University of California, San Diego
GRE Prep – Spring 2022
Practice E&M, Waves, and Optics Problems and Answers
April 18, 2022

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1. When two point charges are a distance d apart, the electric force that each one feels from the other has magnitude F. In order to make this force twice as strong, the distance would have to be changed to

A) $2d$.
B) $\sqrt{2}d$.
C) $d/\sqrt{2}$. ✔
D) $d/2$.
E) $d/4$.

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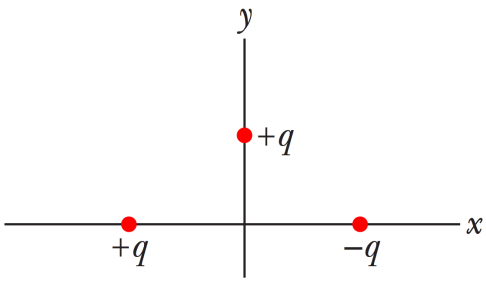
2. In the figure below, three charges (of equal magnitude $|q|$) are located at positions $(x, y) = (\pm 3\text{cm}, 0)$ and $(0, 2\text{cm})$. What is the direction of the net electric force on the charge at location $(0, 2\text{cm})$?

A) Downwards (exactly).
B) To the right (exactly). ✔
C) Upwards (exactly).
D) Downwards and to the right.
E) Upwards and to the right.



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3. The electric field in a certain region of Earth's atmosphere is directed vertically down (towards the center of the Earth). At an altitude of 50. m, the field has magnitude 1.61 kN/C; at an altitude of 25 m, the magnitude is 810 N/C. Find the net amount of charge contained in a cube 25 m on edge, with horizontal faces at altitudes of 25. m and 50. m.

A) $4.4\,\mu$C
B) $-4.4\,\mu$C ✔
C) $13\,\mu$C
D) $-13\,\mu$C
E) None of the above.

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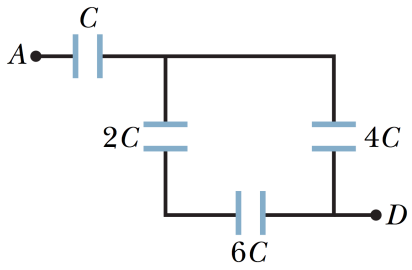
4. As a negative charge moves in the direction of the electric field, the electric potential _____ and the electric potential energy of the charge-field system _____. If we assume no forces other than the electric force act on the negative charge, then the kinetic energy of the negative charge _____.

A) decreases, decreases, remains the same.
B) increases, increases, increases.
C) decreases, increases, decreases. ✔
D) decreases, decreases, increases.
E) increases, decreases, decreases.

5. In the following figure, a constant potential difference is maintained between points A and B, and the capacitors are in equilibrium. If the charge on the capacitor with capacitance C is Q, what is the charge on the capacitor with capacitance $4C$?



A) $(8/11)Q$ ✔
B) Q
C) $(13/22)Q$
D) $(11/13)Q$
E) $(1/3)Q$

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6. A certain wire has a resistance R. What is the resistance of a second wire, made of the same material, that is half as long and has half the diameter?

A) R
B) $4R$
C) $2R$ ✔
D) $R/2$
E) $R/4$

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7. Which of the following statements is NOT true regarding Ohm's law?

A) Diodes, devices in which the resistance is very small if current tries to go one way but very large if the current tries to go the other way, follow Ohm's law. ✔
B) $\tilde{\mathbf{J}} = \sigma\tilde{\mathbf{E}}$ (where σ is the conductivity) is a microscopic version of the macroscopic $V = IR$.
C) The current going through a lightbulb is not proportional to the voltage applied across the terminals, which suggests that light bulbs don't follow Ohm's law.
D) A device is called *Ohmic* if the ratio of voltage across the terminals of the device to the current through the device is equal to a constant independent of the applied voltage.
E) The resistance of a lightbulb does not follow Ohm's law because the resistance of the bulb depends on temperature.

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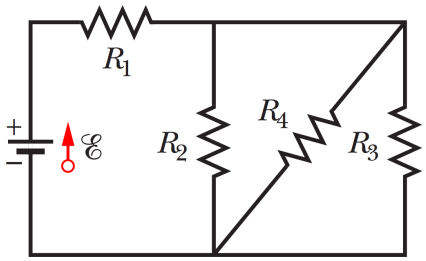
8. Which of the following statements is NOT true concerning the circuit shown?



A) Resistors R_2 and R_4 are in parallel with one another.
B) The voltage drop across R_1 is less than the battery EMF.
C) Assuming all resistances are equal, the voltage drop across R_1 is greater than the voltage drop across R_3.
D) Assuming $R_4 = 2R_2$, the voltage drop across R_4 is twice the voltage drop across R_2. ✔
E) The current through R_3 is downwards.

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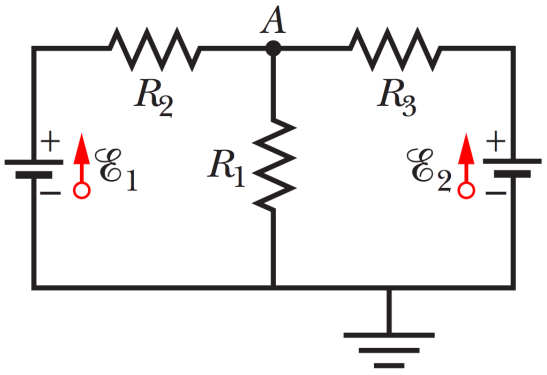
9. For the circuit shown, $R_1 = R_2 = R_3 = 4\Omega$. Battery 1 (on the left side of the circuit) has EMF $\mathcal{E}_1 = 4$ Volts, and battery 2 (on the right side of the circuit) has EMF $\mathcal{E}_2 = 8$ Volts. In addition, the circuit is grounded as shown, where the ground has potential 0 Volts. What is the electric potential at point A?



A) 2 Volts.
B) 4 Volts. ✔
C) 6 Volts.
D) 8 Volts.
E) 12 Volts.

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10. A wire 50.0 cm long carries a 0.500 A current in the positive direction of an x axis through a magnetic field $B = (3.00\text{mT})\hat{\mathbf{j}} + (5.00\text{mT})\hat{\mathbf{k}}$. Which of the following is true?

A) The magnetic force on the wire has positive $\hat{\mathbf{i}}$-component.
B) The magnetic force on the wire has positive $\hat{\mathbf{j}}$-component.
C) The magnetic force on the wire has positive $\hat{\mathbf{k}}$-component. ✔
D) The magnetic force on the wire has negative $\hat{\mathbf{i}}$-component.
E) None of the above statements is true.

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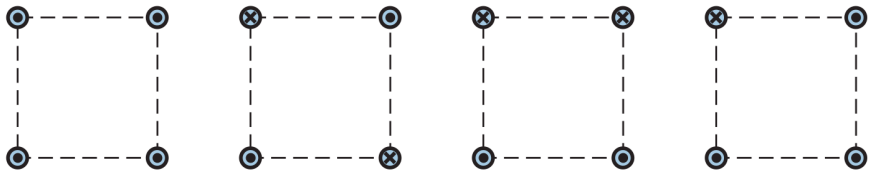
11. The figure shows four arrangements in which long parallel wires carry equal currents directly into or out of the page at the corners of identical squares. How many of the four arrangements have a net magnetic field of zero at the center of the square?

A) 0
B) 1
C) 2 ✔
D) 3
E) 4



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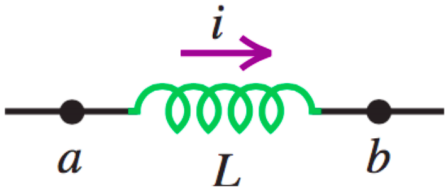
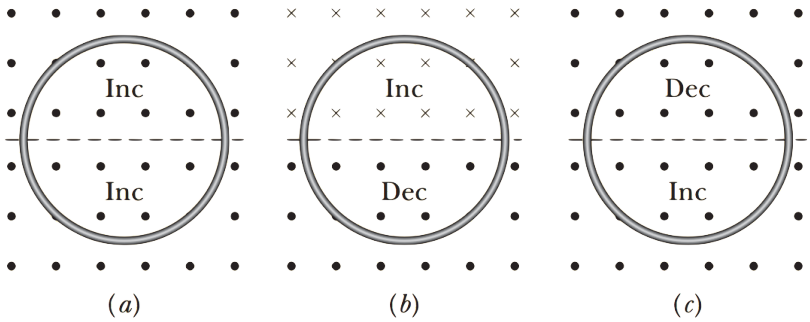
12. Current $i = 0.50$ Amps is decreasing at a rate $|di/dt| = 1.0$ Amps/sec. It passes from point a to point b through an inductor of inductance $L = 2.0$ H. Which point has higher electric "potential" (a or b), and by how many volts relative to the other side?

A) Point a, 1.0 Volt.
B) Point a, 2.0 Volts.
C) Point a, 0.5 Volts.
D) Point b, 1.0 Volt.
E) Point b, 2.0 Volts. ✔



13. The figure shows three situations in which identical circular conducting loops are in uniform magnetic fields that are either increasing (Inc) or decreasing (Dec) in magnitude at identical rates. In each, the dashed line coincides with a diameter. For which of the situations is there a clockwise current induced in the loop?

A) (a) only ✔
B) (b) only
C) (c) only
D) (a) and (b) only
E) (b) and (c) only

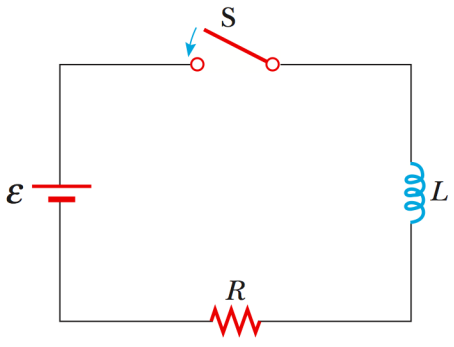


14. You have a spool of copper wire that has resistance per unit length 5.5×10^{-3} Ohms per meter and inductance per unit length of $0.30\,\mu$H per meter. Suppose you take 20.0 cm of this wire and connect the ends to the terminals of a 1.5 Volt battery. How long does it take for the current in the wire to reach 80.% of its maximum value?

A) 123 μs
B) 88 μs ✔
C) 69 μs
D) 55 μs
E) 32 μs

15. For the RL-circuit shown below, let the inductance $L = 1.00\,\text{H}$, the resistance $R = 16.0\,\Omega$, and the battery EMF $\mathcal{E} = 24.0\,\text{V}$. The switch S, initially open, is suddenly closed, and as a result current gradually increases from zero to some maximum value. What is the ratio of the potential difference across the resistor to the voltage across the inductor when the current is 1.00 A?

A) 2 ✔
B) 1
C) 1/2
D) 3
E) 1/3



16. Suppose you have a simple, undriven LC circuit with negligible resistance. At time $t = 0$ the current is zero, but the capacitor is charged. If T is the period of the resulting oscillations, the next time after $t = 0$ that the magnitude of the voltage across the inductor is a maximum (irrespective of sign) is:

A) $0.25T$
B) $0.5T$ ✔
C) $0.75T$
D) T
E) The emf across the inductor asymptotes to a maximum value at $t \to \infty$.

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17. A coil has a resistance of $60\,\Omega$ and a total impedence (i.e., including its inductive reactance) of $100\,\Omega$. Its inductive reactance is:

A) $40\,\Omega$.
B) $60\,\Omega$.
C) $80\,\Omega$. ✔
D) $100\,\Omega$.
E) $117\,\Omega$.

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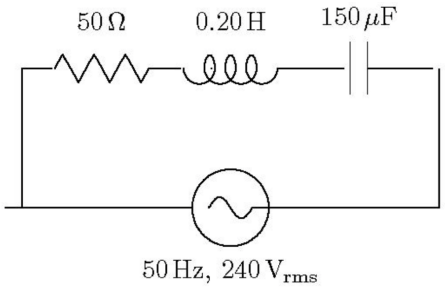
18. For the series RLC-series circuit shown, what is the rms-current? By the way, the numbers shown for the AC source are (close to) what they use in most European countries.

A) 8 Amps
B) 2 Amps
C) 4 Amps ✔
D) 1 Amp
E) 0.5 Amps



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19. The sound intensity of cars on the freeway is 100 times louder than the sound intensity on a city road. If the decibel level of cars on the city road is 65 dB, what is the sound intensity of cars on the freeway?

A) 67 dB.
B) 85 dB. ✔
C) 98 dB.
D) 130 dB.
E) None of the above.

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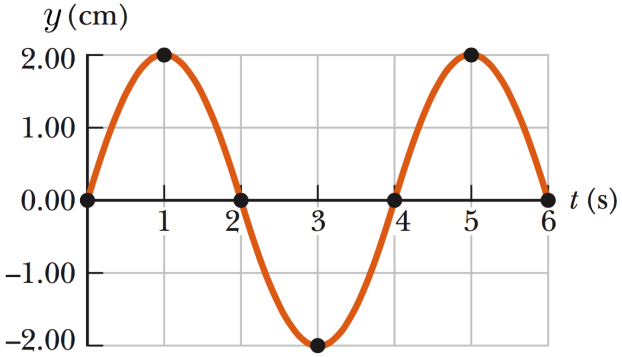
20. The figure below shows the displacement $y(x = 0, t)$ for a transverse wave on a string. To one significant figure, what is the maximum speed that particles on the string move?



A) 1 cm/sec
B) 2 cm/sec
C) 3 cm/sec ✔
D) 4 cm/sec
E) 5 cm/sec

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21. Which of the following statements is TRUE regarding mechanical waves?

A) The denser the material, the higher the speed of sound in that material.
B) Sound waves are the most common example of transverse mechanical waves.
C) Upon reflection, a wave on a string can have its waveform inverted. ✔
D) The doppler effect says that it is the frequency only that changes, and not the wavelength of sound waves, when a source moves towards a receiver.
E) When the frequency of waves doubles, the speed of those waves also doubles.

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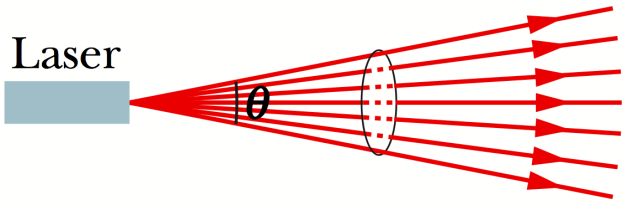
22. A helium-neon laser, radiating at 632.8 nm, has a power output of 3 mW. The beam diverges (spreads) at total angle $\theta = 0.25$ mrad (this is the *total* angle, not the half-angle). What is the amplitude of the electric field due to the laser light 75 m from the laser?



A) 100 V/m ✔
B) 10 V/m
C) 1 V/m
D) 0.1 V/m
E) 0.01 V/m

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23. Total internal reflection occurs at an interface between a plastic and air at incidence angles larger than 60 degrees. What is the refractive index of the plastic?

A) 0.707
B) 1.41
C) 1.5
D) 1.73
E) 1.15 ✔

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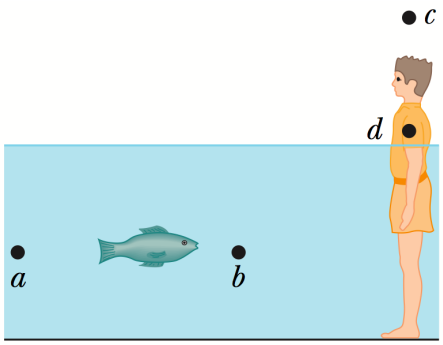
24. In the figure below, a person looks at a fish and a fish looks at a person. (i) Does the person see the fish's image closer to point a or point b? (ii) Does the fish see the person's image closer to point c or point d?



A) (i) Point a ; (ii) Point c ✔
B) (i) Point a ; (ii) Point d
C) (i) Point b ; (ii) Point c
D) (i) Point b ; (ii) Point d

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25. You're designing your very own bathroom mirror. You'd like the mirror to have magnification 5 when your face is 20 cm away from the mirror. What should be the radius of curvature of the mirror? Should the mirror be concave or convex?

A) Concave mirror, radius of curvature 50 cm. ✔
B) Concave mirror, radius of curvature 12.5 cm.
C) Convex mirror, radius of curvature 50 cm.
D) Convex mirror, radius of curvature 12.5 cm.
E) None of the above.

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26. A lens produces an upright, enlarged, virtual image. What can we say about the lens and/or the object location?

A) The lens is converging and the object is closer to lens than the focal point. ✔
B) The lens is diverging and the object is closer to lens than the focal point.
C) The lens is diverging, but we can't tell where the object is relative to the focal point.
D) The lens is diverging and the object is farther away from the lens than the focal point.
E) The lens is converging and the object is farther away from the lens than the focal point.

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27. What is the minimum separation of two objects on Mars in order to resolve them by an observer on Earth with the naked eye? The distance to Mars is 8.0×10^7 km, the diameter of the pupil is 5.0 mm, and the wavelength of light can be taken to be 550 nm.

A) 10^4 km ✔
B) 10^3 km
C) 10^5 km
D) 10^2 km
E) 10^6 km

End of Multiple Choice Questions

ELECTRICITY AND MAGNETISM (18% of exam):

(a) Electrostatics

(i) Electric Forces and Fields
(ii) Gauss's Law
(iii) Electric Potential
(iv) Electric Fields in Matter

(b) Current, Resistance, Circuits

(i) Capacitors and Capacitance
(ii) Current Density and Drift Speed
(iii) Ohm's Law (Microscopic and Macroscopic)
(iv) Kirchhoff's Rules
(v) DC Circuits (including RC Circuits)
(vi) AC Circuits (in particular, series LRC)

(c) Magnetism (Basics / Magnetostatics)

(i) Lorentz Force, Motion of Charged Particles in B-Fields
(ii) Gauss's Law for Magnetism
(iii) Permanent Magnetis; Domains
(iv) Biot-Savart Law

(d) Electrodynamics / Maxwell's Equations

(i) Ampere's Law
(ii) Faraday's Law
(iii) Displacement Current

WAVES AND OPTICS (9% of exam)

(a) Waves

(i) Waves – General Properties, Mathematical Properties
(ii) Transverse Matter Waves; Waves-on-a-string
(iii) Longitudinal Matter Waves (Sound Waves) and the Doppler Effect
(iv) Standing Waves (for both transverse and longitudinal)
(v) EM Waves (including Poynting Vector)

(b) Optics

(i) Geometric Optics – Snell's Law, Total Internal Reflection
(ii) More ray optics: Lenses and Mirrors, Optical Instruments
(iii) Interference and Diffraction, Rayleigh Criterion