CollegeBoard
Advanced Placement Program

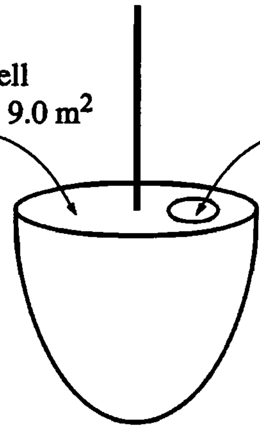
AP® Physics B
2004 Sample Student Responses
Form B

The College Board is a not-for-profit membership association whose mission is to connect students to college success and opportunity. Founded in 1900, the association is composed of more than 4,500 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 23,000 high schools, and 3,500 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT®, and the Advanced Placement Program® (AP®). The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns.

For further information, visit www.collegeboard.com

For the College Board's online home for AP professionals, visit AP Central at apcentral.collegeboard.com.

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 $A = 9.0\ m^2$. 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 ⇒ $v = u + at \Rightarrow 2 = 0 + 0.1 \times t$

∴ $t = 20$, x in this interval ⇒ $x = ut + \frac{1}{2}at^2 = \frac{1}{2} \times .1 \times 400$
$= 20$ m

Constant velocity interval

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

∴ 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 due to water on top of the bell at 80 m depth

$p = \rho g h = (80 \times 1025 \times 9.8)\ N/m^2$

$p = \frac{F}{A}$ ∴ F which is the ⊥ force is same as weight of water above the bell in this case

∴ $W = p \times A = (80 \times 1025 \times 9.8 \times 9)\ N$
$= 7{,}232{,}400$ N

GO ON TO THE NEXT PAGE.

A2

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

Absolute pressure = $P_{atmospheric} + \rho g h$

$= (1.0 \times 10^5 + 803600)\ N/m^2$

$= 9.04 \times 10^5\ Pa$ or $9.04 \times 10^5\ N/m^2$

$1\ Pa = 1\ N/m^2$

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.

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

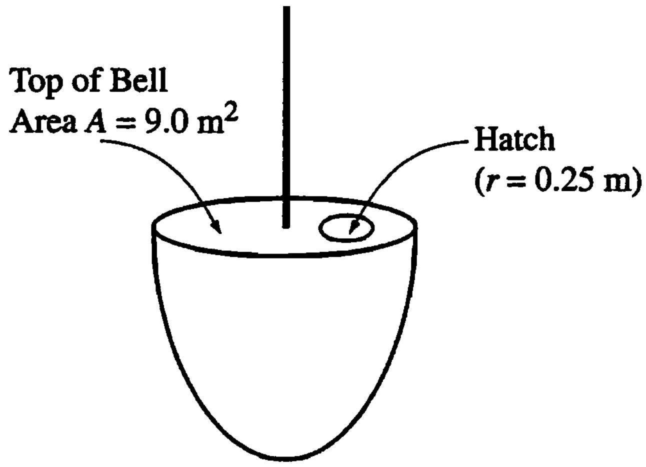
The minimum force required is a perpendicular force $= 803600 \times \pi(.25)^2$

$= 157{,}786.5\ N$

(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.

GO ON TO THE NEXT PAGE.



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 $A = 9.0\ m^2$. 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 cst speed ②.

① $u=0$, $v=2.0$ m/s, $a=0.10$ m/s², $t=?$, $x=?$

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

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

② cst speed $= v=2.0$ m/s; $x=20$ m; $t=?$

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

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

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

Weight $= W = m\times g$.

$\rho=\frac{m}{V} \Rightarrow m=\rho V$. $V=?$

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

~~⇒ V = 1~~ $\Rightarrow V=(\pi r^2)\cdot h = (\text{base } A)\cdot h$.

$\Rightarrow V=(9.0)\cdot 80\text{m} \Rightarrow V=720\text{m}^3$. ~~7.2×10² m³~~

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

⇒ ~~W = 7.232~~ ⇒ $W=7{,}232{,}400$ N

⇒ ∴ $W=7.2\times10^6$ N.

GO ON TO THE NEXT PAGE.

B2

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

~~$P_T = P_{water} + P_{atm}$~~ $\Sigma P = P_{water} - P_{inside}$.

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

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

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

$\Rightarrow \Sigma P = 703{,}600 \text{ Pa} \Rightarrow$ $\boxed{P_{net} = 7.0 \times 10^5 \text{ Pa}}$.

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.

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

$\Rightarrow F_\perp = 138151.5367 \text{ N}$

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

(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.

$P_T = P_{water} - P_{in}$; 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.

GO ON TO THE NEXT PAGE.