

Final Exam

Your Name:

Instructions

Answer each of the following questions to the best of your ability. The exam is worth 100 points total and is calibrated for 120 minutes. Please show all of your work to receive full credit.

Once you have completed the exam, you are free to leave. Have a great summer!

1. Two point charges, each with a charge of $+0.5 \text{ mC}$, are separated by a distance of 1.25 m . What is the electric force between the particles? Do they attract or repel?
2. Sketch a diagram showing some electric field lines and equipotential lines around a single negative point charge. Be sure to label the field lines and the equipotential lines.
3. Two point charges, each with a charge of $+1.1 \text{ mC}$, are separated by a distance of 2.5 m . What is the electric potential energy of the system?
4. A chunk of material has a capacitance of 10 mF . How much charge will be stored on it if I attach it to a 9 volt battery?
5. Three resistors, each with a resistance of 30Ω , are connected in parallel with a battery of voltage 10 V . What is the current drawn from the battery?
6. A positively charged particle is fired into a magnetic field with an initial velocity in the $+y$ direction. If the magnetic field is pointing in the $-z$ direction, in which direction is the initial force on the particle?
7. A velocity selector consists of a crossed electric field (500 N/C) and magnetic field (0.25 T). What speed should I fire a positively charged particle through the velocity selector if I want it to pass through, undeflected?
8. Why might we use a metal core within an inductor in a circuit?
9. A charging DC LR circuit consists of a battery (15 V), a resistor (10Ω), and an inductor (0.5 H) in series. What is the time constant of the circuit?
10. The magnetic flux passing through a loop of wire is given by $\phi_B(t) = 10 t^2 \text{ Wb}$. What is the induced EMF in the loop at time $t = 7 \text{ seconds}$ (including the correct sign)?
11. A sinusoidal signal has a peak voltage of 12 V . What is the RMS voltage of the signal?
12. An AC RLC circuit is made up of a 100-ohm resistor, a 12 mF capacitor, and a 28 mH inductor. What is the resonant frequency of the circuit?
13. A step-up transformer has a turn ratio of $N_2/N_1 = 1000$. If I apply a 9-volt RMS AC voltage to the input of the transformer, what is the RMS output voltage?
14. What is the phase angle of a series RLC AC circuit when it is driven at resonance?
15. In the context of the Ampere-Maxwell equation, how is displacement current different from “regular” current?
16. What is the frequency of a two-meter wavelength wave as it travels through a vacuum?
17. The momentum per unit time per unit area carried by an electromagnetic wave is called _____.
18. An electromagnetic wave has an electric field aligned along the x -axis and travels in the $+z$ direction. What is the direction of the Poynting vector of the wave?
19. Light, initially polarized along the z -axis, encounters a polarizing filter oriented at 35 degrees with respect to the z -axis. What percentage of light passes through the filter?
20. What is Fermat’s Principle?
21. Suppose that a star is located at a distance of $4.0 \times 10^{24} \text{ m}$ from Earth. How long would it take light to travel from the star to Earth in the vacuum of space?

22. A ray of light with a wavelength of 650 nm passes from air ($n = 1.00$) to water ($n = 1.33$). Calculate the angle of reflection if the angle of incidence of the ray of light is 21 degrees.
23. A ray of light with a wavelength of 850 nm passes from air ($n = 1.00$) to water ($n = 1.33$). Calculate the angle of refraction if the angle of incidence of the ray of light is 45 degrees.
24. What is the critical angle as light travels from plate glass ($n = 1.52$) to benzene ($n = 1.501$)?
25. What does wave-particle duality mean in the context of light?
26. An object with a height of 5 cm is located 40 cm in front of a converging mirror with a focal length of $|f| = 10$ cm. Where is the image located?
27. An object with a height of 10 cm is located 20 cm in front of a diverging lens with a focal length of $|f| = 5$ cm. What is the final height of the image?
28. What is spherical aberration in the context of mirrors?
29. The index of refraction of fused silica is around 1.51. What is the wavelength of red light (700 nm in vacuum) as it passes through the material?
30. A double slit interference apparatus has a slit separation of 0.2 mm. At what angle would we see the 10th order maximum if we shine light with a wavelength of 600 nm on it?
31. A thin film of soapy water ($n = 1.35$) is sandwiched between layers of air in a soap bubble. At what minimum thickness of the film would I see red light with a wavelength of 750 nm?
32. In class, we went through a derivation of the equation for electromagnetic waves, starting from Maxwell's equations. What do we mean by the "curl" and "divergence" of a vector field? You do not have to show any mathematics – an explanation will suffice.
33. What is coherence in the context of light waves?