Photonics Research Group
Sample questions covering some of the topics in the syllabus

1. A small dielectric ball of mass 11g, slides freely on a vertical non-conducting string above a fixed, small dielectric ball with a charge of 11nC. If the free-to-move ball has a charge of 1nC, how far above the fixed ball will it float?

2. Derive an expression for magnetic flux density **B** at a distance r from the centre of a long cylindrical wire of radius R where r < R. The wire carries current I_0 distributed uniformly over the cross section of the wire. Plot the variation of **B** with r for r < R and r > R.

3. An electromagnetic wave, given by the equation below, propagates through a medium.

$$E_i = \frac{\sqrt{3}}{2} E_0 \left[\frac{1}{\sqrt{3}} \hat{x} \cos(3\pi\, 10^9 t - 20\pi z) + \hat{y} \cos\left(3\pi\, 10^9 t - 20\pi z + \frac{\pi}{2} \right) \right]$$

a) What is the frequency of the wave? Specify units.
b) What is the wavelength of the wave? Specify units.
c) What is the refractive index of the medium.
d) What is the polarization of the wave? Draw a diagram, label the axis.

4. A uniform plane wave of angular frequency ω, is incident from air on a very large perfectly conducting wall at an angle of incidence θ_i. The electric field direction of the incident wave is perpendicular to the plane of incidence. Find the a) current induced on the wall surface and b) the time average Poynting vector.

5. The open circuit and short-circuit impedances measured at the input terminal of a lossless transmission line of length 1.5 m, which is less than a quarter wavelength, are -j54.5Ω and j103Ω respectively. a) Find Z_0 and γ of the line. b) Without changing the operating frequency, find the input impedance of a short-circuited line that is twice the given length.

6. The position of an electron is determined to within 0.1 nm. What is the minimum uncertainty in its momentum? What is the de-Broglie wavelength of an electron at 10 eV?

7. Show schematically the relative positions of Fermi energy levels (E_F, w.r.t. valence and conduction bands) for: (i) intrinsic, (ii) p-type, and (iii) n-type semiconductors.

8. A Si sample is doped with 10^{17} atoms/cc of As. Is it a p-type or n-type? What is the equilibrium hole concentration at 300K? Where is the changed Fermi level (E_F) position relative to intrinsic Fermi Level (E_i)?

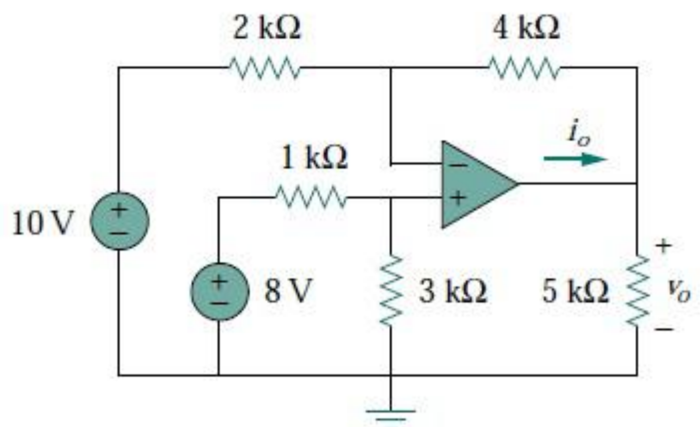
9. What is the difference between direct and indirect bandgap semiconductors? Why must you choose direct bandgap semiconductors for the fabrication of light emitting diodes?

10. If a laser diode emits photon of energy 0.8 eV and the electric field of associated plane EM wave is defined by $\vec{E} = \hat{a}_x E_0 e^{i(\omega t - kz)}$ in free space. Calculate:
    (i) momentum p of the emitted photons

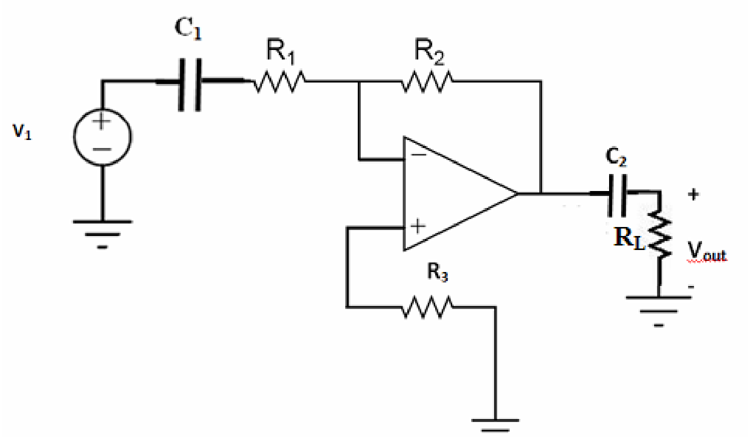
(ii) values of ω and k
(iii) phase velocity of the wave

11. A practical DC current source provides 20kW power to a 50 ohm load and 20kW power to a 200 ohm load. Find the maximum power that can be drawn from the source.

12. Find V_o and I_o in the following differential amplifier circuit.



13. Assume that the op amp shown in circuit below is ideal, find the output voltage, across R_L. Given, $R_1 = 27$ kΩ, $R_2 = 68$ kΩ, $R_3 = 68$ kΩ, $R_L = 40$ kΩ, $C_1 = C_2 = 0.02$ μF and $V_1 = 100 \cos(\omega t)$ (mV). The frequency is 800 Hz.



14. A signal $x(t) = \sin(\pi t)/\pi t$ is convolved with itself to yield y(t).
(a) Sketch x(t). Indicate the zero crossings.
(b) Determine and sketch the Fourier transform of y(t).
(c) Sketch y(t) and indicate its zeros.

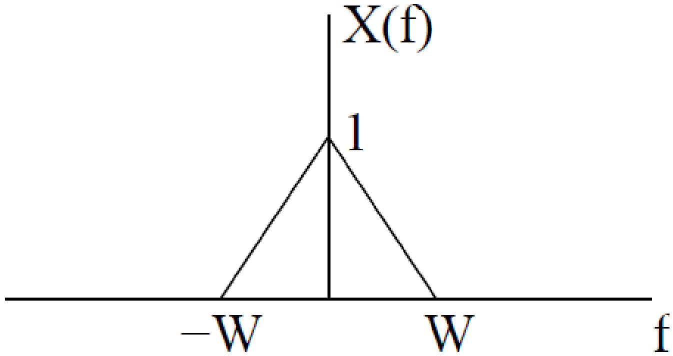
15. Given that x is a Gaussian random variable with x = 2 and $\sigma_x = 2$,
(a) Determine the probability that $x \leq 1$
(b) If $y = (x-2)^2$, determine the probability that $y \leq 1$.

Note: answers may be left in the form of definite integrals.

16. A signal is given by $x(t) = 2\cos(800\pi t) + \cos(1400\pi t)$
It is impulse sampled at 2 kHz to give a sequence x_n.
(a) Draw the spectrum of x(t).
(b) Sketch the spectral components present in x_n.
(c) Determine the frequency and amplitude of the components between 2.5 kHz and 3.5 kHz in the sequence x_n.

17. A transfer function H(s) has two poles located at -1+ j and -1- j and a zero located at -3. If H(0) = 1,
(a) Determine H(s).
(b) Sketch the amplitude of H(jω). Can you identify the type of filter?
(c) Sketch the phase of H(jω) versus ω.

18. A signal x(t) of bandwidth W has a Fourier transform X(f) as shown in the figure below. It is sampled every T seconds, where 1/T > 2W.



a) Sketch the Fourier transform of the sampled version of x(t) given by

$$y(t) = \sum_{n=-\infty}^{\infty} x(nT)\delta(t-nT)$$

b) Sketch the discrete-time Fourier transform, $Z(e^{j\omega})$, of z[n] = x(nT).