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# KIRCHHOFF'S LAW FOR ANISOTROPIC MEDIA INCLUDING THIN FILMS

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ABSTRACT. Kirchhoff's law relates the thermal emission and absorption of materials and hence is very important for thermal engineering applications with significant radiation heat transfer. Due to the advancement of metamaterials, two-dimensional materials, and micro/nanoscale thermal radiation, Kirchhoff's law has been revisited by several groups. Some studies also challenge the derivations and applicability of the statement of Kirchhoff's law that appears in typical radiative heat transfer textbooks. The present study begins with a review of Kirchhoff's law for isotropic objects and its validity for both hemispherical emittance and directional emittance. For anisotropic materials, including opaque media and thin films, Kirchhoff's law is then formulated considering both co-polarization and cross-polarization. It is shown that for macroscopic objects, as long as the Helmholtz reciprocity can be established, conventional expressions of Kirchhoff's law can be applied for engineering thermal analysis and design even with anisotropic media and metamaterials. Numerical examples based on a composite of two anisotropic films are also presented.