

Announcements

- Competition is Thursday, Nov. 10, at 7 PM!
- Bring your own solder & wire strippers
- Need to run car at least once before your lab this week to be prepared to address issues in lab.

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Which Presidential Candidate?



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Unsafe at Any Speed?

- In 1965, Ralph Nader wrote a book called *Unsafe at Any Speed*.
- This book claimed that the rear-engine Chevrolet Corvair could easily tip over at relatively low speeds.
- Although the Corvair was popular, it was eventually discontinued.
- Nader made consumer safety a public issue.

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Was the Corvair Unsafe?

- A two-year DOT NHTSA study concluded:

"The handling and stability performance of the 1960-1963 Corvair does not result in an abnormal potential for loss of control or rollover and it is at least as good as the performance of some contemporary vehicles both foreign and domestic."

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Other Viewpoints

- The Corvair's rear suspension was too light for a rear-engine vehicle. For only \$4 more per car, anti-sway bars could've been added to eliminate the roll problem.
- Corvair was originally intended as an economy car, but it picked up a sporty image and was driven less conservatively than originally designed.

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Safety Lessons

- Safe design is often much cheaper than safe retrofitting.
- Perceived safety is an important part of successful products.
- "Economical" but unsafe designs may ultimately be less profitable than safer designs.
- Products are not always used as intended.
- The proper tradeoff in safety vs. cost is a sticky ethical issue.

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Elements of Safety

In a design project, we must consider the follow elements:

- Safety of the design team
- Safety of the manufacturing process and environment
- Safety of the consumer

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Electrical Safety

- The degree of danger is a function of *current*, not voltage.
- Obviously, higher voltage means higher current.
- Lower resistance means higher current.

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ZAP

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Physiological Effects of Current

Current	Effect
20 A	Permanent brain damage
5 A	Respiratory arrest
2 A	Central nervous system damage
1 A	Burns
80 ma	Ventricular fibrillation

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Physiological Effects of Current

Current	Effect
50 ma	Asphyxia
9 ma	Muscles frozen
1 ma	Pain
0.2 ma	Threshold of perception
0	No effect

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Skin Resistance

- $V=IR$ still works for human bodies.
 - » Wet skin -- resistance is about $1\text{ k}\Omega$
 - » Dry skin -- resistance is about $100\text{ k}\Omega$
 - » Internal resistance is an extra $500\ \Omega$
- For 60 Hz, 120 V:
 - $I = 120/(100\text{k} + 500) = 1.2\text{ ma (dry)}$
 - $I = 120/(1\text{k} + 500) = 80\text{ ma (wet)}$
 - » **Don't have wet skin when working with electricity!**

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Frequency Effects

- Higher frequencies can interfere with nerve signals. 60 Hz is more dangerous than DC.
- Skin behaves more like a capacitor for high frequencies -- current is proportional to frequency!
- Frequencies in the 60-400 Hz range are most dangerous.

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Electrical Safety Precautions

- ALWAYS make sure the power source is off when handling circuits.
- Only use one hand when touching a circuit.
- Avoid touching bare wires when possible.
- Keep hands dry.
- Don't work alone.
- Keep voltage as low as possible.
- Insulate everything you can.

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Risk & Reliability Evaluation

- Components that fail may create *danger* or *unreliability*.
- Failure rate is the fraction of components that fail per unit of time, plotted as a function of time.

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Failure Rate

$$N_f + N_s = N_0$$

- N_0 = # of components put into service at $t=0$
- N_f = # of components failed at arbitrary t
- N_s = # of components surviving at arbitrary t
- Failure rate FR is ($t>0$):

$$FR = \frac{N_f}{N_0 t}$$

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Mechanical Mortality Curve



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Electrical Mortality Curve



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Electrical Component Burn-In

- Mechanical components are generally easy to inspect and test during manufacturing. Eliminates initial failed components.
- Electrical components are often too small (and invisible) to inspect.
- A better procedure is *burn-in testing*, in which components are operated for a time until the initially flawed components are eliminated and the flat part of the curve is reached.

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Probability of Survival

- Assume the failure rate is a constant FR_0 . The probability of survival as a function of time is:

$$P_s(t) = e^{-FR_0 t}$$

- Suppose a Lego motor has a failure rate of 1 per 100 hours of use.
 - » Probability of survival for 100 hours is 63.2%
 - » Probability of failure before 10 hours is 9.5%

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System Reliability

- System reliability involves the reliability of all individual components.
- Consider all the components that must work properly for your design to work:
 - » both motors
 - » wire
 - » car & wheels
 - » circuit
 - » computer, others?

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Series Reliability

- When all components in a system must function for the system to work, this is called a *series* connection.
- For a 3-component system, the probability of survival of the system is:

$$P_s^s = P_{s1} P_{s2} P_{s3}$$

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Series Reliability

- Suppose each component has a survival probability of 0.99. The probability of failure of the system is:

$$P_f^s = 1 - P_s^s = 1 - 0.99^3 = 3\%$$

- Suppose an airplane has 1000 series components, each with a probability of survival of 0.999999 (1 in a million). Would you get on the plane?

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Airplane Reliability

$$P_f^s = 1 - P_s^s = 1 - 0.999999^{1000} = 0.1\%$$

- This is 1 in a 1000!
- Lesson: Don't have 1000 series components!

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Parallel Components

- If only *one* of a set of components must work, we have a parallel connection.
- In this case, the probability of *failure* of the system is a product of the component probabilities of *failure*.

$$P_f^s = P_{f1}P_{f2}P_{f3}$$

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Parallel Components

$$\begin{aligned} P_s^s &= 1 - P_f^s \\ &= 1 - P_{f1}P_{f2}P_{f3} \\ &= 1 - (1 - P_{s1})(1 - P_{s2})(1 - P_{s3}) \end{aligned}$$

- Suppose each system in an airplane has three parallel components, each of which has a 0.1% probability of failure:

$$P_f^s = (0.001)^3 = 1e-7 \%$$

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Combining Parallel and Series

- Combining these redundant components in a series of 1000 yields:
- $$P_f^s = 1 - P_s^s = 1 - (1 - 1e-9)^{1000} = 0.0001\%$$
- Back to 1 in a million probability of failure!
 - Lesson: Redundant (parallel components) can significantly reduce the probability of failure.

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Failure and Safety

- Reliability is not always a matter of safety. May simply be a matter of convenience.
 - » Hard disk crashes
 - » Annoying toy won't play music
 - » Washing machine won't run
- These affect:
 - » consumer confidence
 - » bottom line if still under warranty

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Tradeoffs

- Engineering involves *tradeoffs* between reliability and cost.
 - » Higher reliability can be achieved by using more expensive parts
 - » Higher reliability can be achieved by using redundant parts.
 - » Higher reliability *may* be achieved by spending more effort (and thus money) on a smart design.

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