AP® Physics B
2002 Sample Student Responses

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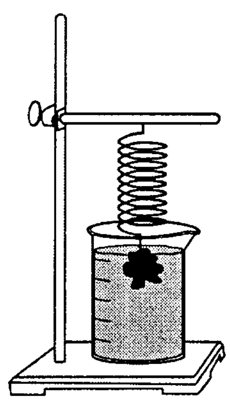
6. (10 points)

In the laboratory, you are given a cylindrical beaker containing a fluid and you are asked to determine the density ρ of the fluid. You are to use a spring of negligible mass and unknown spring constant k attached to a stand. An irregularly shaped object of known mass m and density D ($D >> \rho$) hangs from the spring. You may also choose from among the following items to complete the task.

- A metric ruler
- A stopwatch
- String

(a) Explain how you could experimentally determine the spring constant k.

I could measure the spring's length with no weight on it. I could then measure the spring's length with the irregularly shaped solid on it. I would then subtract the spring's original length from the measured length. I would then find the slope of the line connecting (0,0) and (mg, stretch). That slope would be -k in the equation F=-kx.



(b) The spring-object system is now arranged so that the object (but none of the spring) is immersed in the unknown fluid, as shown above. Describe any changes that are observed in the spring-object system and explain why they occur.

Since there is a buoyant force upwards on the object as a result of submersion in a fluid, the spring would be stretched out less than if the mass were hanging in air. F↓ = k · x↓

GO ON TO THE NEXT PAGE.

(c) Explain how you could experimentally determine the density of the fluid.

I could hang the mass off the spring in air and measure the excess stretch that occurred from when the spring had no mass on it. I would then compare that stretch to the stretched measured when the weight was hanging in the fluid. The difference in stretches would give me a difference in forces. That difference in forces would be the weight of the displaced fluid. I would measure, using the marks on the outside of the beaker, the difference in height between when the mass was in the fluid and when it wasn't. This would be the volume of the displaced fluid. I would then divide the weight of the displaced fluid by g to get the mass of the displaced fluid. I would then divide m_{fluid} by V_{fluid} to get ρ_{fluid}.

(d) Show explicitly, using equations, how you will use your measurements to calculate the fluid density ρ. Start by identifying any symbols you use in your equations.

Symbol	Physical quantity
W = weight of displaced fluid	$F = -kx_1$
ρ_{fluid} = density of displaced fluid	$F_s = -kx_2$
F = spring restoring force	

F_s = force when submerged

V = volume of displaced fluid

m = mass

$$W = (-kx_1) - (-kx_2)$$

$$W = mg$$

$$\frac{W}{g} = m = \frac{(-kx_1) - (-kx_2)}{g}$$

$$\frac{m}{V} = \rho_{fluid} = \frac{(-kx_1) - (-kx_2)}{Vg}$$

GO ON TO THE NEXT PAGE.

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In the laboratory, you are given a cylindrical beaker containing a fluid and you are asked to determine the density ρ of the fluid. You are to use a spring of negligible mass and unknown spring constant k attached to a stand. An irregularly shaped object of known mass m and density D ($D >> \rho$) hangs from the spring. You may also choose from among the following items to complete the task.

- A metric ruler
- A stopwatch
- String

(a) Explain how you could experimentally determine the spring constant k.

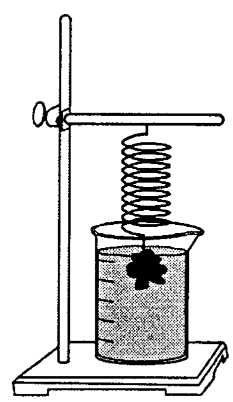
1) Remove the object from spring
2) measure spring length D_1
3) Place object back on spring
4) measure spring length D_2
5) $D_2 - D_1 = x$

$F_s = F_g$

$F_g = 9.8 \cdot m$

$F_g = -kx$

$\frac{F_g}{x} = -k$



(b) The spring-object system is now arranged so that the object (but none of the spring) is immersed in the unknown fluid, as shown above. Describe any changes that are observed in the spring-object system and explain why they occur.

The spring will shorten because there is now a boyant force on the object. So no $F_s + F_B = F_g$ and because F_B is opposite gravity F_s may be smaller.

GO ON TO THE NEXT PAGE.

(c) Explain how you could experimentally determine the density of the fluid.

1) measure the length of the spring w/object ~~[illegible]~~ out of water

2) measure lenghth of spring w/object in water

(d) Show explicitly, using equations, how you will use your measurements to calculate the fluid density ρ. Start by identifying any symbols you use in your equations.

Symbol	Physical quantity
ρ	fluid density
D	object density
F_s	Force spring applys to object out of water
F_g	Force gravity applys to object
F_b	boyant force on object
D_1	Length of spring with no object
D_2	length of spring with object
k	Spring constant
m	mass of object
~~x~~	~~Diffe~~
F_{s_2}	Force of spring w/object in water

$F_s = F_g$

$F_g = 9.8m$

$F_s = -kx$

$D_2 - D_1 = x$

$\frac{9.8m}{x} = -k$

$F_{s_2} + F_b = F_g$

$F_b = F_g - F_{s_2}$

$F_{s_2} = -kx$

GO ON TO THE NEXT PAGE.