Final Exam

Your Name:

Instructions

Solve each of the following problems to the best of your abilities. I will give partial credit for solutions, so show all your work. Each question is worth four points.

You are allowed four 8 1/2 by 11" sheets of paper for notes as well as a calculator to use on the test. I can also provide you with some extra sheets of blank paper if needed.

You have the full period to work on the final exam. Once you have completed the exam, hand it to me and then you are free to leave. Good luck!

1. Two point charges, each with a charge of +1.0 mC, are separated by a distance of 0.15 m. What is the magnitude of the electric force between the point charges?

$$F = \frac{kqq}{r^2} = 400{,}000\ N$$

2. What is the SI unit of electric charge?

Coulomb

3. What are the steps needed to charge an object by induction?

First, bring a conductor close to (but not touching) a charged object so that it becomes polarized. Then, ground the conductor so that charge moves to a new equilibrium. Finally, disconnect the ground and separate the objects.

4. Two parallel plates carry equal and opposite charges. Sketch a diagram of the plates, the electric field vectors around the plates, and a few equipotential lines around the plates.

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/equipot.html

5. An electric field with a magnitude of 1,000 N/C points in the –z direction. A beam of protons is traveling in the +y direction with a speed of 100 m/s. What is the magnitude and direction of the electric force on the protons?

$$F = qE = (1.6 \times 10^{-19} C)\left(1000 \frac{N}{C}\right)$$

$$F = 1.6 \times 10^{-16} N$$

-z direction

6. A positively charged particle is fired into a magnetic field with an initial velocity in the +x direction. If the magnetic field is pointing in the –y direction, in which direction is the initial force on the particle?

-z direction

7. A chunk of material with a capacitance of 100 mF has a stored charge of 30 mC. What is the voltage across the material?

$$V = \frac{Q}{C} = 0.3\ V$$

8. How might an iron core affect the inductance of a solenoid in a circuit?

An iron core would increase the strength of the inductor, thus making it a more potent circuit element.

9. What does Gauss' Law for Magnetism tell us about "magnetic charge" (a.k.a. magnetic monopoles)?

Gauss' law for magnetism tells us that magnetic field lines loop on each other. In other words, there can be no "magnetic charge" - i.e. no magnetic monopoles.

10. What does Lenz's law tell us about the direction of voltage / current due to magnetic induction?

Lenz's law tells us that the direction of the electric potential induced by a changing magnetic field opposes that magnetic field. Nature tries to keep status quo.

11. A charging RL circuit consists of a battery (15 V), a resistor (1000 Ω), and an inductor (0.5 H) in series. What is the time constant of the circuit?

$$\tau = \frac{L}{R} = 5 \times 10^{-4}\, s$$

12. An AC RLC circuit is made up of a 10 Ω resistor, a 1.2 mF capacitor, and a 2.8 mH inductor. What is the resonant frequency of the circuit?

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(2.8\, mH)(1.2\, mF)}} = 545.5\, \frac{rad}{s}$$

13. The Andromeda galaxy is a faint, fuzzy patch in the sky that appears as an oblong object that is estimated to be 1.89 x 10^{22} meters away from Earth. How long would it take light from the Andromeda galaxy to reach Earth?

$$t = \frac{d}{c} = \frac{1.89 \times 10^{22}\, m}{3 \times 10^{8}\, \frac{m}{s}} = 6.3 \times 10^{13}\, s$$

14. Light from a laser pointer is coherent whereas light from a flashlight is incoherent. What does it mean for light to be coherent versus incoherent?

Waves of coherent light oscillate at the same frequency and are in phase. Incoherent light means the waves either oscillate at different frequencies, have different phases, or both.

15. What is the focal length of a spherical mirror with a radius of curvature of 10 cm?

R = f/2 = 5 cm

16. 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?

$$\lambda_n = \frac{700\, nm}{1.51} = 463.6\, nm$$

17. A thin film of soapy water (n = 1.33) 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 700 nm?

$$2t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n}$$

$$2t = \frac{\lambda}{2n}$$

$$t = \frac{\lambda}{4n}$$

$$t = 131.6\,nm$$

18. What is the “correspondence principle” in special relativity?

The correspondence principle states that any predictions of a new scientific theory (in this case, special relativity) must make the same predictions of earlier theories under the right conditions (in this case Newton’s laws at the low-speed limit).

19. A proton is traveling with a speed of 0.87c. What is the value of the Lorentz factor (gamma) for the proton?

$$\gamma = \frac{1}{\sqrt{1 - 0.87^2}} = 2.03$$

20. A spaceship with a mass of 50,000 kg is traveling at a speed of 0.45c. What is the relativistic kinetic energy of the spaceship?

$$\gamma = \frac{1}{\sqrt{1 - 0.45^2}} = 1.12$$

$$K = (\gamma - 1)mc^2 = 5.4 \times 10^{20} J$$

21. The primary decay pathway for Promethium-146 is via electron capture. Write out the equation for the decay of Pm-146 and the resulting particle(s).

Pm-146 plus an electron decays into Nd-146 and a neutrino.

22. Californium-251 can decay via alpha emission or spontaneous fission. Write out the equation for the decay of Cf-251 and the resulting particle(s) via alpha emission.

Cf-251 decays into a helium nucleus and Cm-247

23. The half left of Thorium-234 is about 24.1 days. If I start with five grams of Th-234, how much will be left after one week?

$N_f = N_o (0.5)^{t/T}$

$N_f = (5\ g)\ (0.5)^{(7\ days)/(24.1\ days)}$

$N_f = 4.08\ g$

24. How does the equation $E = mc^2$ relate to the binding energy of a nucleus?

The masses of the constituent particles of the nucleus does not equal the mass of the nucleus itself. This difference (called the mass defect) is converted into binding energy for the nucleus. That equation $E = mc^2$ determines how much energy is produced from the mass defect.

25. What is an electron-volt?

An electron volt is a unit of energy equal to the energy gained by an electron that travels through one volt of potential difference.