Answer THREE questions. Please answer each question in a separate answer booklet.

1. Answer the following in the context of remote sensing using examples where appropriate. All parts carry equal weight.

   (i) Define what is meant by the term ‘atmospheric window’.

   (ii) Describe TWO types of scattering that affect solar radiation in the Earth’s atmosphere, making clear any wavelength and angular dependencies.

   (iii) Define the terms IFOV and PSF.

   (iv) Define the terms whiskbroom and pushbroom scanners.

   (v) Define what is meant by radiometric resolution.

2. (i) Briefly outline the operating principles of discrete return AND full-waveform lidar systems, using figures were appropriate. (30%)

   (ii) Sketch the full-waveform lidar returns that might result from the surfaces and lidar configurations shown below. You should assume that the vertical bin size of all lidar returns is much less than the canopy height. Briefly explain in each case the key features of the returns. (70%)

   a) Small-footprint (<1m).

   [Diagram of small-footprint lidar pulse with canopy height and 30m scale]

   b) Small-footprint (<1m).

   [Diagram of small-footprint lidar pulse with canopy height and 30m scale]

   c) Large footprint (eg 20m).

   [Diagram of large-footprint lidar pulse with canopy height and 30m scale]
3. (i) Draw a figure showing the theoretical Planck blackbody energy distributions for the Sun and the Earth on the same axes, taking care to use appropriate scales on each axis and to label the axes. (50%)

(ii) Describe the relationships of Stefan-Boltzmann’s Law and Wien’s Law to the distributions you have drawn. (30%)

(iii) Outline TWO consequences for biological systems that arise as a consequence of the Sun’s radiant energy distribution in the visible part of the spectrum. (20%)

4. (i) Describe the scattering properties of different types of surface at microwave wavelengths. (40%)

(ii) Describe TWO advantages and TWO disadvantages of RADAR remote sensing over remote sensing in the optical domain. (20%)

(iii) Define the terms layover and foreshortening in the context of RADAR remote sensing. (20%)

(iv) Outline the principles of synthetic aperture RADAR (SAR), describing the advantages of the method over real aperture RADAR (RAR). (20%)

5. The UN Global Climate Observing System (GCOS) has identified large scale (regional to continental) wildfire monitoring as a key requirement for improved understanding of the feedbacks between fire and climate. Outline a system for monitoring the occurrence and impact of fires at 0.5 km resolution globally. Outline your concept for such a system, justifying your choices of platform (or platforms) and orbit as well as spectral, temporal and angular sampling.

6. (i) Outline a linear mixture model approach to describe the reflectance of a region containing predominantly forest, grass and bare soil. (50%)

(ii) What are the limitations of the assumptions made in a linear mixture modelling approach and how might they be dealt with in practice? (20%)

(iii) Outline the key pieces of information and steps required to implement this method as a computer algorithm (you do not need to provide actual code, simply a description of the steps involved). (30%)
7. For a satellite in stable orbit, the (downward) gravitational force \( F_g \) and centripetal (outward force) \( F_c \) are balanced i.e. \( F_g = F_c \) where

\[
F_g = \frac{GM_Em}{R_{SE}^2}
\]

and

\[
F_c = \frac{mv^2}{R_{SE}}
\]

and \( G \) is the universal gravitation constant (6.67x10\(^{-11}\) Nm\(^2\)kg\(^{-2}\)); \( M_E \) is Earth mass (5.98x10\(^{24}\) kg); \( m \) is satellite mass (unknown); \( R_{SE} \) is distance from Earth centre to satellite i.e. \( R_{SE} = R_E + h \) where \( h \) is satellite altitude (in m) and \( R_E \) is the Earth’s radius (6.38x10\(^{6}\) m); \( v \) is linear velocity of satellite (ms\(^{-2}\)) and is related to the angular velocity \( \omega \) (rad s\(^{-1}\)) as \( v = R_{SE}\omega \). Note that \( \omega \) is related to the satellite orbital period \( T \) (seconds) as \( \omega = 2\pi/T \).

(i) Show that an instrument in a stable orbit of altitude \( h = 740\text{km} \) has an orbital period \( T \) of 99.6 mins. (60%)

(ii) If this instrument has a swath width of 2500km, what is the repeat time for the instrument i.e. the time taken for it to cover the whole Earth’s circumference at the equator? (20%)

(iii) Outline ONE advantage and ONE disadvantage of a geostationary orbit for environmental monitoring applications. (20%)

8. (i) Define the term BRDF, giving examples of TWO distinct types of surface angular scattering to illustrate your definition. (40%)

(ii) Outline the key features of volumetric and geometric-optic scattering from vegetation, using figures where appropriate. (40%)

(iii) Give TWO examples of how the BRDF of the Earth’s surface can be exploited for environmental applications. (20%)

9. Describe the pre-processing stages you would apply to transform top-of-atmosphere raw digital numbers (DNs) to at-ground reflectance.