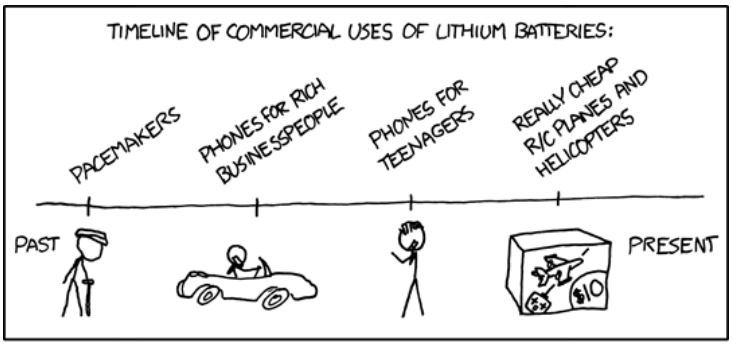
Instructions (shown before students start the test)

Circuit Lab C - Regionals



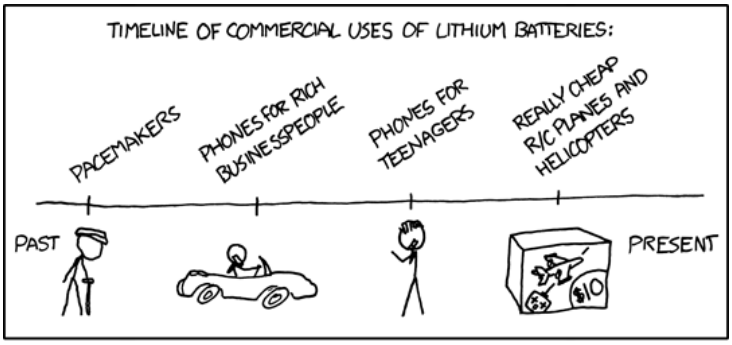
Directions

- Each team will be given **50 minutes** to complete the test.
- There are four sections: **History**, **Multiple Choice**, **Short Answer**, **Free-Response**.
- Do not worry about significant figures. Just make sure to **use 3 or more in your answers** *unless otherwise specified*.
- Also, it is not necessary to show work to receive full credit. However, partial credit may be given if the final answer is incorrect, but sufficient work is shown.
- Tiebreakers, in order: Free-Response Section Score, Multiple Choice Section Score, Short Answer Section Score, FRQ6, FRQ5 ... FRQ1.
- Best of luck! And may the odds be ever in your favor.
- Per Texas Science Olympiad rules, you must have printed notes for this event. If you are communicating with your partner through a voice or video call, please start it before you begin the test itself.

Significant time spent outside of the browser window is grounds for a penalty or disqualification per TSO policies.

Introduction (shown after students start the test)

Circuit Lab C - Regionals



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1. (0.01 pts)
By selecting True for this question, we confirm that for the duration of this exam, we will abide by all Science Olympiad rules, will not communicate with any person except our partner and the event supervisors, will not access the internet or use any resources not explicitly permitted by the official 2021 Science Olympiad rules manual for this event.

We understand that if we violate any of the above, we will likely be disqualified for this event, and will incur adverse effects on both ourselves and our team. Furthermore, we would be violating the spirit of Science Olympiad.

Please do not submit without answering this question.

○ True ○ False

History

All questions in this section are worth 1 point each, with the exceptions of 9 and 13, which are worth 2 points each.
Please follow the instructions for the Fill-In-The-Blank questions carefully.

For the next six questions, answer with one of the following: Ampere, Coulomb, Kirchhoff, Volta, Ohm, Tesla, or Faraday, spelled and capitalized exactly as written here

Names may or may not be repeated.

2. (1.00 pts) The unit of charge bears my name.

3. (1.00 pts) I discovered induced current.

4. (1.00 pts) The law relating V, I, and R bears my name.

5. (1.00 pts) I found that “The algebraic sum of currents in a network of conductors meeting at a point is zero.”

6. (1.00 pts) I created the first induction motor.

7. (1.00 pts) I discovered that a wire with flowing current attracts other nearby wires. I also made a law that described this phenomenon quantitatively.

This set of questions deals with a scientist, and his setup using a torsion balance to quantitatively measure electrical charges.

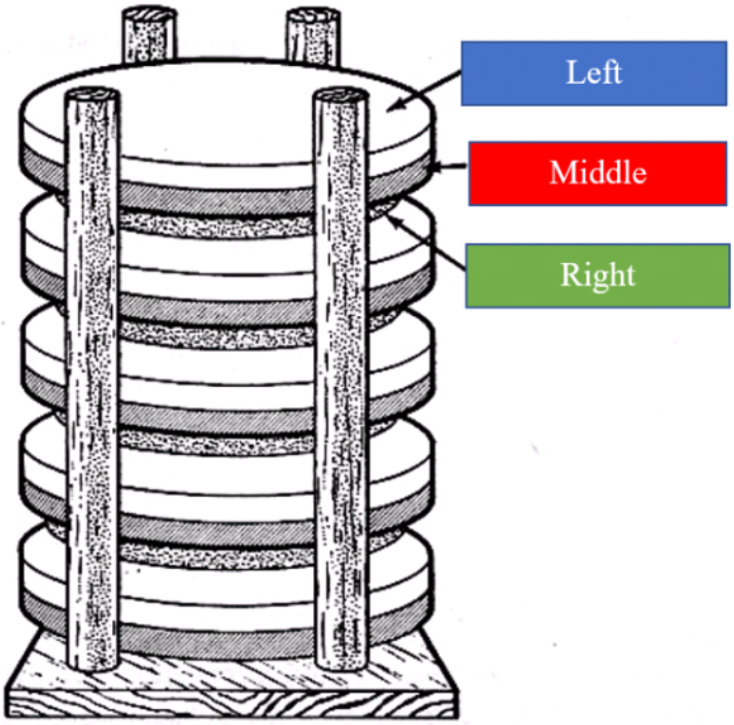
(This setup involves a bar suspended on a tension fibre with a charge on either end, as well as another charge fixed in place)

8. (1.00 pts) What is the name of this scientist (use the Name bank from the first six questions)

9. (2.00 pts) Explain how a torsion balance is used to make measurements?

10. (1.00 pts) Write down the equation for the law that was found using this experiment.

This set of questions deals with the scientist who created this contraption:



11. (1.00 pts) What is this?

12. (1.00 pts) Which scientist first made this? (use the Name bank from the first six questions)

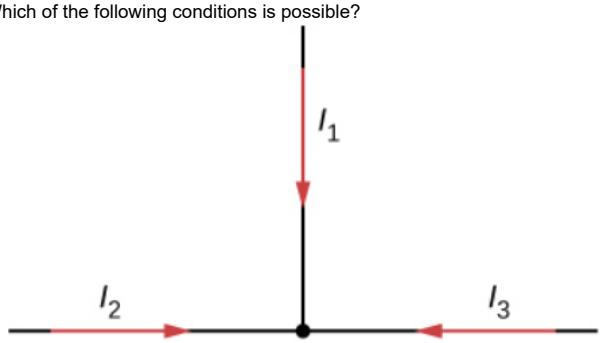
13. (2.00 pts) What are the Blue, Red, and Green labels referring to?

Multiple Choice

14. (2.00 pts) A 100 volt battery is in series with a 25 ohm resistor. What is the current going through the resistor?

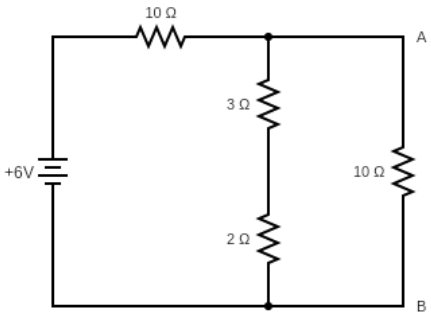
- A) 2500 A
- B) 125 A
- C) 100 A
- D) 25 A
- E) 4 A

15. (2.00 pts) Which of the following conditions is possible?



- A) All three currents are positive
- B) All three current are zero
- C) One current is zero, the other two are negative.
- D) The bottom two currents are equivalent. The vertical current is zero.
- E) None of the above are possible.

Use the following circuit diagram for the next three questions



16. (2.00 pts) What is the total equivalent resistance of the above circuit?

- A) 13.3 Ω
- B) 4.5 Ω
- C) 3.3 Ω
- D) 5.3 Ω
- E) 25 Ω

17. (2.00 pts) What is the voltage at point A?

- A) 4.5 V
- B) .9 V
- C) 6 V

D) 0 V

E) 1.5 V

18. (2.00 pts) As viewed from nodes A and B, what is the Norton equivalent current of this circuit?

A) 0.45 A

B) 0.6 A

C) 1.5 A

D) 1.8 A

E) 2.4 A

19. (2.00 pts)
A and B are the inputs to a logic gate, whose truth table is given below. What type of logic gate is this?

A	B	Output
T	T	F
T	F	T
F	T	T
F	F	F

A) AND

B) OR

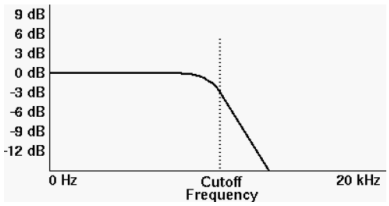
C) NAND

D) NOT

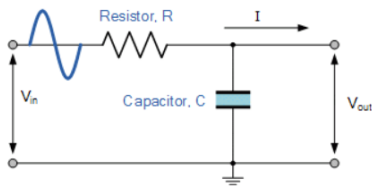
E) XOR

20. (2.00 pts) Which of the following is NOT a low-pass filter

A) A circuit with the following frequency-response graph below.

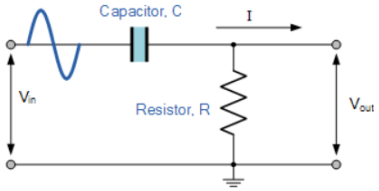


B)

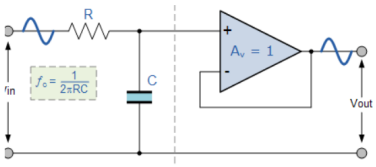


C) A circuit that allows DC current to pass unimpeded, but not high frequency AC current.

D)



E)



A) A
B) B
C) C
D) D
E) E

21. (2.00 pts)
A wire is formed into a coil of length 2 cm, with 100 turns. A current of 2.5 A is run through it. What is the magnetic field in the center of the coil? Assume a total vacuum.

A) 5 T
B) .0016 T
C) .31 T
D) .16 T
E) .0031 T

22. (2.00 pts) Which of the following elements would be present on the n side of a p-n junction?

A) Nitrogen
B) Antimony
C) Aluminum
D) Boron
E) Sodium

23. (2.00 pts) What are the specifications of current supplied from American sockets?

A) 110 V, 50 Hz
B) 110 V, 60 Hz
C) 220 V, 50 Hz
D) 220 V, 60 Hz
E) 230 V, 60 Hz

24. (2.00 pts) Which of the following boolean algebra expressions yield this truth table?

P	Q	R	A
T	T	T	F
T	T	F	F
T	F	T	T
T	F	F	F
F	T	T	T
F	T	F	F
F	F	T	T
F	F	F	F

I. $(\overline{PQ} + P\overline{Q})(R + PQ)$
II. $(\overline{PQ} + P\overline{Q})(R + PQ)$
III. $R(\overline{PQ})$

A) I only

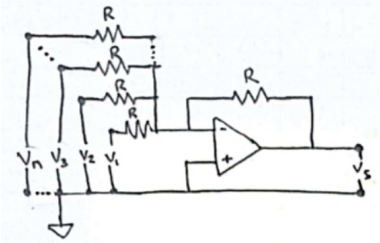
B) III only

C) I and II only

D) I and III only

E) I, II, and III

25. (2.00 pts) Vs is given by which of the following expressions



A) $V1 + V2 + V3 + \cdots + Vn$

B) $\frac{1}{\frac{1}{V1}+\frac{1}{V2}+\frac{1}{V3}+\cdots+\frac{1}{Vn}}$

C) $-(V1 + V2 + V3 + \cdots + Vn)$

D) $V1 * V2 * V3 * \cdots * Vn$

E) $\frac{-1}{\frac{1}{V1}+\frac{1}{V2}+\frac{1}{V3}+\cdots+\frac{1}{Vn}}$

26. (2.00 pts) Which of these resistor arrangements would yield the lowest overall resistance?

A) Large resistors in parallel

B) Large resistors in series

C) Small resistors in parallel

D) Small resistors in series

E) Large and small resistors in series

27. (2.00 pts) Gallium Phosphide is NOT used in LEDs of which color

A) Red

B) Blue

C) Orange

D) Green

E) Yellow

28. (2.00 pts) Which is not a reason circuit diagrams do not accurately represent real phenomena?

A) Resistance of a component changes as it heats up

B) Energy is lost as heat

C) Batteries do not have constant voltage

D) Wires have resistance

E) Circuit analysis laws are only theoretical; they do not apply to real circuits

29. (2.00 pts) A fully discharged 2.7μF capacitor is in series with a 9.6V battery and a 330 kΩ resistor circuit. The capacitor charges _____.

A) Fully in 0.891 seconds

B) ~63% in 0.891 seconds

C) Fully in 0.944 seconds

D) ~63% in 0.944 seconds

E) None of the above

30. (2.00 pts) Which is an advantage AC has over DC?

A) It's safer

B) It's transmitted easily over long distances

C) It's easily stored

D) It requires fewer transmission lines

E) None

31. (2.00 pts) If a positively charged particle is traveling east, what direction is the magnetic force on it? Assume the Earth's magnetic field is oriented with geographic north.

A) South

B) North

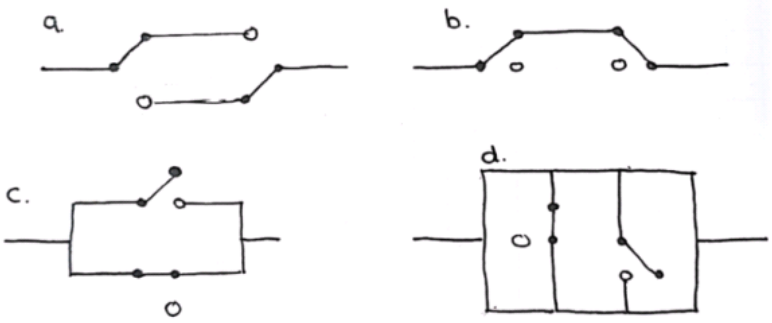
C) West

D) Down

E) Up

Use the diagram below to answer the next two questions:

32. (2.00 pts)
For this question, assume that terminals Ⓐ and Ⓑ are connected with a bulb. Which of the following configurations would be necessary, between ① and ② to be able to toggle the bulb using either switch, from any configuration?



A) A

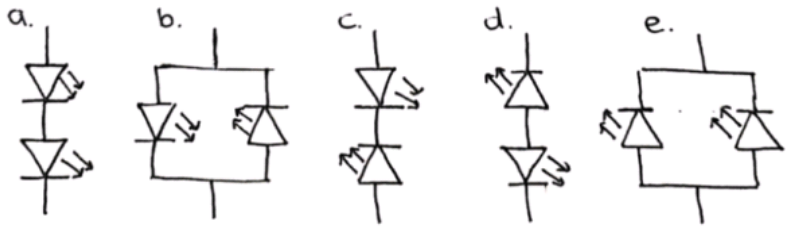
B) B

C) C

D) D

E) None of the options

33. (2.00 pts)
For this question, assume that terminals ① and ② are shorted. Which of the following LED configurations, between terminals Ⓐ and Ⓑ would guarantee that at least one LED would shine, even if the polarity of the battery was flipped?



- A) A
- B) B
- C) C
- D) D
- E) E

Short Answer

34. (2.00 pts)
If you wish to connect capacitors to maximize their overall capacitance, how would you connect them? What if you wanted to connect resistors to maximize their effective resistance?

35. (3.00 pts) I want to decrease the resistance of a copper bar.

Should I increase, decrease, or ignore (ignore if it has no effect) each of the following?

Left: Temperature

Middle: Length

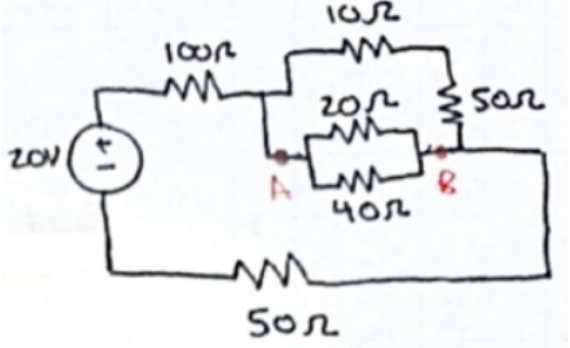
Right: Area

(Your choices are: Increase, Decrease, Ignore exactly as spelled and capitalized here)

36. (2.00 pts) Explain the role of a commutator in a DC motor

37. (2.00 pts) At what AC current threshold does one experience paralysis?

Consider the following circuit diagram for the next 3 questions

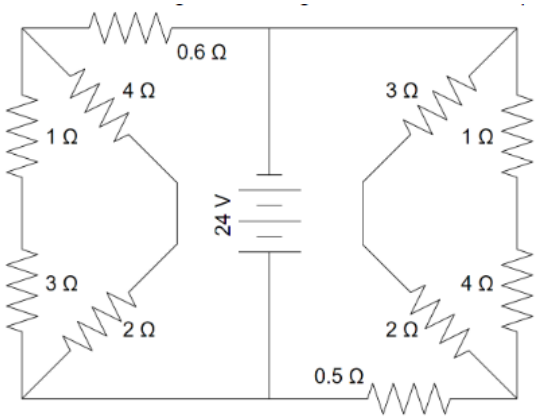


38. (2.00 pts) What is the current going through the 100 ohm resistor, in mA? (round to the nearest 10 mA, do not write the unit)

39. (2.00 pts) What is the voltage drop across the 50 ohm resistor on the bottom of the circuit, in V (round to the nearest .1 V, do not write the unit)

40. (2.00 pts) What is the power dissipated between nodes A and B, in mW (round to the nearest 10 mW, do not write the unit)?

Use the following circuit diagram for the next 3 questions (round to two decimal places or add trailing zeroes to two decimals, no unit)



41. (2.00 pts) Compute the total equivalent resistance of the above diagram, in Ohms (Hint: redraw it!)

42. (2.00 pts) Determine the current running through the .6 Ohm resistor

43. (2.00 pts) What is the power consumed by the entire circuit, in W?

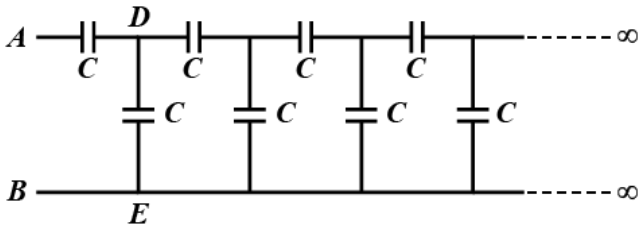
Free-Response

Point-values vary throughout this section.

Please show as much work as you can (We know its hard online). We want to give you as much credit as we can, and showing us your work makes it easier for us to do that.

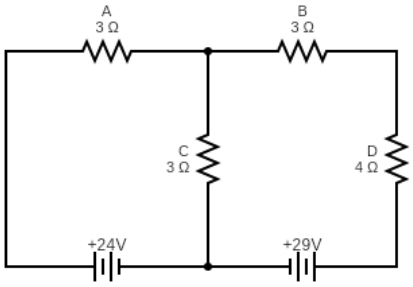
FRQ1

1. Find the equivalent capacitance of the infinite ladder of capacitors below, if C = 1 F.
   Hint: Observe the circuit made by taking all capacitors to the right of nodes D and E. Compare this to your original circuit.



FRQ2

Consider the following circuit diagram.



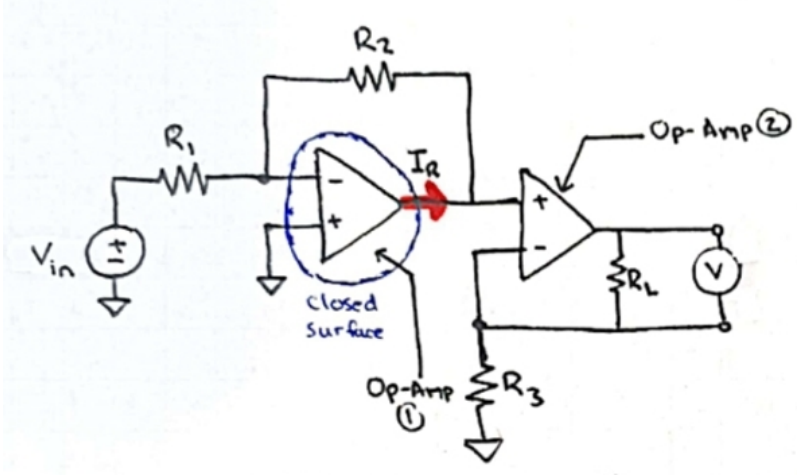
44. (3.00 pts) What is the current running through resistor C?

45. (3.00 pts) What is the voltage drop across resistor A?

46. (1.00 pts) What current law helps us understand this circuit?

FRQ 3

Here, we will analyze the following Op-Amp circuit. R1 = 100 ohms. R2 = 300 ohms, R3 = 50 ohms, RL = 1000 ohms, and V_{in}= 10 V. (assume ideal op-amps)



47. (1.00 pts) What approximations can you make about the voltages of the input terminals for ideal op-amps, as well as the current flowing into these terminals?

48. (2.00 pts) What is the current represented by the red arrow (I_R) in milliamps?

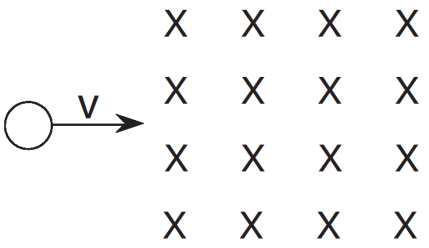
49. (3.00 pts)
KCL would suggest that there should be no current flowing into or out of the closed surface given by the blue circle and that since no current flows into the input terminals of Op-Amp ①, the current in the red arrow (I_R) should be 0. What is wrong with this argument?

50. (3.00 pts) What is the voltage at the negative terminal of Op-Amp ② (remember your answer to 47)?

51. (3.00 pts) What does the voltmeter read?

52. (4.00 pts)
What is the power gain of this circuit (that is, how many times more power is dissipated in RL than is given by the voltage source V_{in}? Don't worry about conservation of energy; your answer to 49 should have addressed this!)

FRQ 4
Consider the motion of the electron as shown below. The uniform magnetic field is of strength .4 T and the particle moves at 200 m/s. The charge of an electron is -1.602E-19 coulombs



53. (3.00 pts) Calculate the magnitude of the force exerted on the particle, in N.

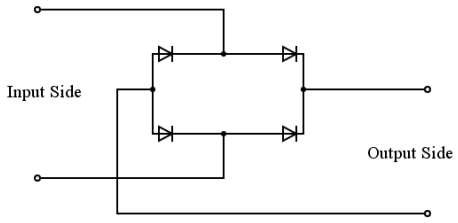
54. (3.00 pts) At the first instance the particle enters the field, what direction is the applied force? Explain.

55. (3.00 pts) If the particle is observed over a length of time, describe the path the particle takes.

56. (3.00 pts) Scientists can make use of this kind of particle motion. Name the apparatus that utilizes the phenomenon seen in this question, and explain what data it can provide.

FRQ 5

Use the following diagram for this question



57. (2.00 pts) What is the above circuit used for?

58. (3.00 pts) In practical use, the setup shown above is inefficient. Explain the inefficiency.

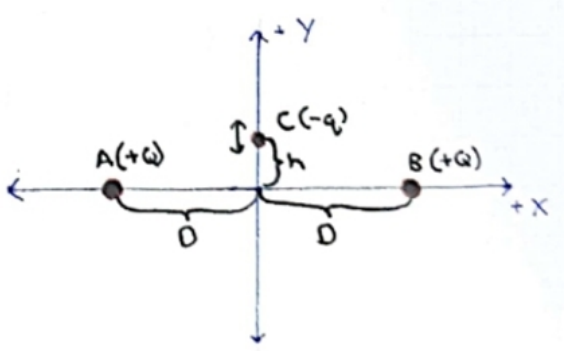
59. (3.00 pts) What is the simplest and most common modification that can improve it? Explain what is changed, and where.

FRQ 6

In this problem, we assume a standard x-y grid. At some distance +D and -D along the x-axis, there are two fixed particles A and B, each with charge +Q. Now, there is another particle C with charge -q, constrained to move along the y-axis.

We will show in this problem that for some conditions, particle Z approximates a simple harmonic oscillator (like a pendulum moving at small angles, or a mass-spring system).

Hint: The defining feature of SHM (simple harmonic motion) is that the restoring force $F = -Kr$, where r is the distance from equilibrium, and k is a constant of proportionality (not to be confused with Coulomb's constant, k.



This is a fairly difficult, but satisfying problem. Unless you've seen this before, I would recommend solving other problems before attempting this one.

60. (2.00 pts) Qualitatively or quantitatively argue that when C is at the origin, the system is in equilibrium.

61. (2.00 pts) What is the distance R between C and either A or B, in terms of h and D?

62. (3.00 pts)
Find the force (negative if towards the origin, positive if away) felt by the particle C if it is at some non-zero displacement h from the origin, in terms of k$, Q, q, h, and R?

63. (3.00 pts)
For small displacements h, make an approximation for the distance between the particle C and each of the positive charges (in other words, make an approximate relation between R and D, for small values of h).

Hint: think about what happens to the "h" term.

64. (4.00 pts) Using your approximation, show that for small displacements, C approximately follows simple harmonic motion.

!!! Congratulations on finishing the test !!!

Written by:

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If you have any feedback about any of the exams at this tournament, please let us know through this form: https://tinyurl.com/utreg21feedback (https://tinyurl.com/utreg21feedback)

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