**Multiple choice questions.**
Just the answer counts for these. (8 points each)

1) Two little beads have charges on them, q and \(-2q\), a distance d apart. What is the strength and direction of the electric field at a point I marked “X” a distance d on the other side of the bead with charge q?

![Diagram of two beads with charges](image_url)

a) \(E = \frac{kq^2}{d}\), to the right.
b) \(E = \frac{kq}{2d^2}\), to the right.
c) \(E = \frac{3kq}{d^2}\), to the left.
d) \(E = \frac{3kq}{4d^2}\) to the left.
e) \(E = 0\).

2) Two resistors are connected in parallel as part of a circuit. One has twice the resistance of the other. Compare the current through, voltage across, and power used for the 2R resistance to the 1R.

![Diagram of parallel resistors](image_url)

The 2R resistor

a) has twice the current through it, twice the voltage across, and uses twice the power.
b) has half the current through it, the same voltage across, and uses twice the power.
c) has half the current through it, the same voltage across, and uses half the power.
d) has same current through it, twice the voltage across, and uses the same power.
e) has half the current through it, the same voltage across, and uses the same power.

3) Two movable metal plates are connected to a storage capacitor. The storage capacitance is very large, say 1 F; the capacitance of the plates is much smaller, say \(10^{-10}\) F. The plates have net charges of +Q and \(-Q\), and there’s a potential difference \(\Delta V\) between them.

If we pull the plates away from each other, keeping them connected to the storage capacitor, what effect will that have on Q and \(\Delta V\)?
a) Both $Q$ and $\Delta V$ will increase.
b) Both $Q$ and $\Delta V$ will decrease.
c) $Q$ will increase; $\Delta V$ will stay about the same.
d) $Q$ will decrease, $\Delta V$ will stay about the same.
e) $Q$ will stay about the same, $\Delta V$ will decrease.

4) It’s possible to make materials with variable indices of refraction, so that a lens doesn’t have to be shaped in the usual way, convex or concave. That’s an excuse for me to ask this question this way… The diagram shows light leaving the object and passing through the fancy material. According to this diagram, there would be

a) A magnified, upright image to the right of the lens.
b) A reduced, upright image to the right of the lens.
c) A reduced, inverted image to the left of the lens.
d) A magnified, inverted image to the left of the lens.
e) Two images, an upright one to the right of the lens and an inverted one to the left.

5) Light from a distant source (it could be the sun) shines on a piece of cardboard with a hole the shape of an arrow, 4 cm tall. The source is so far away that the light is essentially parallel. The light that makes it through the hole then gets to a lens (focal length = 60 cm) and then a screen.

On the other side of the lens, 30 cm away, is a screen. What is the best description of what you would see on the screen?
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a) A clear arrow, right side up, 8 cm tall.
b) A clear arrow, upside down, 4 cm tall.
c) A clear arrow, right side up, 2 cm tall.
d) An unfocused splotch of light.
e) A small dot of light.

6) Light is incident on an air/water surface, coming from the water (n=1.33), at an angle as shown. Which ray best represents what the light does at the surface?

a) 1  b) 2  c) 3  d) 4  e) 5

7) We’ve seen that when two equivalent sinusoidal waves travel toward each other on a spring they interfere in such a way that (a) they sometimes cancel in displacements so that the whole spring is flat and (b) there are points on the spring that never move (nodes).

What if the waves traveling toward each other aren’t sinusoidal but a series of pulses like these (the same shape but flipped over and reversed)?

Will the spring go flat? Will there be any nodes?

a) The spring will sometimes go flat and there will be some nodes.
b) The spring will sometimes go flat, but there won’t be any nodes.
c) The spring will never go flat, but there will be some nodes.
d) The spring will never go flat, and there won’t be any nodes.
e) There’s not enough information to answer the question.

8) When a wave propagates, no mass moves along with it, but energy does. Think of a wave propagating along a spring: Each piece of the spring makes the next piece of spring move, which is to say each piece of spring passes energy to the next.

For this question, I’d like you to make a plausible guess of an expression for the amount of energy a sinusoidal wave carries with it along a spring. Some possible variables:

- The mass per unit length of the spring, \( \mu \)
- The tension of the spring, \( T \)
- The speed of waves along the spring, \( v_w \)
- The frequency, \( f \)
- The wavelength, \( \lambda \)
Which is the most plausible formula?

a) $E = (\text{constant}) \mu v_w^2$

b) $E = (\text{constant}) \mu T/\lambda$

c) $E = (\text{constant}) \mu f^2 A^2$

d) $E = (\text{constant}) A^2 T/\mu$

e) $E = (\text{constant}) \mu \lambda^3 f$

Short answer questions, with explanations. For these, you need to explain, and clarity counts!

9) (10 points) You’re sitting in a room 3 meters from a window. The window is 1.5 meters tall. Outside, 20 meters away from the window, there is a tree. From where you are sitting, the tree just fits in the window: You can see the base of the tree through the bottom of the window and the top of the tree through the top of the window.

How tall is the tree?
10) In many small houses, turning on a toaster (or an air conditioner, or anything that draws a lot of current) makes the lights dim a little bit. In this question you’ll explain why.

We’re used to treating wires as ideal, with no resistance at all. But real wires have some small resistance. In drawing a circuit diagram of a house, we can take that resistance into account by including a resistor in the circuit.

So here’s a circuit diagram with a simplified model of wiring to explain why the lights dim. Notice the resistor, and suppose it’s a small resistance. It models resistance in the wires.

Without that resistance, turning on the toaster wouldn’t affect the lamp. With that resistance, turning on the toaster makes the lamp dim a little bit. Explain why.
11) This is a diagram from the solutions to assignments 10 and 11. It depicts a pattern of peaks and troughs from the two sources in phase, and it shows places of constructive and destructive interference.

In the diagram, both sources are emitting pulse after pulse, a complete wavelength every T seconds.

In this question, I want to think about single pulses leaving the two sources.

a) Suppose we block these sources, both of them, and then we remove the block just enough so that each source emits a single half-wavelength pulse, just one peak like this, at exactly the same time.

Explain where, if anywhere, there will be constructive and/or destructive interference between these two pulses (one from each source). Be precise.

b) Now suppose we do the same thing, but this time we let one half-wave pulse out from the source on the left first and then in the next cycle we let out a half-wave pulse from the source on the right.

Explain where, if anywhere, there will constructive and/or destructive interference.
c) Finally, suppose you wait \( n \) cycles to let out the second pulse. Write a formula for the angle from the perpendicular where the two pulses would interfere.

12) One of the first things we did in the course was to develop the basic idea that the motion of charge in a wire is like the motion of rope when we pull on it or of water in filled pipes when we turn on a faucet: It all moves at the same time. By that reasoning, when you turn on a wall switch, current immediately starts to flow everywhere in the wires, and the lights come on instantly.

Now we know about waves, and that gives us a way to refine that reasoning. If you tug on a rope, you pull the piece of rope at your hand, which pulls the next piece, which pulls the next, and so on: The movement of rope propagates. The same reasoning works for water and for electricity: The occurrence of motion travels through the medium, and it can travel much faster than the material itself (water or electric charge). For rope and water, the motion travels at the speed of sound; for electricity, it travels at the speed of electromagnetic waves, that is at the speed of light.
a) In a wire, the speed electric charge along the wire that makes the current is pretty slow—it could be \(10^4\) m/s (=0.1 mm/sec). The speed of electromagnetic waves, on the other hand, is close to the speed of light in a vacuum, \(3 \times 10^8\) m/s.

Suppose there’s 20 meters of wire between a wall switch and a 120 Watt ceiling light. By this refined reasoning, how much time delay should there be between turning on the switch and charge starting to move through the ceiling light?

b) Now suppose the switch is connected to a whole lot of lights, say a chandelier, with 1200 Watts worth of bulbs. According to this model, should that affect the delay between turning on the switch and the current flowing through the bulbs?

c) Finally, one of the first things we did studying light was to use the basic idea that light travels in straight lines to explain the phenomenon of a pinhole camera: The smaller the pinhole, the dimmer but sharper the image a pinhole camera produces.

How does the wave model of light refine that reasoning? Explain.