SECTION B: WRITTEN ANSWER QUESTIONS
ANSWER IN THE SPACES PROVIDED

The following information relates to question 56.

Roxanne had been reading up on Europa, one of Jupiter's moons, in the hope of doing well in an upcoming interview for a crew position on the next human mission to the Jovian system. Roxanne's friend Cameron Brian was on the first Europa mission so she asked him for some tips. His advice was to learn as much about the Jovian moons as possible!

In her readings she discovered that Europa has an equatorial radius of 1,560.5 km, making it about 90% the size of Earth's Moon (with a radius of 1,737.5 km). However, Europa's surface is water ice so, if it were orbiting Earth, it would be a lot brighter since it would reflect 5.5 times more sunlight than the Moon's surface does. Europa has a density of 3.013 g/cm^3 and a total mass of 4.799 x 10^{22} kg while the Moon's density is 3.344 g/cm^3 and mass is 7.348 x 10^{22} kg. Since her mission to Europa might involve surface exploration and she has recently been exploring on the surface of the Moon, she wondered what the gravity would be like on Europa as compared with the Moon's. As an exercise in mindful maths she decided to calculate them using a table she doodled.

56. Fill in the table to see what Roxanne discovered about Europa's gravity. Show all your working calculations on the Blank Working Page at the back of the exam booklet.
(4 marks)

Values	The Moon	Europa
Equatorial radius	1,737.5 km	1,560.8 km
Average Density	3.344 g/cm^3	3.013 g/cm^3
Mass	7.348 x 10^{22} kg	4.799 x 10^{22} kg.
To calculate g use: $g_{planet} = G \times M_{planet} / R^2_{planet}$ where M is mass, R is radius and G = 6.67 x 10^{-11} Nm^{2}kg^{-2}		
Surface gravity (g)	g_{Moon} = 1.62 m/s^2	g_{Europa} = 1.31 m/s^2
From these calculations Roxanne was able to see that she would feel slightly Heavier / Lighter on Europa's surface compared with her recent time on the surface of the Moon		

The following information relates to questions 57 and 58.

Roxanne spent a long time reviewing all the materials about Europa as she studied for her interview. She was particularly intrigued by data concerning the spectra obtained with the Hubble Space Telescope, which detected a 450-nm absorption line on the surface that is indicative of irradiated sodium chloride -NaCl (Figure 19).

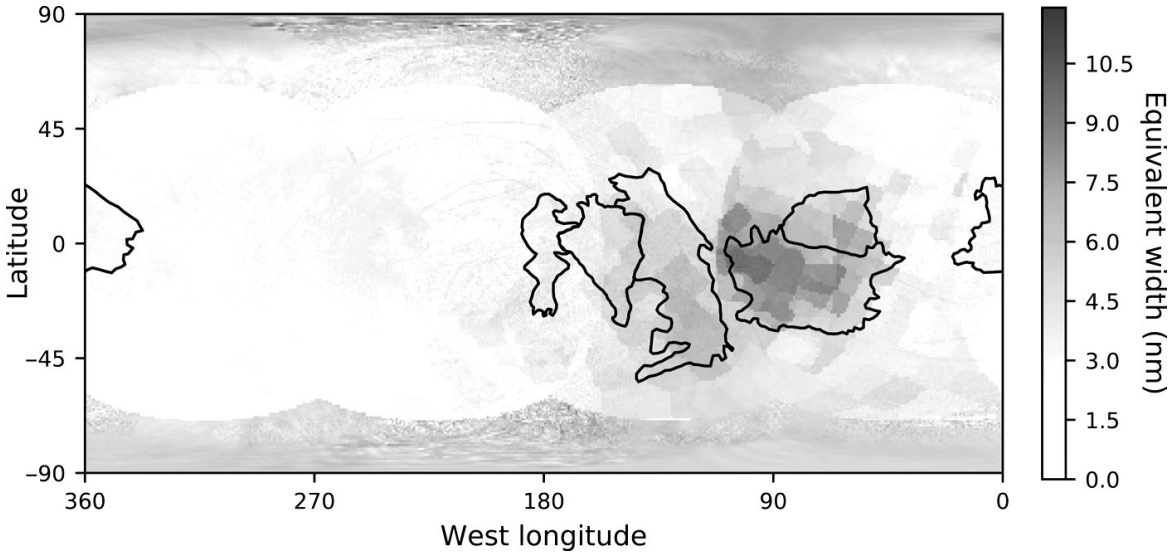

Figure 19: A map of Europa's surface. The black outlined areas are the large-scale chaos regions. The shaded regions show absorption at 450 nm with darker shades showing greater absorption.
Image modified from Trumbo et al 2019. Science Advances V5 (6) eaaw7123

The mission she is applying for intends to land in a chaos region. These regions are composed of fragments of the pre-existing ice crust tens of kilometres in diameter, or larger, separated by a chaotic, lumpy matrix of material of all sizes and shapes below about 1000m in diameter. The shape of the individual fragments varies from smoothly circular to polygonal blocks of ridged terrain. The matrix material can be either low lying or high standing relative to the surroundings. Some of the individual plates appear to have moved from their original position. Roxanne noted that there is a visual similarity between chaos terrain and Earth-ocean pack ice. Her working model being that the chaos regions are where subsurface liquid water has broken through a crustal shell of water ice, chaotically jumbling blocks of ice, followed by a refreezing of the crust.

57. What did the Hubble spectral data tell Roxanne about Europa?

    (2 marks)

The subsurface water within Europa (beneath the ice crust) contains SALT – sodium chloride he salt on the surface corresponds to the chaotic terrains suggesting the model of water upwelling to create the chaos terrains is valid

58. Roxanne wondered where the NaCl could have come from, given Europa's crust is almost entirely water ice and yet the average density of Europa is more than 3 times that of water. What did she conclude?

(2 marks)

Europa's average density is greater than 3 and the Moon's density is 3.344 suggesting that beneath the crust and any subcrustal water-rich zone there must be denser rocky material (rock sea floor)

On Earth NaCl is leached out of rocks by both surface weathering and movement of [hot] fluids through the rocks. On Europa leaching of soluble ions from deeper "submarine" systems is the likely source but …

other options could be considered

i) original water source for Europa could be NaCl rich watery comets

ii) NaCl on surface could be deposited from am external source and have no subsurface origin

The following information relates to questions 59, 60, 61 and 62.

Studying Europa further, she examined an image of a proposed landing area for the mission. Landing at this spot would enable exploration of the dark pits and domes, which are an unusual feature not seen in most chaotic terrain (Figure 20).

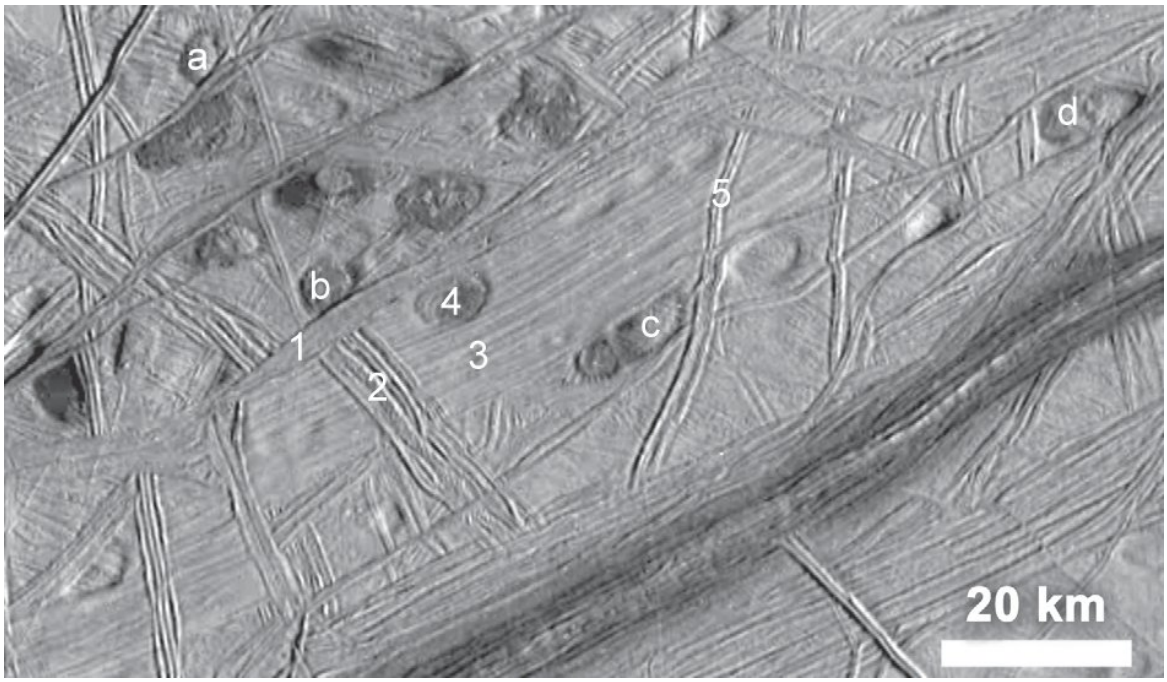

Figure 10: Chaotic terrain on Europa displaying blocks, ridges, pits and domes. Sites a, b, c and d are proposed landing sites for dome exploration.

Image modified from Collins and Nimmo 2009.

59. Background notes that Roxanne read about proposed landing sites a, b c and d suggested the dome structures were the youngest features within this chaotic terrain. She wasn't so sure about this. Why?
(1 mark)

all four sites have truncations to the shape of the domes, suggesting other events have taken place after the domes formed to 'cut off' the edges of the domes in some places

60. Roxanne was intrigued by how much had happened to the surface in the chaotic regions. She tried to figure out what order the structures labelled 1, 2, 3, 4 and 5 occurred in. What did she conclude about the relationship between linear structures 1, 2, 3, and 5?
(**5 marks**)

The oldest linear structure is …. 3 because … it is cross cut by #2 and #5 and #2 is cross cut by #1
(2 marks of the 5)

The youngest linear structure is … 1 because … it is not cross cut by any of the others and it cross cuts #2 (2 marks of the 5)

What additional comments would she add to help explain the age relationships between all the linear structures:
(1 mark of the 5)

#3 is cut by #2 and #5 but no information if they happened at the same time or not

61. What did Roxanne conclude about the age relationship between the linear structures and structure 4?
(2 marks)

#3 is cut or 'intruded' by structure #4 so #4 is younger than #3 but
… it is impossible to say for certain if #4 happened before or after #1 or #2 and #5

62. Roxanne noted that the linear structures seemed to have formed a bit like Mid-Ocean-Ridges on Earth, with a linear fracture spreading apart and upwelling watery material from below, filling the widening gap to form parallel linear structures in the ice. What else did she notice to add weight to that idea?
(2 marks)

Some linear structure are off-set by others eg: #2 off set by lateral movement on #1

The off-sets appear to be similar to transform faults seen on MORs

The following information relates to questions 63 and 64.

The next message Gemma received from Roxanne read:
Hi Sis! Guess what? I got the job … I'm going to Europa!!!!
Gemma was excited for her sister and more than a little envious. However, she knew that getting to Mars from Earth, even with the new Epstein Drive, takes a long time and Europa is even further away again. Gemma knows that on average Jupiter is 778.5 million km from the Sun with its closest point (perihelion) being 741 million km and its farthest point (aphelion) being 817 million km. Earth is 150 million km from the Sun on average with a perihelion of 147 million km and an aphelion of 152 million km. On average Mars is 228 million km from the Sun with a perihelion of 206.7 million km and an aphelion of 249.2 million

63. Gemma did the maths. If there was a time when Mars and Jupiter were as close together as possible and Mars was at aphelion and Jupiter was at perihelion they would still be

_____491.8 million _____km apart (fill in the blank)
(1 mark)

64. A) Assuming the Epstein Drive results in an average speed of 10,000 m/s Gemma figured it would take Roxanne at least

_____569_____days to travel from Mars orbit to Jupiter orbit (ignoring all the complications of the planets constantly moving in their orbits).
(0.5 mark)

65. B) Gemma wrote back to Roxanne knowing her message would travel at approximately 300,000,000 m/s. She figured Roxanne's last message took 20 minutes to reach Earth so she must be about

_____360 million _____km distant.

(0.5 mark)

66. Gemma sent her sister a special message that read:

Hi Roxy! Great news about your new job, it will be awesome, Looking forward to seeing more of you on the news and some amazing pictures from the Chaos Terrain on Europa. Make sure the outcome isn't like the scifi film please!

To keep you grounded I have included a few Down to Earth exercises for you to have a go at when you are bored on the long trips out and back. Send me your answers and I'll send you some more!

Time to fill in the table just like Roxy would! Thanks for playing along.

Maybe see you at Summer School ☺

Word	Description or chemical formula
Quartz	SiO_2
Cirrus	A type of cloud
Porosity	The void space fraction in sedimentary rock
Permeability	The amount of interconnectedness of void space in sedimentary rock
Unconformity	An erosional or non-depositional surface separating two rock masses or strata of different ages
Oil/gas	Organic residue left behind in rocks after plankton and other organisms have decayed in anaerobic conditions and then broken down further under the elevated temperatures and pressures of deep burial
Wind	Atmospheric air movement from a high-pressure region to a low-pressure region
Marble	Metamorphosed limestone
Calcite or equiv	$CaCO_3$
Gneiss	High grade metamorphic rock derived from Mudstone

(0.5 mark per answer for a total of 5 marks)

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Integrity of Competition

If there is evidence of collusion or other academic dishonesty, students will be disqualified. Markers' decisions are final.