2001 HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Centre Number

Section I (continued)

Student Number

Part B – 60 marks
Attempt Questions 16–26
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (4 marks)

Muons are very short-lived particles that are created when energetic protons collide with each other. A beam of muons can be produced by very-high-energy particle accelerators.

The high-speed muons produced for an experiment by the Fermilab accelerator are measured to have a lifetime of 5.0 microseconds. When these muons are brought to rest, their lifetime is measured to be 2.2 microseconds.

(a) Name the effect demonstrated by these observations of the lifetimes of the muons. **1**

Time dilation.

(b) Calculate the velocity of the muons as they leave the accelerator. **3**

$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$

$5 = \frac{2.2}{\sqrt{1-\frac{v^2}{c^2}}}$

$\sqrt{1-\frac{v^2}{c^2}} = \frac{2.2}{5}$

$1-\frac{v^2}{c^2} = \left(\frac{2.2}{5}\right)^2$

$\frac{v^2}{c^2} = 1-\left(\frac{2.2}{5}\right)^2$

$v = c\sqrt{1-\left(\frac{2.2}{5}\right)^2}$

$\doteq 2.61$

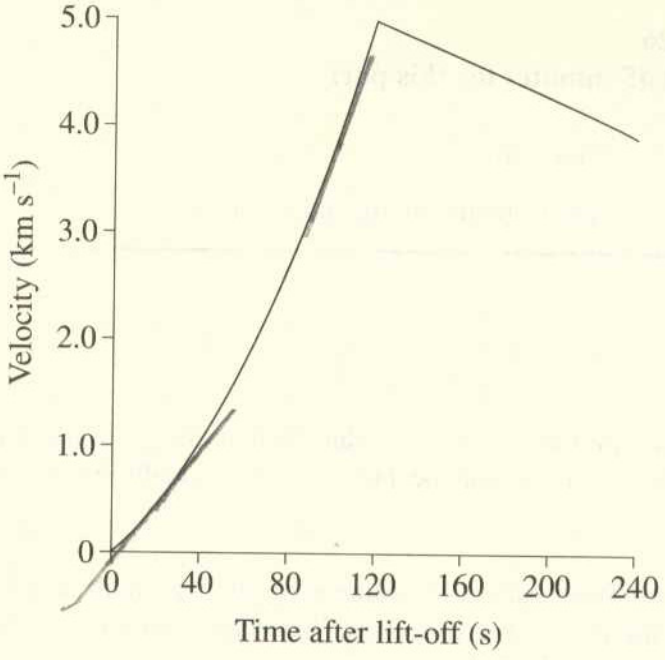
$= 269399331.8 \text{ ms}^{-1}$

$\doteq 2.7 \times 10^8 \text{ ms}^{-1}$

Marks

Question 17 (6 marks)

A rocket was launched vertically to probe the upper atmosphere. The vertical velocity of the rocket as a function of time is shown in the graph.



(a) Using either words or calculations, compare the acceleration of the rocket at $t = 20$ s with its acceleration at $t = 100$ s. **2**

The gradient of the function after 20 seconds is significantly less than the gradient after 100 seconds. Since acceleration is equal to the change in ~~acceleration~~ velocity ÷ time (gradient of function), the acceleration is greater at 100 seconds.

(b) Account for the shape of the graph over the range of time shown. **4**

There are 3 reasons why the acceleration increases as shown. The first and most significant is that, even though the thrust of the rockets is constant, the mass of fuel (which makes up most of the rocket's mass) decreases. Given the equation $F = ma$, since F is constant and m decreases, a must increase. This means that acceleration and thus gradient of the curve increases. Another reason for increasing acceleration is that ~~gravitational forces~~ acceleration due to gravity decreases with increasing height. Another is that there is less friction in the upper atmosphere. These 3 reasons explain the increasing gradient of the curve until 120 seconds.

(throttling back or being switched off)

The velocity (and acceleration) decreases after 120 seconds. This may be due to ~~the engines~~