

2001 HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

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Centre Number

Section I (continued)

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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

$$t = 5 \text{ microsec} = 5 \times 10^{-6} \text{ sec}$$

$$t_0 = 2.2 \text{ microsec} = 2.2 \times 10^{-6} \text{ sec}$$

$$t = \frac{t_0}{\sqrt{1 - v^2/c^2}} \Rightarrow 5 \times 10^{-6} = \frac{2.2 \times 10^{-6}}{\sqrt{1 - v^2/c^2}}$$

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

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

$$v^2/c^2 = \frac{504}{625}$$

$$v = \frac{504}{625} c$$

$$\therefore v = 0.8064 c$$

$$= 2.69 \times 10^8 \text{ m/s}$$~~

$$\sqrt{1 - v^2/c^2} = 4.4 \times 10^{-1}$$

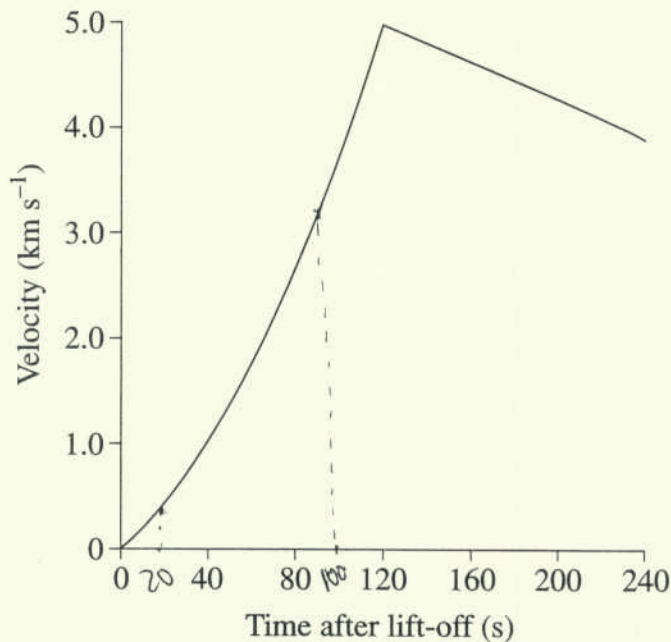
$$\therefore v^2/c^2 = 8.06 \times 10^{-1}$$

$$\therefore v = 8.98 \times 10^{-1} c$$

$$= 2.69 \times 10^8 \text{ m/s}$$

**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.



$F = ma$   
 $F = \frac{d(mv)}{dt}$   
 $v = u + at$   
 when  $u = 0$ :  
 $v = at$

- (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 graph  $\frac{v}{t}$  is the acceleration  $a$ . (ie  $a = \frac{dv}{dt}$ )  
 $\therefore \frac{dv}{dt}$  at  $t = 100$  is greater (greater slope) than  $\frac{dv}{dt}$  at  $t = 20$ . (curve concave up).

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

initial velocity is  $u = 0$   
 Since force of thrust (from engines is constant for each type of engine ie in its own 'stage'),  
 $F = ma$   
 After launch,  $m$  decreases as fuel is used up. Since  $F$  constant,  $a$  increases from  $t = 0$  to  $t = 120$ . At  $t = 120$ , thrust runs out.  
 After  $t = 120$ , the velocity decreases at a constant rate. (ie  $\frac{dv}{dt}$  is constant). (could be due to end of engine thrust).