Exercise 5 – Gravitation and Special Relativity

Past paper Homework Questions

1. A satellite orbits a planet at a distance of $5{\cdot}0 \times 10^7$ m from the centre of the planet.

The mass of the satellite is $2{\cdot}5 \times 10^4$ kg.

The mass of the planet is $4{\cdot}0 \times 10^{24}$ kg.

The gravitational force acting on the satellite due to the planet is

A $1{\cdot}7 \times 10^{-6}$ N

B $2{\cdot}7 \times 10^{3}$ N

C $1{\cdot}3 \times 10^{11}$ N

D $2{\cdot}7 \times 10^{14}$ N

E $2{\cdot}7 \times 10^{32}$ N.

2. The length of a spaceship at rest is L.

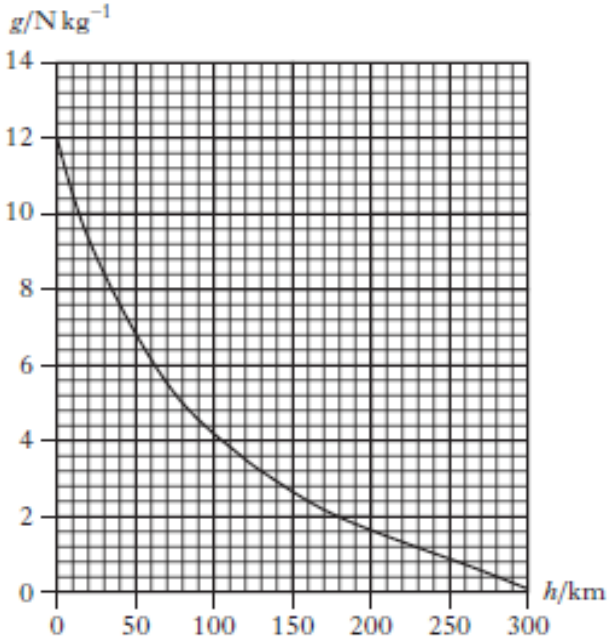
This spaceship passes a planet at a speed of $0{\cdot}95c$.

Which row in the table gives the measured lengths of the spaceship according to an observer on the spaceship and an observer on the planet?

	Length measured by observer on spaceship	*Length measured by observer on planet*
A	L	L
B	L	less than L
C	less than L	L
D	less than L	less than L
E	greater than L	less than L

3. A rock of mass 0·80 kg falls towards the surface of a planet.

The graph shows how the gravitational field strength, g, of the planet varies with height, h, above the surface of the planet.



At one point during its fall the weight of the rock is 4·0 N. The height of this point above the surface of the planet is

A 15 km

B 80 km

C 105 km

D 130 km

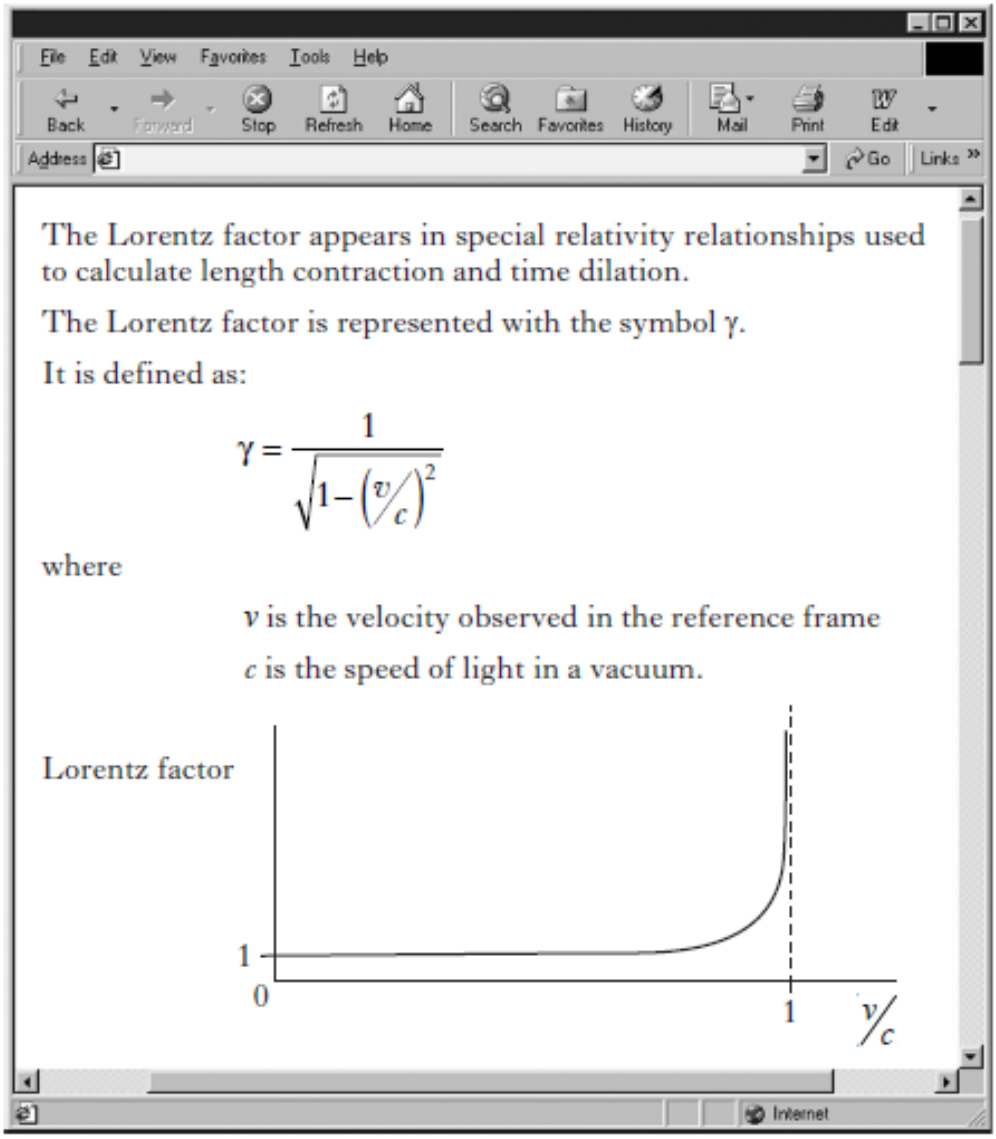
E 255 km.

4. A spaceship on a launch pad is measured to have a length L. This spaceship has a speed of $2{\cdot}5 \times 10^8\ \text{m s}^{-1}$ as it passes a planet.

Which row in the table describes the length of the spaceship as measured by the pilot in the spaceship and an observer on the planet?

	Length measured by pilot in the spaceship	*Length measured by observer on the planet*
A	L	less than L
B	L	greater than L
C	L	L
D	less than L	L
E	greater than L	L

5. A page from a website on special relativity is shown.



(*a*) Explain what is meant by the term *length contraction*. **1**

(*b*) Calculate the Lorentz factor when the ratio $v/c = 0{\cdot}80$. **1**

(*c*) Length contraction calculations use the relationship

$$l' = l\sqrt{1-\left(v/c\right)^2}$$

where the symbols have their usual meanings.

State this relationship in terms of l', l and γ. **1**

(*d*) Explain, in terms of the Lorentz factor, why an observer can ignore relativistic effects for an object which is moving with a velocity much less than *c*. **2**

(5)

6. Estimate the gravitational force of attraction between two students sitting beside each other.

Clearly show your working for the calculation and any estimates you have made. **(3)**

7. According to Newton's Universal Law of Gravitation, the force exerted by the Earth on an object is proportional to the mass of the object. A student suggests that this means that a heavy object will fall with a greater acceleration than a light object.

Use your knowledge of physics to explain why this is not true.

(3)

8 What is meant by the term "dark energy "and describe the evidence scientists used to conclude its existence. (2)

9 What is meant by the term "dark matter" and describe the evidence scientists used to conclude its existence. (2)

19 Marks