Assignment 1
Electrodynamics and Radiative Processes I

Due on 19th August 2019

25 marks for each question

(1) a) Define specific intensity, radiative energy density, flux density and total luminosity

b) Show that specific intensity is constant along a ray in free space.

c) How will number density decide the transparency/opaqueness of an object, in other words how will optical depth change with increase of number density. Draw the spectra of an optically thick source.

d) What is the specific intensity of sun at 1 GHz? (Consider sun as a black body of temperature T=5800 K)

e) What is flux density of sun measured at earth at 1GHz

f) What is spectral luminosity of sun at 1 GHz

g) Calculate the total flux at a point P coming from an isotropic, optically thick sphere of radius R.(Optically thick: emission comes from only surface, Isotropic: I is same for each point of the surface)

h) Define brightness temperature. Write down radiative transfer equation in terms of brightness temperature.

(2) (i) Upon reaching a planet, part of the central star radiation will be reflected and the rest will be absorbed and re-emitted as a cooler blackbody. In the spectra of planets both of these components are observed. Consider the case of Jupiter, with radius $R_J = 7.1 \times 10^9$ cm and mean orbital radius $a_J = 7.8 \times 10^{13}$ cm. Assume that the spectrum of the Sun is a perfect blackbody.

(a) Suppose that Jupiter perfectly reflects 10% of the light coming from the Sun. Calculate its reflected luminosity. At which wavelength does it peak? In which spectral band is it observed?

(b) At which wavelength does the re-emitted luminosity peaks? In which spectral band is it observed?

(ii) An optically thin cloud surrounding a luminous object is estimated to be 1pc in radius. If the central object is clearly seen, what is an upper bound for the electron density of the cloud, assuming that the cloud is homogeneous.

(3) a) Show that the condition that an optically thin cloud of material can be ejected by radiation pressure from a nearby luminous object is that the mass to luminosity ratio (M/L) for the object be less than $\kappa/(4\pi Gc)$. Where G is gravitational constant, c is speed of light, κ is mass absorption coefficient of the cloud material.

b) Calculate the terminal velocity attained by such a cloud under the radiation and gravitational forces alone, if it starts from rest a distance R from the object.

c) Derive expression for Eddington Luminosity Limit (maximum luminosity that a central mass M can have and still not spontaneously eject hydrogen by radiation pressure). What is the value of Eddington Luminosity of sun? What will be the Eddington Luminosity of another star that is 10 times more massive than Sun.

d) Comment on Eddington accretion rate.

(4) A semi transparent body at a temperature T_s has the following optical depth profile in the frequency range 0 to 2 ν_0.

For $x \sim |\nu-\nu_0|/\nu_0$

τ_ν= 5.5-10x(0.0<x<0.5)

=0.5 (0.5<x<0.75)

=0 (0.75<x<1.0)

A black body of temperature T_0 T_0 ($kT_o >> 4h\nu_0$) shines from behind this object. Sketch the brightness temperature of the emergent radiation as a function of frequency in the range 0 to $2\nu_0$ in the following cases

(a) In the absence of foreground semi transparent body
(b) When temperature T_s of the foreground semi-transparent body is $2T_0$
(c) $T_S=T_0$
(d) $T_S= 0.5\ T_0$
(e) $T_s=0$