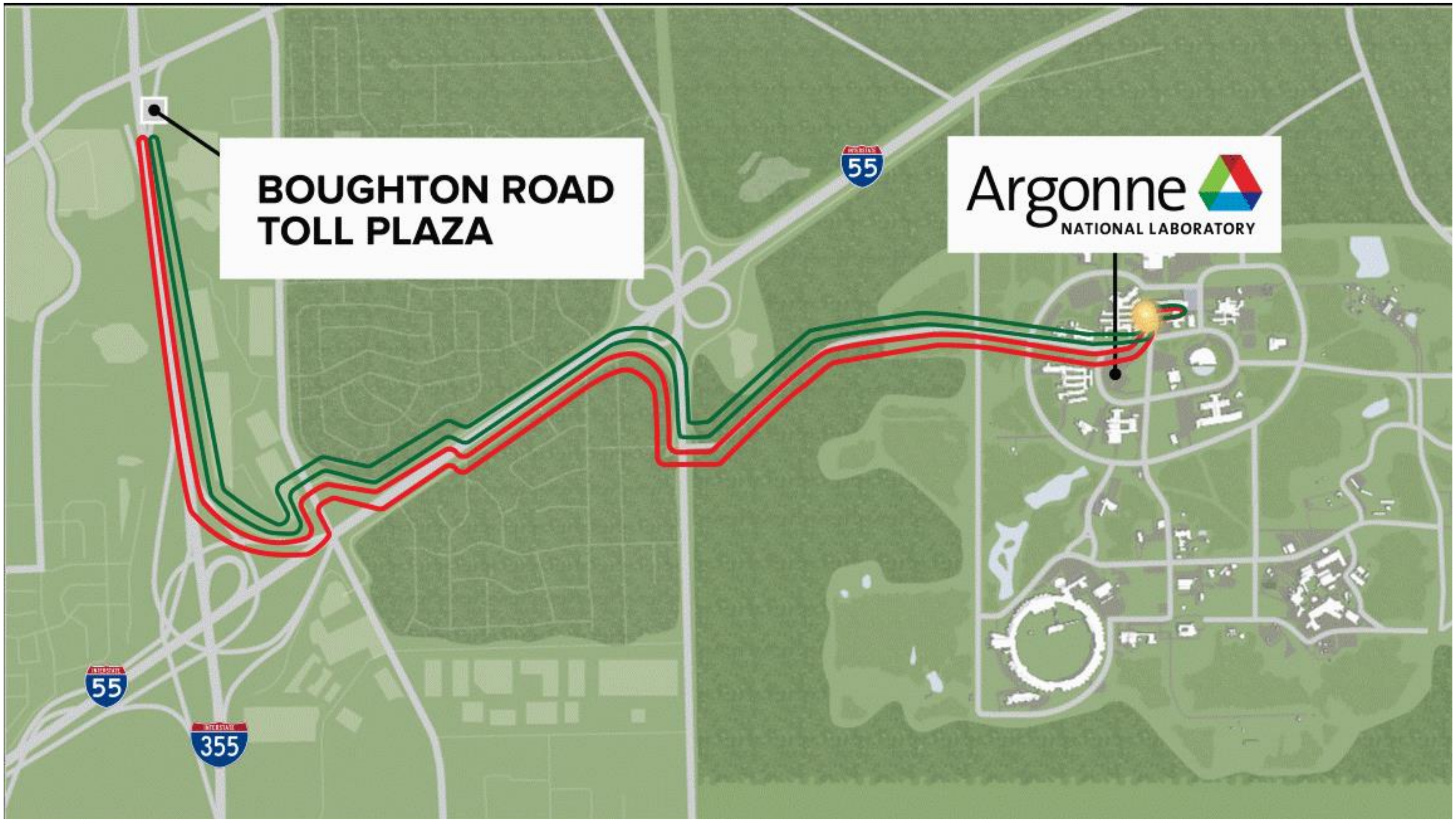




- In quantum mechanics, can insert one “unit” of energy into the circuit, or can place the circuit into combination of multiple frequencies simultaneously

Example 4

The Quantum Loop: Beginnings of the Quantum Internet Near Chicago
Photons = fundamental quantum mechanical particle of light
Entanglement = “spooky action at a distance”
Use entanglement to communicate information securely over long distance



Example 4

Need to detect the entangled photons with ultra-high timing precision and efficiency and very low noise

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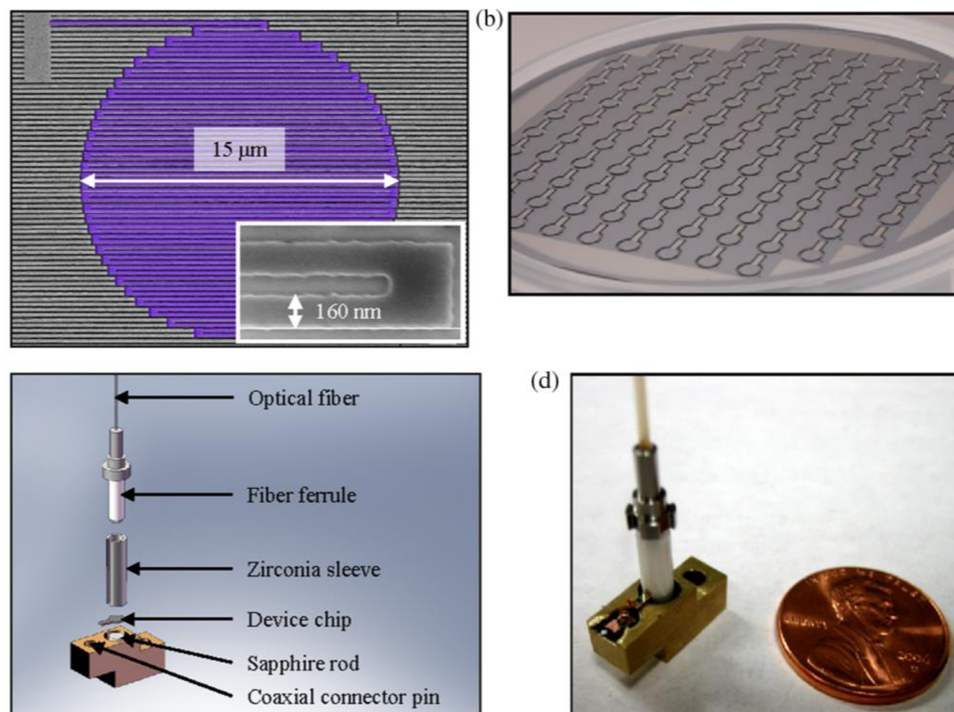
SNSPDs = superconducting nanowires that can detect a single photon with nearly 100% efficiency



used in nearly all quantum photonics technologies/applications

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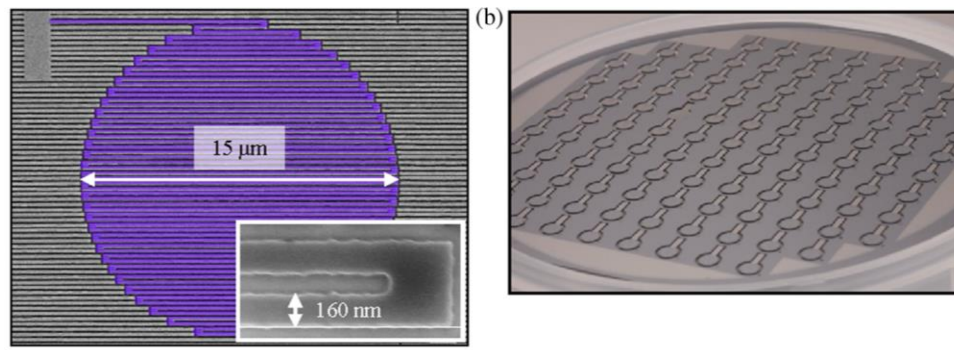
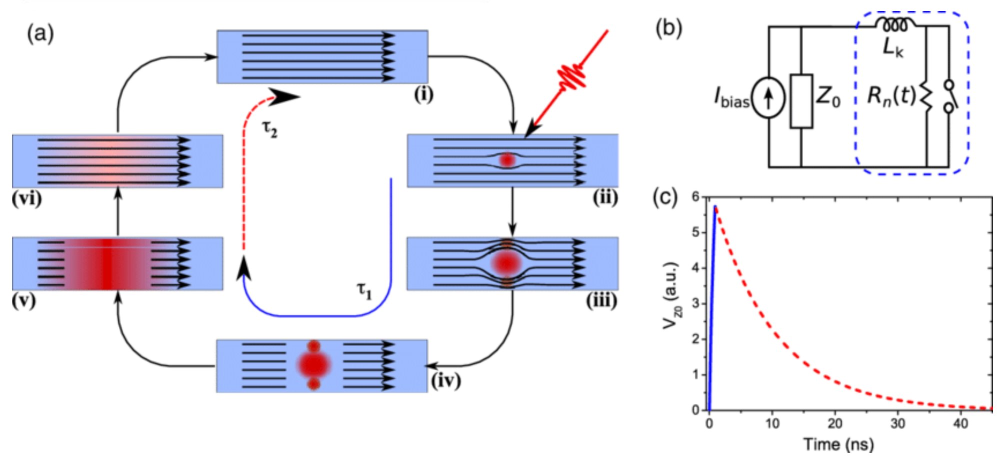
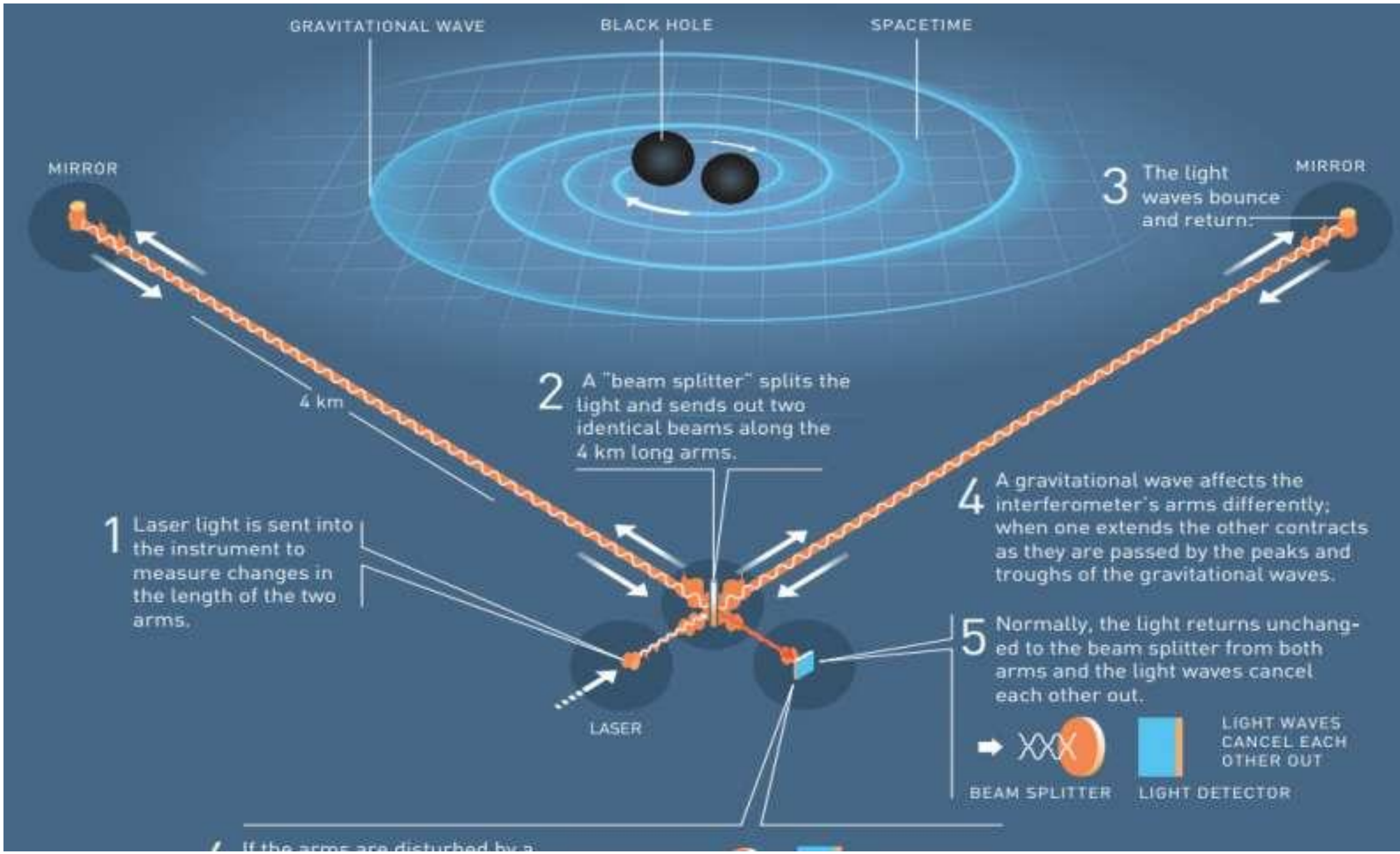




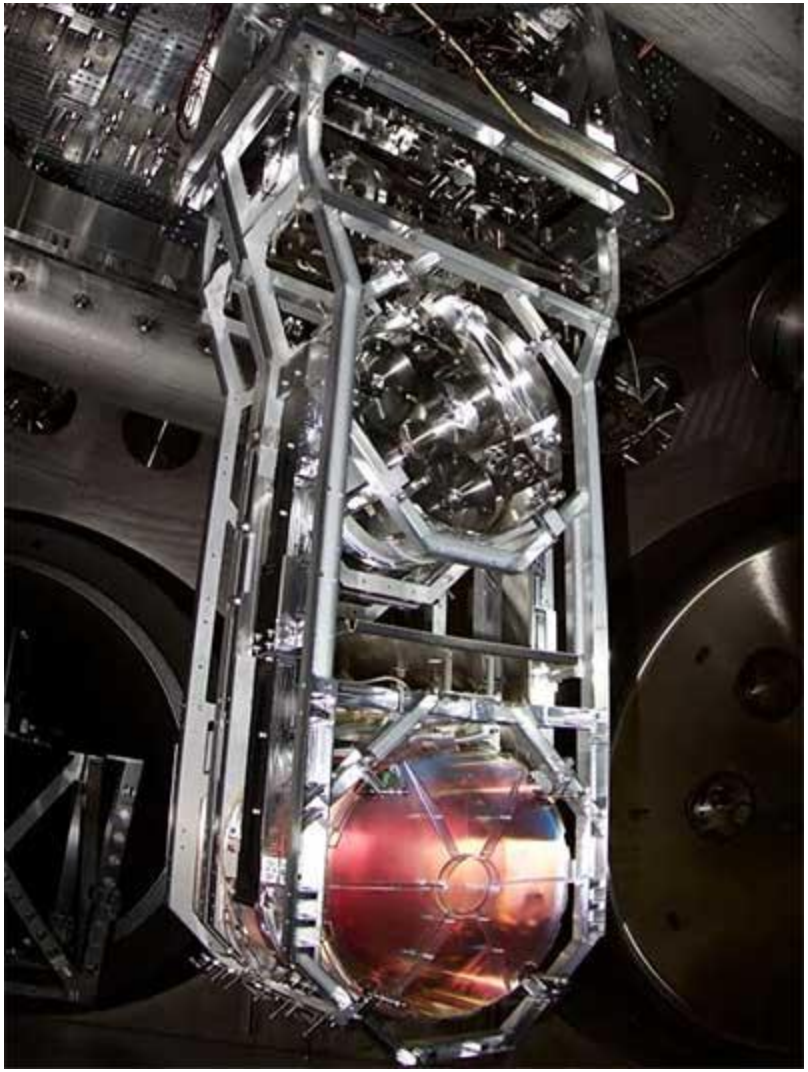
Example 5

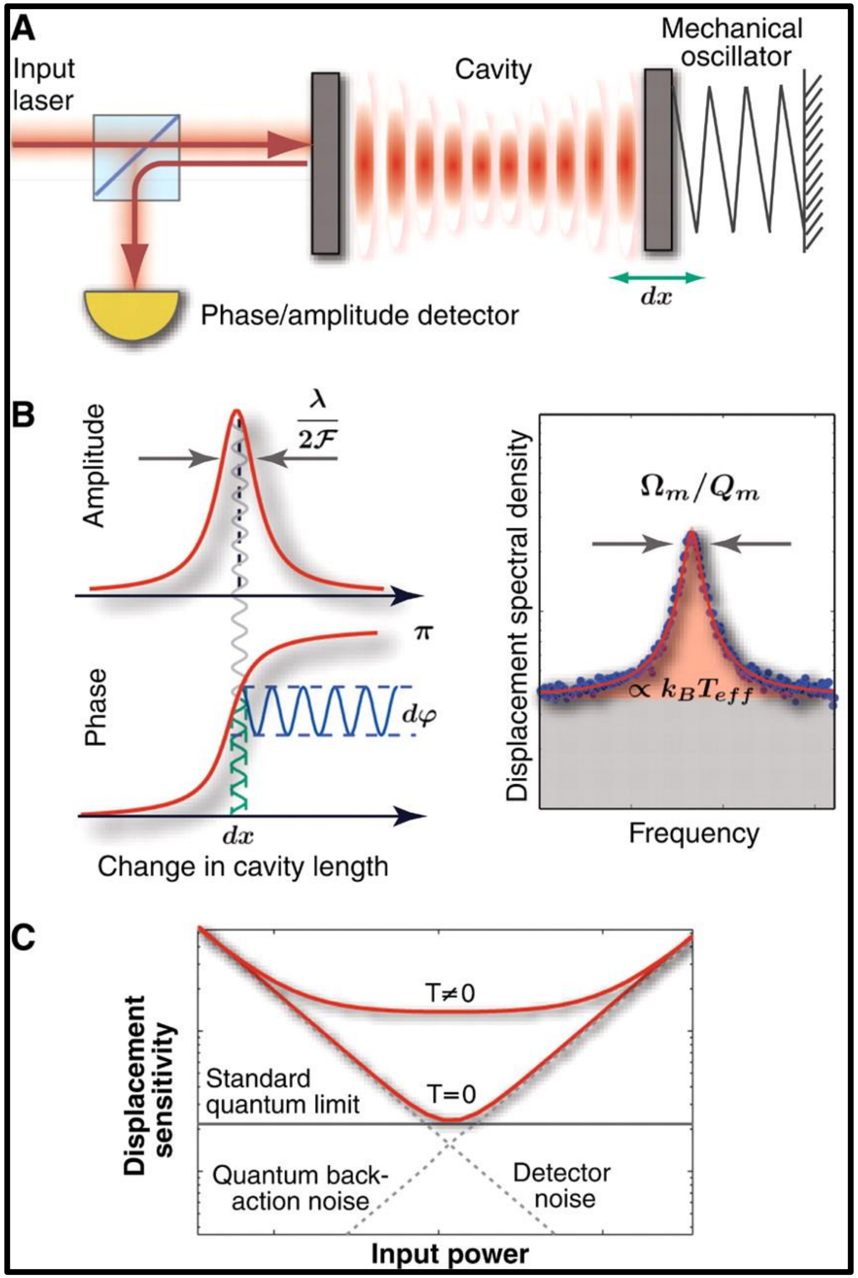
Example 5

The Laser-Interferometer Gravitational Wave Observatory (LIGO)
2017 Nobel Prize in Physics to LIGO founders



Example 5




A
Input laser
Cavity
Mechanical oscillator
Phase/amplitude detector
dx
B
Amplitude
$\frac{\lambda}{2\mathcal{F}}$
Phase
π
$d\varphi$
dx
Change in cavity length
Displacement spectral density
Ω_m/Q_m
$\propto k_B T_{eff}$
Frequency
C
Displacement sensitivity
T≠0
Standard quantum limit
T=0
Quantum back-action noise
Detector noise
Input power

Reminders

- HW 1 will be posted next week, due October 15th
- Lab 1 due October 15th
- **Class next week:** Review of Thevenin circuits, KCL/KVL, RC circuits, 1^{st}-order ODEs, energy (review these, quizzes!)