Examiner only

SECTION B

Answer **all** *questions.*

The questions refer to the case study.
Direct quotes from the original passage will not be awarded marks.

7. *(a)* Give two reasons why only a **small** fraction of the work done in compressing the gas is transferred to gravitational potential energy of the football (paragraphs 3 & 4). Note that losses due to heat and sound are negligible. [2]

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(b) Use the values $u = 20\,\mathrm{m\,s^{-1}}$, $m_0 = 1.5\,\mathrm{kg}$ and $\frac{\Delta m}{\Delta t} = 5.9\,\mathrm{kg\,s^{-1}}$ to calculate the speed of the rocket after 0.175 s (paragraph 11 and equation 2). [2]

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(c) Check that the units (or dimensions) of equation 4 are correct.

$$\frac{\Delta m}{\Delta t} = \pi r^2 \rho u$$

[2]

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(d) Calculate the exhaust speed of water from the rocket assuming a rate of change of mass of $9.5\,kg\,s^{-1}$ and the radius of the bottle neck is 1.1 cm using equation 4 (density of water = $1\,000\,kg\,m^{-3}$). [2]

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(e) Using your own words explain why 'the actual rocket does not keep up with its theoretical counterpart' (paragraphs 16-19 and equation 6). [3]

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(f) Calculate the initial exhaust speed of water leaving a bottle pumped to a pressure of 7.8×10^5 Pa (the outside atmospheric pressure is 1.0×10^5 Pa) using equation 6 (density of water = $1\,000\,kg\,m^{-3}$). [2]

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(g) The table below refers to the terms on the right hand side of equation 8.

$$F_{res} = \pi r^2 \rho u^2 - mg - 0.0107v^2$$

Complete the table, the first row has been completed for you (paragraphs 20-22). [3]

Term	Description	During the first 0.2 s, this term		
		increases	remains constant	decreases
$\pi r^2 \rho u^2$	*Thrust force from exhaust water*			✓
mg				
$0.0107v^2$				

(h) Show that the first term ($\pi r^2 \rho u^2$) in equation 8 can be written as $2(p - p_{atm}) \times A_{neck}$ where A_{neck} is the cross-sectional area of the bottle opening (see equation 5 or 6). [2]

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(i) In practice, using Boyle's law is inappropriate because the gas cools as it expands.

(i) Explain why little or no heat flows when the gas in the bottle expands. [1]

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(ii) Use the first law of thermodynamics to explain why the temperature of the gas decreases. [1]

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