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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/s² 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 $1025 \text{ kg/m}^3$.

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

\[ \text{Acceleration interval} \Rightarrow v = u + at \Rightarrow 2 = 0 + 0.1 \times t \]
\[ \therefore t = 20 \text{ s} \]
\[ \text{In this interval} \Rightarrow x = ut + \frac{1}{2} at^2 = \frac{1}{2} \times 1 \times 1 \times 400 = 20 \text{ m} \]

\[ \text{Constant velocity interval} \]
\[ t = \frac{80 - 20}{2} = 30 \text{ s} \]
\[ 30 + 20 = 50 \text{ s} \]

\[ \therefore \text{The time taken to reach 80 m was 50 s} \]

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

\[ \text{Pressure on top of the bell at 80 m depth} \]
\[ P = \rho g h = (80 \times 1025 \times 9.8) \text{ N/m}^2 \]

\[ P = \frac{F}{A} \rightarrow \text{Which is the force is same as weight of water above the bell} \]

\[ \therefore W = P \times A = (80 \times 1025 \times 9.8 \times 9) \text{ N} \]
\[ = 7,232,400 \text{ N} \]

GO ON TO THE NEXT PAGE.
(c) Calculate the absolute pressure on the top of the bell at the maximum depth.

\[ \text{Absolute pressure} = p_{\text{atmospheric}} + (g \cdot h) \]

\[ = (1.0 \times 10^5 + 803600) \text{ N/m}^2 \]

\[ = 9.036 \times 10^5 \text{ Pa} \quad \text{or} \quad 9.036 \times 10^5 \text{ N/m}^2 \]

\[ 1 \text{ Pa} = 1 \text{ N/m}^2 \]

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.

\[ F = \frac{F_L}{A}, \quad \therefore F_L = p \times A \]

The minimum force required is a perpendicular force:

\[ = 803600 \times \pi (0.25)^2 \]

\[ = 157786.5 \text{ N} \]

(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.
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/s² 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 \text{ 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 and at constant speed.

1. \( u = 0, v = 2.0 \text{ m/s}, a = 0.10 \text{ m/s}^2, t = ?, x = ? \)
   \[ v = ut + \frac{1}{2}at^2 \]
   \[ t = \frac{v-u}{a} = \frac{2.0}{0.10} \Rightarrow t = 20 \text{ seconds} \]
   \[ x = \frac{v^2 - u^2}{2a} = \frac{4.0}{0.20} \Rightarrow x = 20 \text{ m} \]

2. At constant speed, \( v = 2.0 \text{ m/s}, x = 20 \text{ m}, t = ? \)
   \[ x = vt \Rightarrow t = \frac{x}{v} = \frac{20}{2} \Rightarrow t = 10 \text{ seconds} \]

\[ \hat{t} = t_1 + t_2 = 30 \text{ sec} \Rightarrow T_{tot} = 30 \text{ seconds} \]

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

Weight = \( W = \dot{m} \times g \)

\[ \dot{m} = \frac{\ln}{v} \Rightarrow \dot{m} = \frac{\dot{V}}{v} \]

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

\[ v = \pi r^2 h = (\text{base} A) \times h \]

\[ V = (2.0 \text{ m/s}) \times 80 \text{ m} \Rightarrow V = 720 \text{ m}^3 \]

\[ m = (0.25) (720) \Rightarrow m = 180 \text{ kg} \]

\[ \Rightarrow \dot{m} = 720 \text{ kg/s} \Rightarrow \dot{W} = 7,232,100 \text{ N} \]

\[ W = 7.2 \times 10^6 \text{ N} \]
(c) Calculate the absolute pressure on the top of the bell at the maximum depth.

\[ P = P_{\text{water}} + P_{\text{atm}} \]
\[ P_{\text{water}} = \frac{F}{A} = \frac{F \cdot V \cdot g}{A} = \frac{F \cdot A \cdot h_{\text{g}}}{A} \Rightarrow P_{\text{water}} = F \cdot h_{\text{g}} \]
\[ P_{\text{atm}} = 10^5 \text{ Pa} \]
\[ P_{\text{inside}} = 1 \text{ atm} = 1 \times 10^5 \text{ Pa} \]
\[ P = 703,600 \text{ Pa} \Rightarrow P_{\text{net}} = 7.0 \times 10^5 \text{ Pa}. \]

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.

\[ F = \frac{P}{A} \Rightarrow F = P \cdot A = 7.0 \times 10^5 \cdot \pi \cdot r^2 \Rightarrow F = 13,815,153 \text{ N} \]
\[ F = 1.4 \times 10^5 \text{ N}. \]

(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. So since \( F = P \cdot A \), when \( P \) decreases \( F \) decreases.

\[ P = P_{\text{water}} - P_{\text{atm}} \Rightarrow P_{\text{in}} \text{ increases, } P \text{ decreases} \]

Alternately (or we could do both together), we could make the hatch smaller (decrease \( A \)) and \( F \) decreases.