



AP[®] Physics B
2004 Sample Student Responses
Form B

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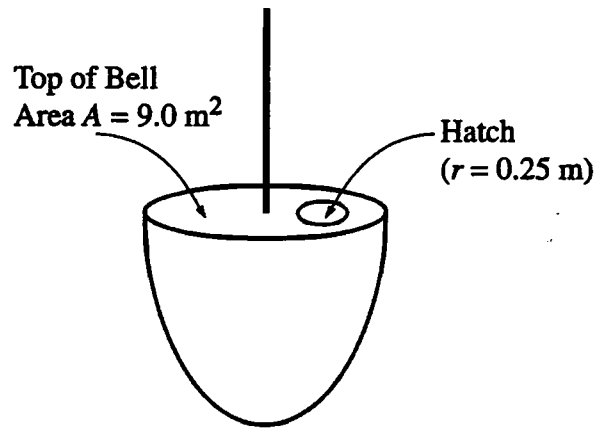
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A1



2. (15 points)

The experimental diving bell shown above is lowered from rest at the ocean's surface and reaches a maximum depth of 80 m. Initially it accelerates downward at a rate of 0.10 m/s^2 until it reaches a speed of 2.0 m/s , which then remains constant. During the descent, the pressure inside the bell remains constant at 1 atmosphere. The top of the bell has a cross-sectional area $A = 9.0 \text{ m}^2$. The density of seawater is 1025 kg/m^3 .

(a) Calculate the total time it takes the bell to reach the maximum depth of 80 m.

Acceleration interval $\Rightarrow v = u + at \Rightarrow 2 = 0 + 0.1 \times t$
 $\therefore t = 20$, x in this interval $\Rightarrow x = ut + \frac{1}{2}at^2 = \frac{1}{2} \times 0.1 \times 400$
 $= 20 \text{ m}$

Constant velocity interval

$$t = \frac{80 - 20}{2} = 30 \text{ s} \quad ; \quad 30 + 20 = 50 \text{ s}$$

\therefore The time take to reach 80 m was 50 s

(b) Calculate the weight of the water on the top of the bell when it is at the maximum depth.

Pressure \uparrow on top of the bell at 80 m depth
 due to water

$$P = \rho gh = (80 \times 1025 \times 9.8) \text{ N/m}^2$$

$$P = \frac{F}{A} \quad \therefore F \text{ which is the } \perp \text{ force is same as weight of water above the bell in this case}$$

$$\therefore W = P \times A = (80 \times 1025 \times 9.8 \times 9) \text{ N}$$

$$= 7,232,400 \text{ N}$$

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- (c) Calculate the absolute pressure on the top of the bell at the maximum depth.

$$\begin{aligned} \text{Absolute pressure} &= p_{\text{atmospheric}} + \rho gh \\ &= (1.0 \times 10^5 + 803600) \text{ N/m}^2 \\ &= 9.04 \times 10^5 \text{ Pa or } 9.04 \times 10^5 \text{ N/m}^2 \\ &1 \text{ Pa} = 1 \text{ N/m}^2 \end{aligned}$$

On the top of the bell there is a circular hatch of radius $r = 0.25$ m.

- (d) Calculate the minimum force necessary to lift open the hatch of the bell at the maximum depth.

$$P = \frac{F_{\perp}}{A}, \quad \therefore F_{\perp} = P \times A$$

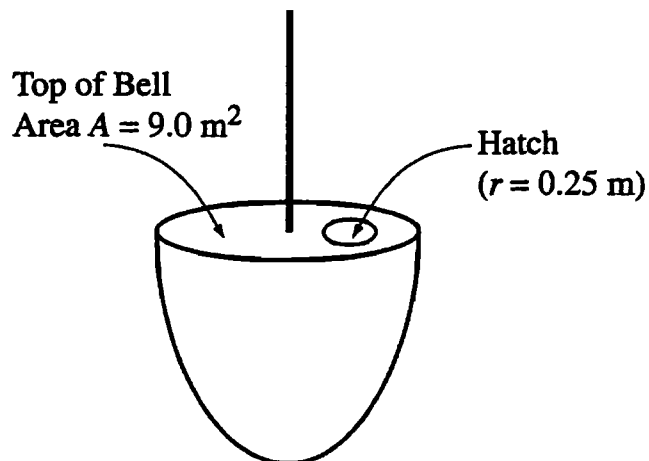
The minimum force required is a perpendicular force

$$\begin{aligned} \text{force} &= 803600 \times \pi (0.25)^2 \\ &= 157,786.5 \text{ N} \end{aligned}$$

- (e) What could you do to reduce the force necessary to open the hatch at this depth? Justify your answer.

Increase the pressure inside the diving bell so that the net pressure on its top surface is reduced.

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2. (15 points)

The experimental diving bell shown above is lowered from rest at the ocean's surface and reaches a maximum depth of 80 m. Initially it accelerates downward at a rate of 0.10 m/s^2 until it reaches a speed of 2.0 m/s , which then remains constant. During the descent, the pressure inside the bell remains constant at 1 atmosphere. The top of the bell has a cross-sectional area $A = 9.0 \text{ m}^2$. The density of seawater is 1025 kg/m^3 .

(a) Calculate the total time it takes the bell to reach the maximum depth of 80 m.

Consider the distance as 2 parts - during acceleration ①, and at est speed ②.

① $u=0, v=2.0 \text{ m/s}, a=0.10 \text{ m/s}^2, t=? , x=?$

$$v = at + u \Rightarrow t = \frac{v - u}{a} = \frac{2.0}{0.10} \Rightarrow t = 20 \text{ seconds.}$$

$$v^2 = u^2 + 2ax \Rightarrow x = \frac{v^2 - u^2}{2a} = \frac{4.0}{0.20} \Rightarrow x = 20 \text{ m.}$$

② est speed = $v = 2.0 \text{ m/s}; x = 20 \text{ m}; t = ?$

$$x = vt \Rightarrow t = \frac{x}{v} = \frac{20}{2.0} \Rightarrow t = 10 \text{ seconds.}$$

$$t_{\text{tot}} = t_1 + t_2 = 30 \text{ sec} \rightarrow \boxed{T_{\text{tot}} = 30 \text{ seconds.}}$$

(b) Calculate the weight of the water on the top of the bell when it is at the maximum depth.

$$\text{Weight} = W = m \times g.$$

$$F = \frac{m}{V} \Rightarrow m = FV \quad v = ?$$

The water on the surface of the bell is like a cylinder with base = top of bell.

$$\Rightarrow V = \pi r^2 \cdot h = (\text{base } A) \cdot h.$$

$$\Rightarrow V = (9.0) \cdot 80 \text{ m} \Rightarrow V = 720 \text{ m}^3. \quad \left[\text{~~7.2 \times 10^3 m}^3 \right]~~$$

$$\Rightarrow m = (1025)(720) \Rightarrow m = 738,000 \text{ kg.}$$

$$\Rightarrow \text{~~W = 7323~~} \Rightarrow W = 7,232,400 \text{ N}$$

$$\Rightarrow \therefore \boxed{W = 7.2 \times 10^6 \text{ N.}}$$

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(c) Calculate the absolute pressure on the top of the bell at the maximum depth.

$$P_T = P_{\text{water}} + P_{\text{atm}} \quad \Sigma P = P_{\text{water}} - P_{\text{inside}}$$

$$P_{\text{water}} = \frac{F}{A} = \frac{\rho \cdot V \cdot g}{A} = \frac{\rho \cdot A \cdot h \cdot g}{A} \Rightarrow P_{\text{water}} = \rho h g$$

$$\Rightarrow P_{\text{water}} = 803600 \text{ Pa}$$

$$P_{\text{inside}} = 1 \text{ atm} = 1 \times 10^5 \text{ Pa}$$

$$\Rightarrow \Sigma P = 703600 \text{ Pa} \Rightarrow \boxed{P_{\text{net}} = 7.0 \times 10^5 \text{ Pa}}$$

On the top of the bell there is a circular hatch of radius $r = 0.25 \text{ m}$.

(d) Calculate the minimum force necessary to lift open the hatch of the bell at the maximum depth.

$$P = \frac{F_{\perp}}{A} \Rightarrow F_{\perp} = P \cdot A = \rho \cdot \pi r^2 \Rightarrow F_{\perp} = (7.0 \times 10^5) \cdot (\pi (0.25)^2)$$

$$\Rightarrow F_{\perp} = 138151.5369 \text{ N}$$

$$\Rightarrow \boxed{F_{\perp} = 1.4 \times 10^5 \text{ N}}$$

(e) What could you do to reduce the force necessary to open the hatch at this depth? Justify your answer.

We could increase the pressure within the bell.

Since $F = P \cdot A$, when P_T decreases F decreases.

$P_T = P_{\text{water}} - P_{\text{in}}$; so when P_{in} increases, P_T decreases

$\Rightarrow F$ decreases.

Alternately (or we could do both together)

we could make the hatch smaller (decrease A)

$\Rightarrow F$ decreases.

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