

Sample *Electromagnetics*

PhD Qualifying Exam Questions

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Electromagnetics

Many questions in the Electromagnetics section may be quite similar to those in the optics section.

General

- 1 Describe the approaches you would use to measure the wavelength of a coherent electromagnetic source if the wavelength is in the range: i) 1-10 Angstrom; ii) 2000-10000 Ang; iii) 1-10 m.
- 2 Why is the sky blue?
- 3 Estimate the time it takes for a charge disturbance to decay in a copper wire. The resistivity of copper is 1.7×10^{-6} Ohm-cm.
- 4 When an em radiation impinges on an amplifier the effect can be represented by a sinusoidal E-field ignoring the H-field. Why is this possible?
- 5 Consider two rectangular iron bars which are identical. One of them is magnetized while the other one is not. How can you tell which one is magnetized without any external magnetic field or apparatus?
- 6 Discuss how a microwave oven cooks food. Why can't we place certain kinds of cook ware in the oven?
- 7 A charged particle going in a circular orbit radiates energy. However, an electron in an atom going around the nucleus does not radiate. How do you resolve this apparent contradiction?
- 8 An em beam with intensity I_0 impinges along the +z-axis on a perfect mirror in the x ,y plane. The mirror is moving in the +z- direction with a velocity V_0 . What is the intensity of the reflected beam?
- 9 How would you measure the wavelength of coherent radio waves?
- 10 Discuss how you would measure a magnetic field with value close to :
i) earth's field; ii) 1 Tl; iii) 10 T
- 11 Discuss the physics of the shielding process. Why can one use a mesh for shielding and have shielding almost as good as offered by a solid sheet?
- 12 Why does lightning often strike on the same spot in a storm?
- 13 Calculate the force between the plates of a capacitor.
- 14 An amplifier is able to detect a signal of 10^{-9} W/cm². What is the E-field associated with this signal?
- 15 There is a vertical electric field of 100 V/cm as we move away from the earth. Thus there is a 200 V across the height of a typical person. Why don't we get a shock from this field?
- 16 The earth is negatively charged and there is a potential difference of ~

400,000 V between the top of the atmosphere and the earth. This causes a current of 1800 Amps to flow into the earth. Why does this current not discharge earth's charge?

17 What do you understand by gauge invariance in EM theory?

Propagation of waves in plasma

18 Discuss the need for high frequency waves for satellite communication.

19 A typical free electron density in the ionosphere is $5 \times 10^6 \text{ cm}^{-3}$.

Estimate the plasma frequency of the carriers. What is the effective dielectric constant for em waves?

20 Derive the maximum usable frequency for em waves sent from the earth towards the sky.

21 Describe how an earth-bound radar system is able to look beyond the visible horizon. What kind of em waves would you use to see beyond the horizon.

22 A X-ray with wavelength λ impinges on a metal plate with N free electrons per unit volume. Estimate the critical angle for total reflection.

Guided Waves and Transmission of Waves

23 Show that it is possible for em waves to propagate in a hollow metal pipe of rectangular cross-section. Show that there is a cutoff frequency below which there is no propagation.

24 Discuss the importance of load matching in sending signals from an antenna to a receiver.

25 You are to design transmission systems to transfer AC power across two points. What is the simplest (most cost effective) system you would use for the following frequencies:

i) signals at $\sim 50 \text{ Hz}$?

ii) telephone signals?

iii) cable TV signals at $\sim 5 \text{ GHz}$?

26 Compare a coaxial cable and a waveguide in terms of their ability to transmit high power-high frequency ($\sim \text{GHz}$) signals.

27 Discuss the operating principles of a unidirectional coupler for a waveguide. This coupler should be able to detect the direction of flow of power inside the guide.

28 Derive the propagation speed of electronic signals on a VLSI chip.

Radiation Sources

29 Discuss the radiation emitted from a dipole.

30 How would you combine a series of dipole radiators to produce highly directional radiation.

31 A spherically symmetric charge distribution of finite extent pulsates with a frequency ω . How would you detect the pulsations?

32 calculate the em energy radiated by a rotating flywheel whose rim has a uniform charge distribution.

Radar and Antennas

33 Describe how the SAR works. What is the advantage of an airborne radar over a ground based one?

34 Why are the antennas of most cars vertical?

35 Discuss the physical basis for the expression for the radar cross section of a target.

36 Discuss why the use of high frequency electronics has allowed the TV antennas to shrink in size.

37 How does an aircraft with radar use the Doppler effect to calculate its velocity?

28 You are to design an earth-based antenna for a space project to observe stars. Discuss the considerations involved in the design. Examine considerations such as size of the antenna, size of the stars to be observed, detection frequency, etc.

28 Discuss the principles of operation of a phased array radar. Discuss its pros and cons with respect to ordinary radars.

OPTICS [EDITED FOR E-MAG MAJORS]

- 1 What is the difference between light coming from a laser and from a light bulb?
- 2 Describe what you mean by polarization of light. What does one mean by linearly and circularly polarized light?
- 3 How can you use a few glass plates to create linearly polarized light from an unpolarized light source?
- 4 Discuss the conditions under which you would use wave optics and not ray optics.
- 5 Why does the reflectivity of a periodic structure have strong dependence on the wavelength of the incoming light?
- 6 Discuss why and how certain crystals can be used to make polarizers.
- 7 Light of wavelength λ impinges vertically on a horizontal plane film of thickness d (adjustable) and index n_1 placed on a semi-infinite substrate of index n_2 . How would you choose d to design an anti-reflecting coating?
- 8 In a liquid crystal display an electric field can alter the optic axis of the crystal through rotation of molecules. Discuss how this property can be used for displays where a back light (unpolarized) illuminates a liquid crystal cell.
- 9 Using a simple ray optics description discuss why in a rectangular waveguide only certain modes can propagate.
- 10 Discuss the relationship between the absorption coefficient of light in a medium and the conductivity of the material.
- 11 Why is CAEN able to use a 0.98 μm transmission system in its fiber system but for long haul communications one needs a 1.55 μm system?
- 12 The dispersion in a particular material is given by

$$n(\omega) = n_o - \frac{\Gamma(\omega - \omega_o)}{\Gamma^2 - (\omega - \omega_o)^2}$$

Calculate the group velocity and group velocity dispersion in the material.

- 13 How would you design a tunable filter using a periodic structure made from an electro-optic material?
- 14 What is the difference between guided and radiation modes in a waveguide? Using a simple ray optics approach discuss the conditions for cutoff for a slab waveguide with a core of index n_1 and thickness h and cladding of index n_2 .
- 15 Why does a film of oil on water display a rainbow of colors?
- 16 Describe how sunglasses with polarizers cut down on the glare from a water surface.
- 17 What kind of image do you expect to see from a laptop display screen if you are wearing polarized glasses?
- 18 Describe how you would go about designing a telescope.
- 19 Describe how you would design a microscope. Why is an objective and an eyepiece used in a microscope instead of a single lens?
- 20 Describe the basis of holography.
- 21 How would you find the refractive index of a fluid using an interferometer?