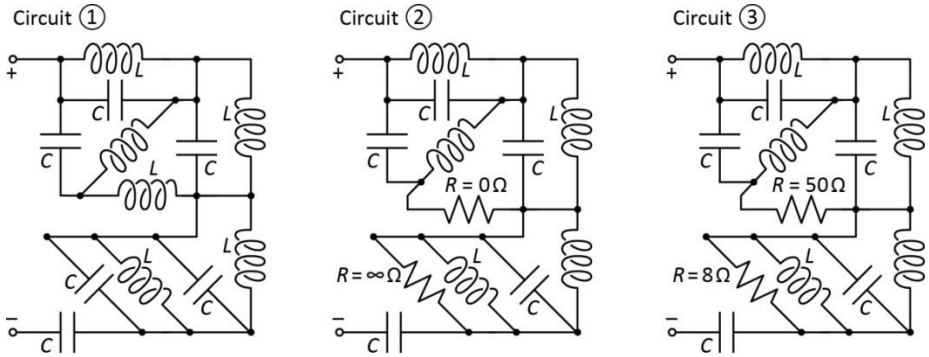
Exam-04

1. Some applications require substances to be electrically conductive as well as optically transparent. For example a smartphone display requires conductivity as well as transparency.
   (a) Justify why, based on electrodynamics theory, the two properties, (i) high electrical conductivity and (ii) high optical transparency, are mutually exclusive properties[1]. Give a specific equation to justify your answer.
   (b) Given that the two properties are mutually exclusive, how would you proceed if you wanted a material that is both conductive and transparent?

2. Consider the following electrical circuits subjected to an AC signal:



   (a) Which one(s) of the above circuits *dissipates* electrical power (i.e. consumes electrical power and converts it to heat)? Also, which one(s) of these circuits *does not dissipate* electrical power?
   (b) A material may be polarizable ($\varepsilon_r > 1$), magnetizable ($\mu_r > 1$), or electrically conductive ($0 < \sigma < \infty$). Which of these properties causes an electromagnetic wave to be attenuated? Why?
   (c) Make an analogy between (i) electromagnetic wave propagation in a material and (ii) electrical signal propagation in a circuit by explaining which material property (ε_r, μ_r, and σ) corresponds to which circuit element (*R*, *L*, and *C*).

3. Consider the reflection of an EM-wave at a (i) air-glass boundary and (ii) air-diamond boundary for normal incidence ($\varepsilon_{r,\,Glass} = 2.1$; $\varepsilon_{r,\,Diamond} = 4.8$).
   (a) Draw the experimental setup and label the objects. Calculate the power reflection coefficients (*R*).
   (b) Compare the amplitude reflection coefficient (*r*) of the EM wave entering the diamond (air-to-diamond) to the amplitude reflection coefficient of the EM wave when exiting the diamond (diamond-to-air). Describe the difference.
   (c) Next calculate the power reflection coefficient (*R*) of an EM wave propagating first through air, then entering glass, and then entering diamond.
   (d) What does Question (c) teach us about antireflection coatings?

4. Determine if the following statements are (i) true, (ii) false, or (iii) impossible to determine due to lack of information. Explain each of your answers with a few words.
   (a) Sea water is weakly conductive due to the Na^+ and Cl^- ions in the water. As a result, an electromagnetic wave propagating in sea water will heat up the sea water.
   (b) The $\vec{E}$- and $\vec{H}$-fields of an electromagnetic plane wave propagating along the *z*-direction will also depend on the *x* and *y* direction, so that $\vec{E} = \vec{E}(x, y, z)$ and $\vec{H} = \vec{H}(x, y, z)$.

[1] The phrase "mutually exclusive properties" means that we can have either one of the two, but not both.