Answer THREE questions.

The numbers in square brackets in the right-hand margin indicate the provisional allocation of maximum marks per sub-section of a question.

[Part marks]

1. Reflectance spectroscopy can provide considerable information about the composition of a planetary surface without having to handle a sample. On the Moon, a mature soil sample and a sample from a fresh crater may have the same composition, but their spectra will be different in important ways. State what these are and describe why this difference occurs.

[2]

Sketch an appropriate reflectance spectrum within the wavelength range 750mm to 2800nm for each of the following with a short description of their main features:

i) high Ca pyroxene
ii) low Ca pyroxene
iii) olivine
iv) plagioclase feldspar

Include a description of the absorption features that might be seen for each material in this wavelength region and describe how some band centres may change with the addition of particular elements or minerals. [7]

On the Moon, a mare basalt and a gabbro may have an absorption band centre at the same wavelength. What would be the critical difference between the two and what is the mineral component in the gabbro which would cause this difference? This component is the major constituent of the highland crust. Give a detailed explanation of how the crust came to form, including a description of the formation of the maria. How and why can we use KREEP material as an indicator of the thickness of the crust just after formation? How do we determine the thickness of the crust today, and in general terms what do we find?

[11]

2. Describe why the icy satellites of the outer planets were probably undifferentiated when they formed. Discuss what happens during the differentiation process and include detail of three heating processes by which the satellites may have differentiated. Use diagrams if you wish. By consideration of their radii, state which of these heating processes would have operated on each of the satellites in Table 1. [13]

Table 1

Satellite	Radius (km)	Density (g cm^{-3})
Io	1820	3.52
Europa	1500	3.45
Ganymede	2635	1.95
Callisto	2500	1.62

Briefly describe the surface of Europa, including some mention its spectral properties and what the density tells us of its interior composition. [4]

Which of the three heating processes provides most of the heat on Io? How do we know that the surface of Io is young? What is the cause of its youth? [3]

3. Explain the difference between meteorite falls and meteorite finds. Discuss the compositional differences between the two and the implications that this has for the true population of meteorite classes close to the Earth. [3]

Give a short description of the three major classes of meteorite: the irons, stony-irons and stones. Compare their densities and compositions, and discuss in particular the SNC meteorites and eucrites. From which parent body are the eucrites believed to have come? [12]

Name and describe the two dominant types of asteroid currently known. How does the composition of asteroids vary through the asteroid belt? What implication does this have regarding their origin? [5]

4. The age of a meteorite can be determined using radiometric dating techniques. Define the half-life, T_, of a radionuclide and state how it is related to the decay constant, λ. Table 2 shows the half-lives and daughter elements of three radionuclides. Which one would be most suitable to date primitive meteorites and why? [2]

Table 2

Parent	**Daughter**	**Half-life (10^9 yr)**
^{40}K	^{40}Ar, ^{40}Ca	1.25
^{87}Rb	^{87}Sr	48.8
^{235}U	^{207}Pb	0.704

A rock sample has been dated using the ^{87}Rb to ^{87}Sr decay such that

$$\frac{^{87}Sr}{^{86}Sr} = \left(\frac{^{87}Sr}{^{86}Sr}\right)_0 + \frac{^{87}Rb}{^{86}Sr}\left(e^{\lambda t} - 1\right)$$

where $(^{87}Sr/^{86}Sr)_0$ is the ratio of $^{87}Sr/^{86}Sr$ present at time t=0. Why are ^{87}Sr and ^{87}Rb measured as ratios to ^{86}Sr rather than as direct quantities? [2]

When plotted on a graph of $^{87}Sr/^{86}Sr$ versus $^{87}Rb/^{86}Sr$, this particular rock sample produced a straight line with a slope of 6.12×10^{-2}. How old is the rock? [4]

For bodies where we have no sample, dating of their surfaces must be estimated using crater counts. Describe three potential problems when attempting to date a surface using this technique. Explain why the cratering flux is important and discuss the problems associated with its determination. [12]

5. During which phase of the impact cratering process is ejecta thrown out of the crater'? Describe how material is ejected from the crater using Figure 1 as a guide and explain briefly what each of the terms in the figure means. Discuss the process of ejecta emplacement from the time it is removed from the crater to the time it is laid on the ground, concentrating in particular on the velocity of the ejecta and order of emplacement. [8]

Use Meteor Crater. Arizona as an example of the structure of an ejecta blanket and describe the different ejecta units you would see around a complex crater. [6]

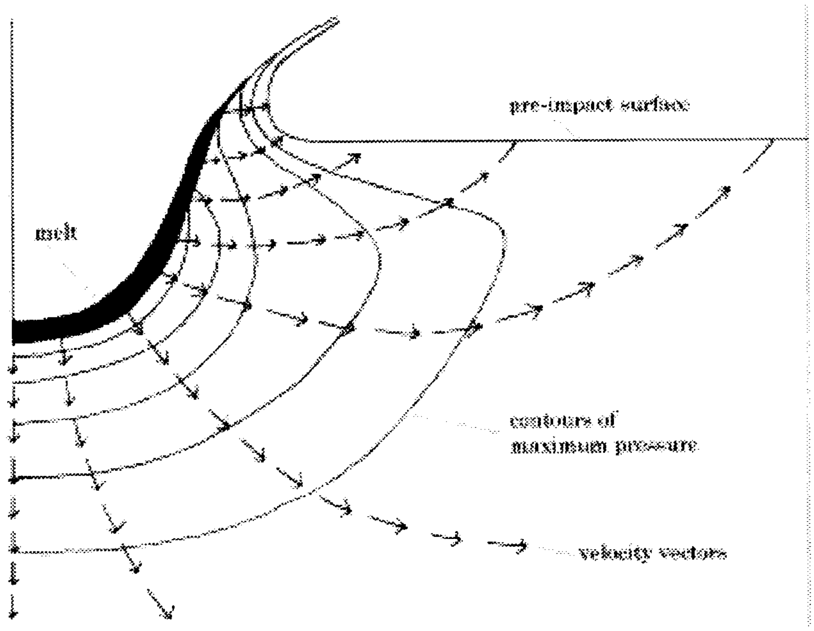

Figure 1

In oblique impacts, the ejecta blanket may not be laid down symmetrically. Describe, with the aid of diagrams, what t he ejecta pattern would look like for impacts of 45^{o}

and 20º. What angle of impact is required before the crater itself becomes non-circular? [2]

On Mars there are examples of craters with unusual lobate ejecta forms. Describe how these are believed to have been emplaced. [4]

END OF PAPER