Question 16 **(14 marks)**

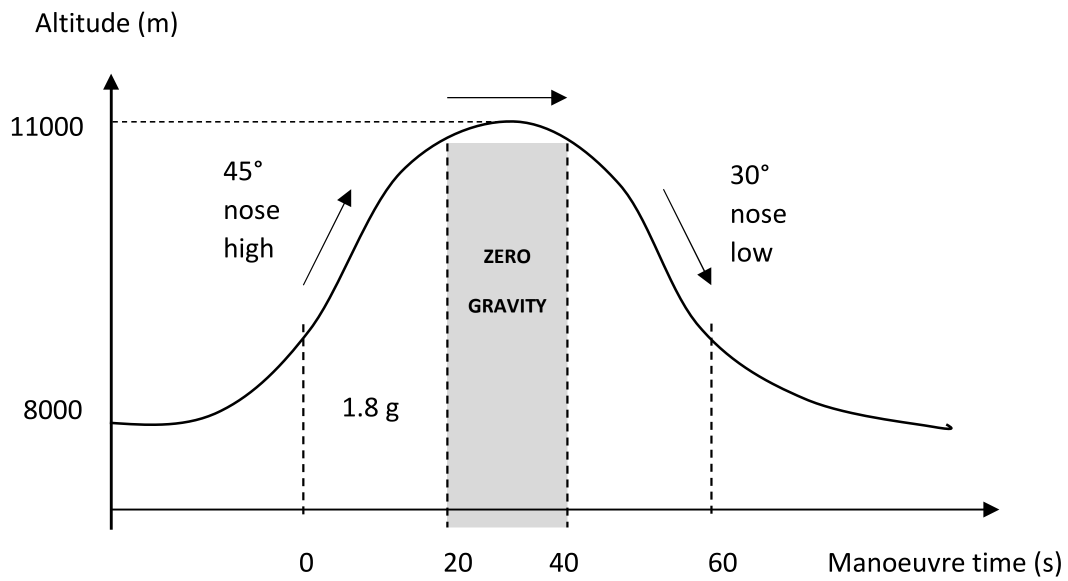
NASA astronauts need to train to operate in the weightless conditions they experience when they are in orbit around the Earth. A specially designed aeroplane called G-FORCE-ONE (known as a ZERO-G plane) is employed to do this training.

a) Explain why astronauts in orbit experience weightlessness. As part of your response, answer this question: are the astronauts actually weightless?

(3)

The astronauts are not actually weightless; they are in orbit due to the gravitational field of the earth.	1 mark
Both the astronauts and the satellite they occupy are in free fall around the earth.	1 mark
Hence, the net force between the satellite and the astronaut is zero.	1 mark

In order for the passengers on G-FORCE-ONE to feel weightless, the aircraft must climb at a steep angle (45° nose high), level off, and then dive, creating a **parabolic path**. In the diagram below, the arrow represents the direction of flight of the ZERO-G plane.



As the ZERO-G plane climbs to the peak of its arc, the pilot orients it at a 45-degree angle upwards (as shown).

b) During the climb, the plane and its passengers experience a net acceleration equal to 1.8 times the strength of gravity alone; ie – the passengers' apparent weight becomes nearly twice as much as their true weight. Explain. As part of your answer, calculate the plane's acceleration vertically upwards that creates the 1.8 g force on the passengers.

(4)

The net acceleration (Σa) experienced by the astronauts will be: $\Sigma a = g + a_{up}$	1 mark
The net acceleration experienced by the astronaut is greater than acceleration due to gravity.	1 mark
$\Sigma a = 1.8 \times 9.80 = 17.6\ ms^{-2};\ \Sigma a = g + a_{up};\ 17.6 = 9.80 + a_{up}$	1 mark
$\therefore\ a_{up} = 17.6 - 9.80 = 7.80\ ms^{-2}$	1 mark

c) Explain how weightlessness ('zero gravity') is achieved at the top of the parabolic arc.

(3)

At the top of the arc, the centripetal force required can be entirely supplied by gravity.	1 mark
In this case, the normal force experienced by the astronaut will be zero.	1 mark
Hence, the astronaut will be weightless.	1 mark

d) If the radius of the arc at the top of the parabolic path is equal to 500 metres, calculate the speed that the plane must be travelling at to achieve 'weightlessness'. Assume that the plane's motion is circular at this point.

(4)

$\text{At the top of the arc: } N = \frac{mv^2}{r} - mg$	1 mark
$\text{If weightless, } N = 0;\ \therefore\ \frac{mv^2}{r} = mg;\ v = \sqrt{gr}$	1 mark
$v = \sqrt{9.80 \times 500}$	1 mark
$v = 70.0\ ms^{-1}$	1 mark