



## **AP<sup>®</sup> Physics B (Operational) 2004 Sample Student Responses**

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2. (15 points)

While exploring a sunken ocean liner, the principal researcher found the absolute pressure on the robot observation submarine at the level of the ship to be about 413 atmospheres. The density of seawater is  $1025 \text{ kg/m}^3$ .

(a) Calculate the gauge pressure  $p_g$  on the sunken ocean liner.

$$1 \text{ atm} = 1 \times 10^5 \text{ Pa} \quad 413 \text{ atm} = 4.13 \times 10^7 \text{ Pa}$$

$$\text{Abs. Pressure} = 4.13 \times 10^7 \text{ Pa}$$

$$\text{gauge pressure} = \text{abs. pressure} - \text{initial pressure}$$

$$4.13 \times 10^7 - 1 \times 10^5 = 4.12 \times 10^7 \text{ Pa}$$

(b) Calculate the depth  $D$  of the sunken ocean liner.

$$P = P_0 + \rho gh \quad P - P_0 = \rho gh$$

$$4.13 \times 10^7 - 1 \times 10^5 = \rho gh \quad 4.12 \times 10^7 = \rho gh$$

$$h = \frac{4.12 \times 10^7}{\rho g}$$

$$h = \frac{4.12 \times 10^7}{1025(9.8)}$$

$$h = 4101.54 \text{ m}$$

$$h = d \quad d = 4101.54 \text{ m}$$

(c) Calculate the magnitude  $F$  of the force due to the water on a viewing port of the submarine at this depth if the viewing port has a surface area of  $0.0100 \text{ m}^2$ .

$$P = \frac{F}{A}$$

$$F = PA$$

$$F = 4.13 \times 10^7 (0.01 \text{ m}^2)$$

$$F = 413000 \text{ N}$$

Suppose that the ocean liner came to rest at the surface of the ocean before it started to sink. Due to the resistance of the seawater, the sinking ocean liner then reached a terminal velocity of 10.0 m/s after falling for 30.0 s.

- (d) Determine the magnitude  $a$  of the average acceleration of the ocean liner during this period of time.

$$v_f = v_i + at$$

$$v_i = 0$$

$$v_f = 10$$

$$T = 30$$

$$a = \frac{v_f}{T} = \frac{10}{30} = \frac{1}{3} = \boxed{0.333 \text{ m/s}^2}$$

- (e) Assuming the acceleration was constant, calculate the distance  $d$  below the surface at which the ocean liner reached this terminal velocity.

$$d = v_i t + \frac{1}{2} a t^2$$

$$v_i = 0$$

$$v_f = 10$$

$$T = 30$$

$$a = 0.333$$

$$d = \frac{1}{2} a t^2 = \frac{1}{2} (0.333) (30)^2$$

$$d = 150 \text{ m below the surface}$$

- (f) Calculate the time  $t$  it took the ocean liner to sink from the surface to the bottom of the ocean.

$$AT, t = 30 \text{ s}, d = 150 \text{ m.}$$

$$d = v_i t + \frac{1}{2} a t^2$$

$$d = d_{\text{tot}} - d_{\text{initial}}$$

$$d = 4101.54 - 150$$

$$d = 3951.54 \text{ m}$$

$$t_a = 30 \text{ s}$$

$$t_b = \frac{d}{v_i} = \frac{3951.54}{10}$$

$$t_b = 395.154 \text{ s}$$

$$T_{\text{total}} = T_A + T_B$$

$$T_{\text{total}} = 30 \text{ s} + 395.154 \text{ s}$$

$$T_{\text{total}} = 425.154 \text{ s}$$

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2. (15 points)

While exploring a sunken ocean liner, the principal researcher found the absolute pressure on the robot observation submarine at the level of the ship to be about 413 atmospheres. The density of seawater is  $1025 \text{ kg/m}^3$ .

(a) Calculate the gauge pressure  $p_g$  on the sunken ocean liner.

$$\frac{413 \text{ atm}}{1} \times \frac{1.0 \times 10^5 \text{ Pa}}{1 \text{ atm}} = 413 \times 10^5 \text{ Pa}$$

$$4.13 \times 10^7 \text{ Pa}$$

(b) Calculate the depth  $D$  of the sunken ocean liner.

$$4.13 \times 10^7 \text{ Pa} = 1.0 \times 10^5 + \rho g h$$

$$4.12 \times 10^7 = 1025 \frac{\text{kg}}{\text{m}^3} \left( \frac{\text{m}}{\text{s}^2} \right) h$$

$$4.101 \text{ m} = h$$

(c) Calculate the magnitude  $F$  of the force due to the water on a viewing port of the submarine at this depth if the viewing port has a surface area of  $0.0100 \text{ m}^2$ .

$$413 \text{ atm} = 1.0 \text{ atm} + \text{Water Pressure}$$

$$412 = \text{Water Pressure}$$

$$4.12 \times 10^7 \text{ Pa} = \frac{4.12 \times 10^7 \text{ Pa}}{0.0100 \text{ m}^2} = 4.12 \times 10^9 \text{ N}$$

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**B2**

Suppose that the ocean liner came to rest at the surface of the ocean before it started to sink. Due to the resistance of the seawater, the sinking ocean liner then reached a terminal velocity of 10.0 m/s after falling for 30.0 s.

(d) Determine the magnitude  $a$  of the average acceleration of the ocean liner during this period of time.

$$v = v_0 + at$$

$$10 \text{ m/s} = 0 \text{ m/s} + a(30 \text{ s})$$

$$10 \text{ m/s} = a(30 \text{ s})$$

$$\frac{1 \text{ m}}{3 \text{ s}^2} = a$$

$$.333 \text{ m/s}^2 = a$$

(e) Assuming the acceleration was constant, calculate the distance  $d$  below the surface at which the ocean liner reached this terminal velocity.

$$x = x_0 + v_0 t + \frac{1}{2}(a)t^2$$

$$x = 30 + 0 + \frac{1}{2}(.333)(30)^2$$

$$x = 150 \text{ m}$$

(f) Calculate the time  $t$  it took the ocean liner to sink from the surface to the bottom of the ocean.

30 sec for 150 m

$$4,100 - 150 = 3,950 \text{ m to bottom of ocean}$$

$$t = \frac{x}{v}$$

$$t = \frac{3,950 \text{ m}}{10 \text{ m/s}}$$

$$t = 395.0 \text{ sec}$$

$$395.1 \text{ sec}$$

$$+ 30 \text{ sec}$$

$$\hline 425.1 \text{ sec}$$

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