Hello Science Olympians! **This is the Division C Circuits Lab Test**.

The test has many questions covering all topics in the Rule Manual and emulating the hands-on lab portion of the event.

Since this test contains more questions than you can solve alone in the allotted time, please chose the questions which you are **most prepared for**, and **most interested in**. The questions are ordered by themes:

1. History
2. Hands/On Lab Questions
3. Electrostatics
4. Ohms Law
5. Magnetism
6. Digital Logic
7. PN Junctions

[**Important**] The online platform allows us to auto-grade your answers (which saves a lot of time!). Please do us a favor and **follow the answer formatting exactly, when/as requested**. If you make a formatting error but otherwise get the right answer, we will do our best to find the mistake and award you the points.

Enjoy!

Name that [Device that changed the history of electricity] ! A SciOly Trivia Game Show.

Instructions: Match the pictures (indexed by letter) with the corresponding name of the device in the following word bank.

A	Van de Graaff Generator	F Wilmschurst Machine
B	Voltaic Pile	G Faraday's Cage
C	Light Bulb	H Transistor
D	Tesla Coil	I Electric Dynamo
E	Leyden Jar	J Oudin Coil

For Questions 1-7, please input the correct letter (capitalized, without spaces,) to match each picture to it's name. For example, if you think that device 1 is a light bulb, type in "C" into the short answer blank under question 1. These questions are auto-graded so please try to get it right .

1. (4.00 pts)   Device 1 is ...

[ ]

2. (4.00 pts)   Device 2 is ...

[ ]

3. (4.00 pts)   Device 3 is ...

[ ]

4. (4.00 pts)   Device 4 is ...

[ ]

5. (4.00 pts)   Device 5 is...

[ ]

6. (4.00 pts)   Device 6 is ...

[ ]

7. (4.00 pts)   Device 7 is ...

[ ]
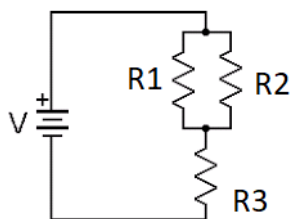
8. (30.00 pts)

The Resistor Scramble!

As you and your SciOly team are sailing in a ship, one of your crew members reports that the ship's analog radio, the only means of communication you have available, stopped working. As a Circuit Lab specialist, the entire team is pinning their hopes on you to solve the problem.

After some investigations, you determined that one of the resistors got fried. Being the super-prepared and well-studied SciOlympian that you are, you came prepared with a toolkit of spare resistors to replace the old one. Your toolkit has the following resistors:

Resistor Name	Resistor (in ohms)	Quantity	Wattage (in Watts)
R1	100	1	0.75
R2	500	3	0.5
R3	750	2	0.5
R4	1000	3	0.25
R5	2000	2	0.25
R6	5000	1	0.125

Design a resistor from the components available to you that has a **resistance of 650 Ohms** and can handle **1 Watt of power**. (points for getting close to specified wattage and resistance values will be awarded separately).

Denote parallel combinations of resistors using the | symbol, and series combinations using the + symbol. For example, the circuit below will be represented as **[[R1 | R2] + R3]**

9. (30.00 pts)
Design a logic circuit!

A ball bearing factory has asked you to design a circuit to perform a quality control on the steel balls. You have three sensors, which can output either a 0 or 1 based on the following conditions:

Sensor #	1	0
S_1	Ball is too small	Ball meets size tolerance
S_2	Ball is too heavy	Ball is within weight limits
S_3	Ball surface is rough	Ball surface is smooth

Design a circuit that outputs a one (digital 'high') if at least two of the sensors detect an anomaly (and thus output a 1). Please type in a logic expression using the following conventions:

+ = OR; * = AND; ~ = NOT, ! = NOT, use A, B, C to denote sensors 1- 3, respectively; don't forget to use parentheses to denote order of operations.


[If you're curious about how ball bearings are actually manufactured, check this out! https://www.youtube.com/19duYMdiXi0 (https://www.youtube.com/19duYMdiXi0)]

10. (5.00 pts)
In the following diagram, the top plate of the capacitor has a voltage of 0V and the bottom plate is at voltage +20V. The electric field lines between the plates are drawn, but the direction arrows have been left out. Is the direction of the electric field up (toward the top plate) or down (toward the bottom plate)?

0V

+20V
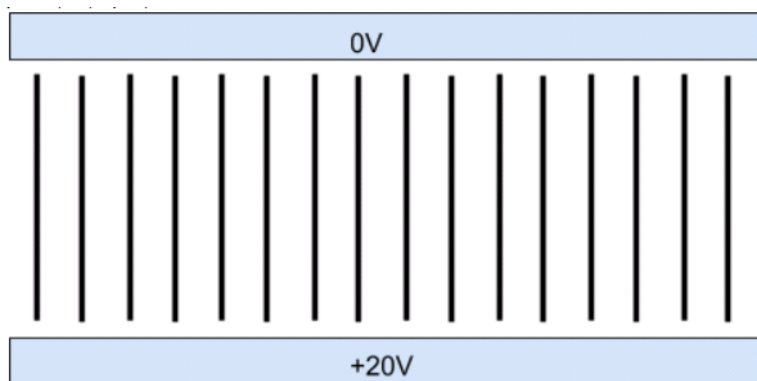
Two negatively charged particles are in a uniform electric field pointing downward. Particle A has a charge of -q and a mass m, while particle B has double the charge (-2q) and three times the mass (3m). Both particles are initially at rest. There is no gravity acting on these objects.

A

-q
m

B

-2q
3m

$\overrightarrow{E}$
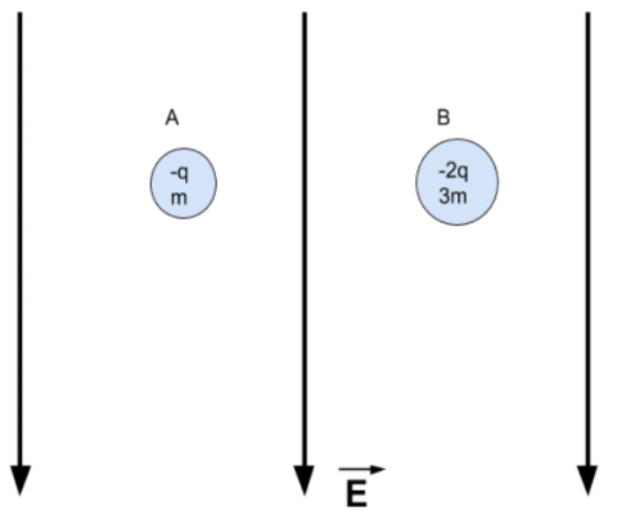
Reference this figure for the following 2 questions.

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11. (5.00 pts)   What is the direction of particle A's initial acceleration?

○ A) up
○ B) down
○ C) left
○ D) right

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12. (10.00 pts)   Which particle has a larger magnitude of initial acceleration?

○ A) Particle A
○ B) Particle B

Which capacitor has the higher capacitance value, if A = 5cm^2, d = 1mm, k_1 = 3.1 (Mylar) and k_2 = 6.7 (Neoprene)?

Capacitor 1
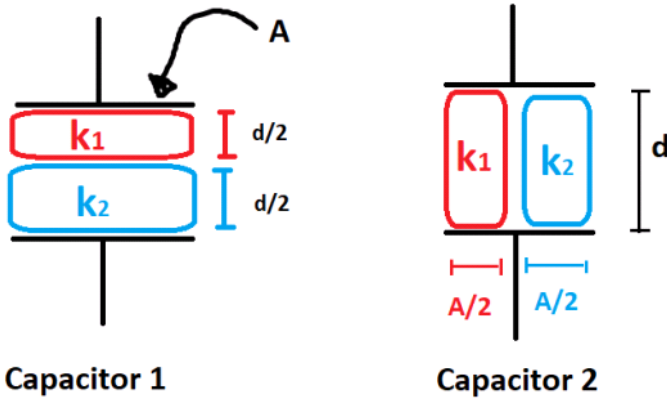
Capacitor 2

What is the value of the capacitor with the greater capacitance? Report your value in scientific notation to 3 significant figures, with units of Faradays.

For example, you would **report 137.2 microFarads as 1.37E(-4)** .

Follow this format exactly (no extra spaces as this will be auto-graded)

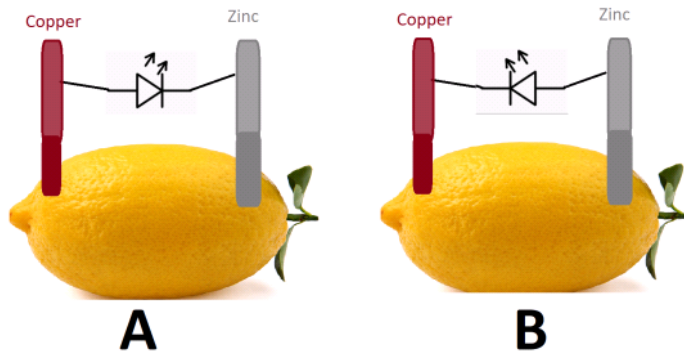**13. (10.00 pts)** The capacitor with the highest value is...

(Mark **ALL** correct answers)

☐ A) Capacitor 1

☐ B) Capacitor 2

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14. (10.00 pts) The value of the capacitor with largest capacitance, in Farads, is...

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15. (5.00 pts)
You can build a battery out of a lemon, a copper rod, and a zinc-plated nail. Assuming the battery provides enough voltage, how should you connect an LED for it to glow?
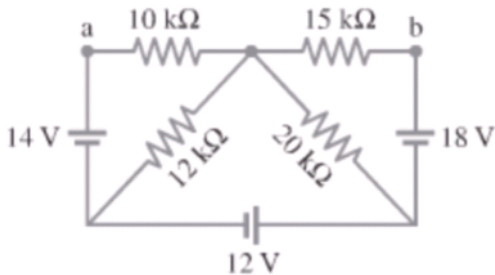

○ A) Option A

○ B) Option B

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16. (15.00 pts) Provide a justification for your answer to the lemon-battery-LED question above.
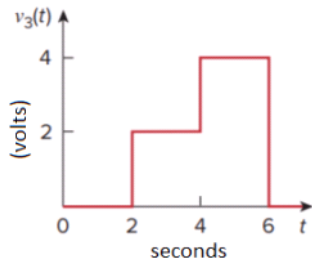
17. (15.00 pts)

For the circuit shown in Fig. 19–65, determine (*a*) the current through the 14-V battery and (*b*) the potential difference between points a and b, $V_a - V_b$.

Report your answer in scientific notation, correct to 2 significant figures. **For example, a value of 31 Volts should be reported as "3.1E(1)", without spaces or quotation marks**
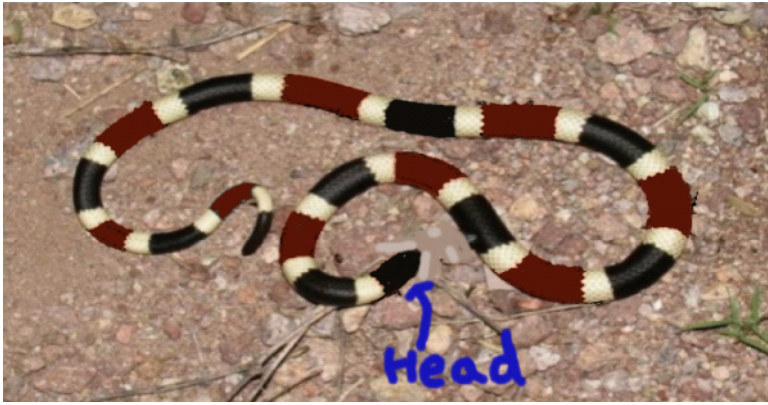
18. (5.00 pts)

If this alternating-current source has a period of 6 seconds, what is the average, or root-mean-square power delivered by the source?

Report the answer to 2 significant digits in scientific notation, in Volts. **For example, a value of 31 Volts should be reported as "3.1E(1)", without spaces or quotation marks**

Find the resistivity of the snake! (with <3 from your friends in herpetology)

Just like resistors, some snakes have colored stripes. A stripe is a band of non-white color between that is separated on both sides by white color. Starting with the head and ending at the tail stripe, **calculate the resistivity of the snake**. Note that these snakes do not have tolerances.

Useful givens: length of snake is 40cm, and is 2cm in diameter throughout its entire length.

Source: [https://www.desertmuseum.org/books/nhsd_coral_snake.php (https://www.desertmuseum.org/books/nhsd_coral_snake.php) , https://arizonadailyindependent.com/2015/10/31/arizona-coral-snakes-pretty-and-very-venomous/ (https://arizonadailyindependent.com/2015/10/31/arizona-coral-snakes-pretty-and-very-venomous/)]

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19. (15.00 pts)   Type in the resistivity of the snake in Ohms*meter, to three significant figures using scientific notation.

For example, if your calculator gives resistivity is 0.45773 Ohms*meter, type in **"4.58E(-1)", without spaces or parenthesis**

[   ]

(II) A hair dryer draws 7.5 A when plugged into a 120-V line. (*a*) What is its resistance? (*b*) How much charge passes through it in 15 min? (Assume direct current.)
c) What is the power drawn by the hair dryer?

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20. (5.00 pts)   Use the first blank to report the Resistance, in Ohms, to 3 significant figures;

Use the following notation: **report 4500 Coulombs as "4.50E(3)", without spaces and quotation marks**.

[   ]

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21. (5.00 pts)   Use the blank to report the Charge, in Coulombs, to 3 significant figures;

Use the following notation: **report 4500 Coulombs as "4.50E(3)", without spaces and quotation marks**.

[   ]

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22. (5.00 pts)   Use the blank to report the Power, in Watts, to 3 significant figures.

Use the following notation: **report 4500 Coulombs as "4.50E(3)", without spaces and quotation marks**.

[   ]

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23. (10.00 pts)   Consider this circuit:
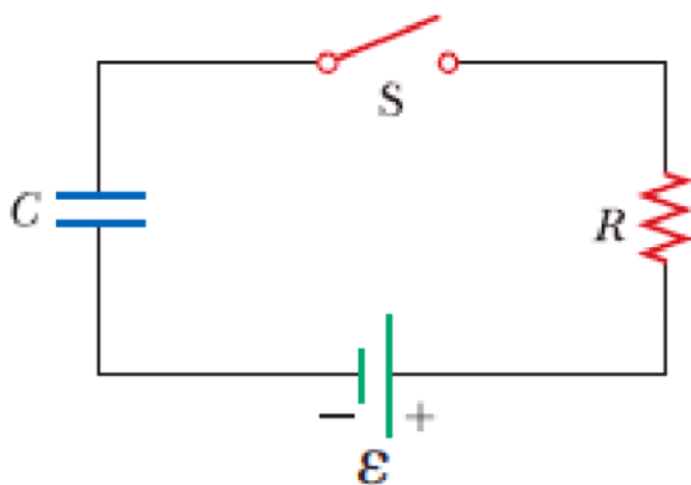
If the capacitance of C is 1.00 microFarad,

the resistance of R is 2.00 MegaOhms

the voltage of battery is 10.0V,

the switch is closed at time t = 0;

Find the voltage on the capacitor after 3 seconds. Report your answer to 3 significant figures in scientific notation, "3.14E(0)"

The two wires of a 2.0-m-long appliance cord are 3.0mm apart and carry 8.0 A of DC current. Calculate the force one wire exerts on the other. Is the force repulsive or attractive?


24. (5.00 pts)   The Force between wires is

○ A) Repulsive

○ B) Attractive

25. (10.00 pts)   Report the magnitude of Force between the wires, in Newtons, to significant figures using Scientific notation.

For example, **456N should be entered as "4.6E(2)", without spaces or quotations**.

26. (15.00 pts) Label the parts of the DC motor identified by the arrows.

Upward
Force

D   C

South
Pole

North
Pole

S   N

B

Downward
Force

+   —

A
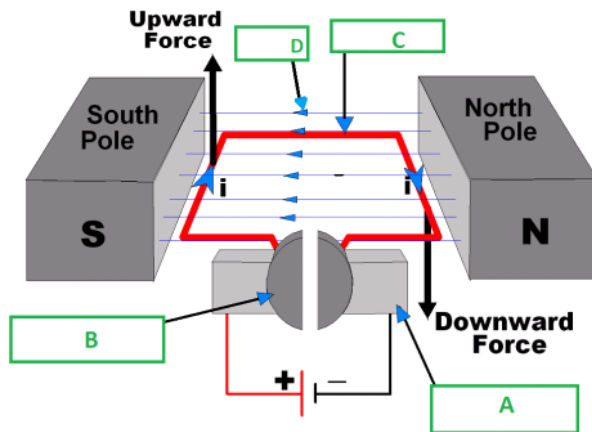
DC Motor Conceptual Diagram

Please format your answer as: (these answers are fake, for example purpose)

A: magnet

B: wire

C: neutron

D: electrons

A loop of wire lies in the x-y plane. The arrows in the diagram point in the positive directions for each axis (x, y, and z). The net charge of the wire is 0, but there is a clockwise current of constant magnitude in the wire (when looking downwards). Point P is underneath the center of the current loop.

z   y

I

x

P
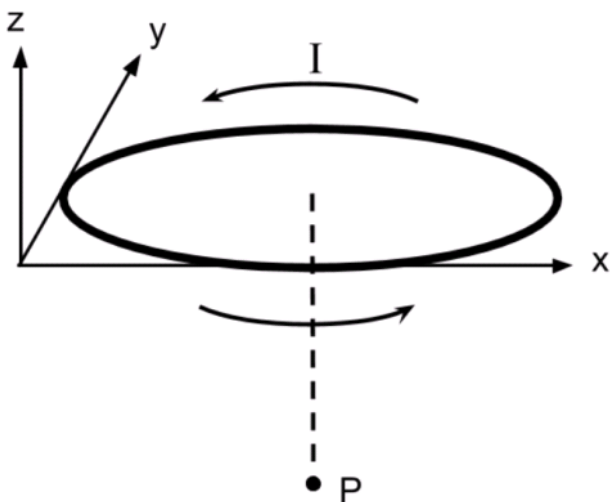
Use this information for the following 3 questions.

27. (5.00 pts) What is the direction of the **electric** field at point P?

○ A) Up (+z)
○ B) Down (-z)
○ C) In the +x or +y direction
○ D) In the -x or -y direction
○ E) The electric field is 0 at point P

28. (5.00 pts) What is the direction of the **magnetic** field at point P?

○ A) Up (+z)
○ B) Down (-z)
○ C) In the +x or +y direction
○ D) In the -x or -y direction
○ E) The magnetic field is 0 at point P

29. (5.00 pts) If there was a positively charged particle at rest at point P, which direction would it begin to accelerate in?

○ A) Up (+z)
○ B) Down (-z)
○ C) In the +x or +y direction
○ D) In the -x or -y direction
○ E) It would not move

30. (10.00 pts)
Did you know that charged particles accelerating in the Earth's magnetic field are the cause of Aurora Borealis? Explain why these effects are most noticeable near the north and south pole.

31. (10.00 pts) Three particles, a, b, and c, enter a magnetic field as shown in Fig. 20–46.
What can you say about the charge on each particle?
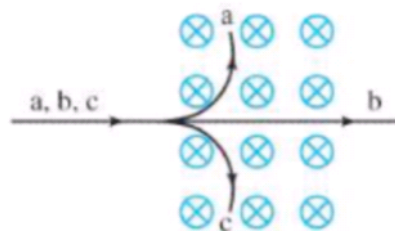
Please write the charge of particle A, B, and C in the first, second, and third blank. Don't worry about formatting, we will grade this manually.

32. (15.00 pts) Use the short-answer field to enter the name for each of the 4 switches shown in the picture below:
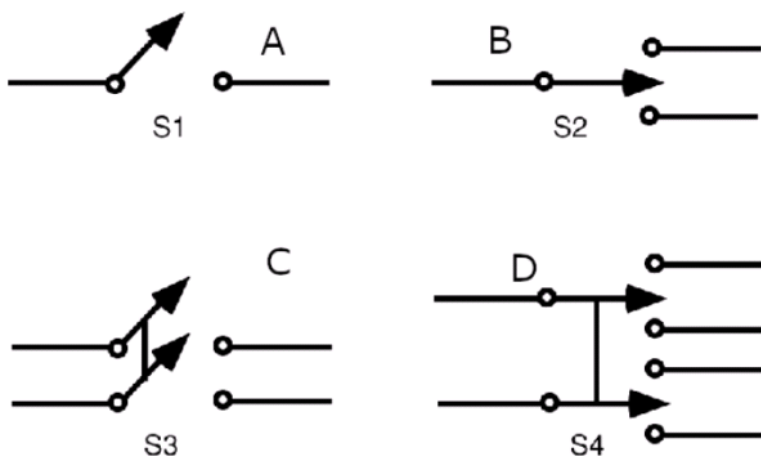
Please format your answer as: (these answers are fake, for example purpose. We will manually grade this.)
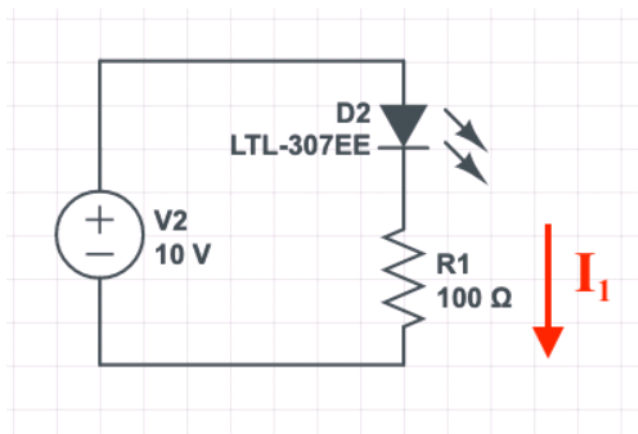
A: magnet

B: wire

C: neutron

D: electrons

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33. (10.00 pts) Assume that D2 has the characteristics of a real-life red light emitting diode (LED). Which range of currents would I1 through the resistor be?

○ A) Less than 1 micro-Ampere

○ B) Between 1 micro-Ampere and 1milli-Ampere

○ C) Between 1 milli-Ampere and 100 milli-Amperes

○ D) 100 mili-Amperes

○ E) Greater than 100 mili-Amper

**34. (10.00 pts)** Which logic gate is equivalent to the following circuit?
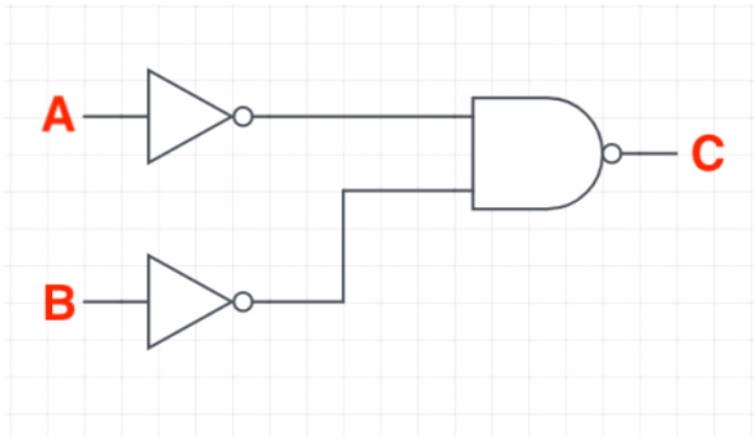
○ A) NAND

○ B) AND

○ C) NOR

○ D) OR

○ E) None of the above

Radio Communications:

Transistors: A transistor is a 3 terminal device with one input, one output, and one "control" terminal conventionally called Emitter, Collector, and Base or Source, Drain, and Gate, respectively.

The invention of the transistor revolutionized electronics technology as it enabled us to control electric circuits using purely electrical means more efficiently. One cutting-edge technology that the transistor first enabled was the compact, high quality AM radio receiver.
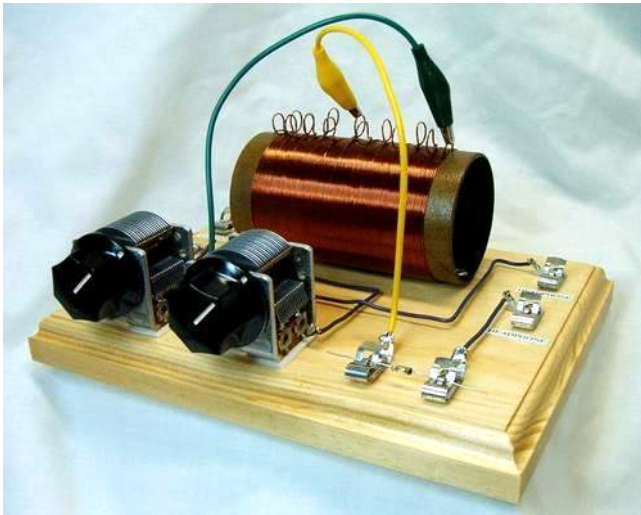

(this is the precursor to the modern radio: a crystal AM radio)

35. (5.00 pts)   What technology (used in the 1910s - 1940s) was the fore-runner of the transistor? (answer in the blank, don't worry about formatting)

36. (10.00 pts)

Explain how Zener diodes are used in Varactors. How will Zener diodes prevent sudden jolts in input voltage from damaging sensitive electronic components which can't handle more than Vn? (see picture below).

Graph of V(t)

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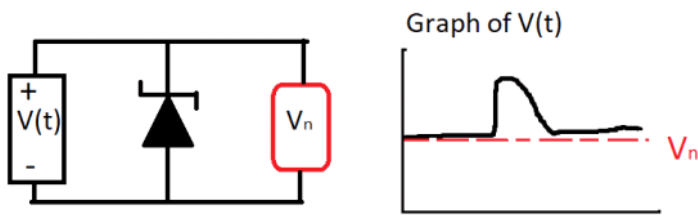
37. (10.00 pts)

A Varactor is an electronic component with variable capacitance that is made by reverse-biasing a PN junction. Explain why would a small input voltage result in a large capacitance across the varactor?
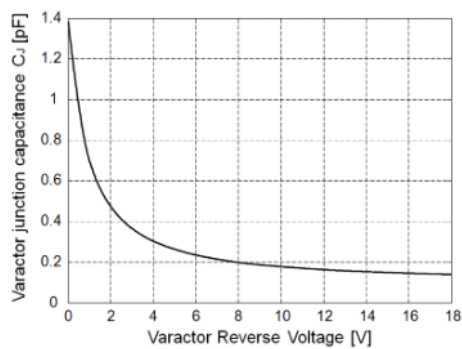
Thank you for taking this test! We will try our hardest to get any questions/ concerns answered. Scores will be released within 1 week.