1. **Radiative equilibrium.**
Total insolation over a 24 hour period at the top of the atmosphere \( (Q_0) \) depends on latitude \( (\phi) \), solar declination \( (\delta) \), length of daylight \( (LOD) \) 24H/\( \pi \) in hours (where LOD in radians is 2H = 2 \( \arccos\{ - \tan\phi \tan\delta \} \)), and solar constant \( (S = 1370 \text{ W/m}^2) \). (See Physics of Climate, by Peixoto and Oort, 1992, p.99 for details). Let:

\[
Q_0 = \left(\frac{24}{\pi}\right) S \{ H \sin\phi \sin\delta + \cos\phi \cos\delta \sin H \}
\]

You will find the radiative equilibrium temperature from \( Q_0 \) for these situations: (i) equator at the equinox, (ii) 38N at the equinox, (iii) 38N at the summer solstice (23.5 degree declination) (iv) 38N at the winter solstice (v) north pole at the summer solstice. Hint: be aware that the units of \( Q_0 \) are W m\(^{-2}\) (24 hrs).

a.) (15 pts) Find the daily insolation for the 5 situations in the problem description
b.) (10 pts) Find the radiative equilibrium temperature for the 5 situations in part a) assuming a blackbody.
c.) (10 pts) repeat part b except using these greybody shortwave reflectivities: (i) 0.1, (ii)-(iv) 0.2, (v) 0.7 and greybody longwave emissivities of 0.9 in each case.
d.) (3 pts) find the radiative equilibrium temperature for the earth as a whole assuming it to be a blackbody.
e.) (8 pts) Start with the expression for \( Q_0 \) above then write down the general expression for the precise latitude where the *average* daily insolation (units = W/m\(^2\)) equals the radiative equilibrium value for the whole Earth. Then solve the expression for that latitude at the vernal equinox to 5 significant digits.
f.) (9 pts) Using your general formula in part e, find the latitude where the average daily insolation equals the radiative equilibrium value for the whole Earth at the southern ('December') solstice. A graphical solution, using \( S=1368 \) is adequate with accuracy to the nearest 0.1 degree.

**NOTE:** all homework is to be done by you as an INDIVIDUAL: no ‘group’ efforts, please. For written answers, please use a word processor, so that penmanship is not an issue. Equations and derivations can be *neatly* hand-written.

Any plot must be completely and unambiguously labeled, including title and axes.