

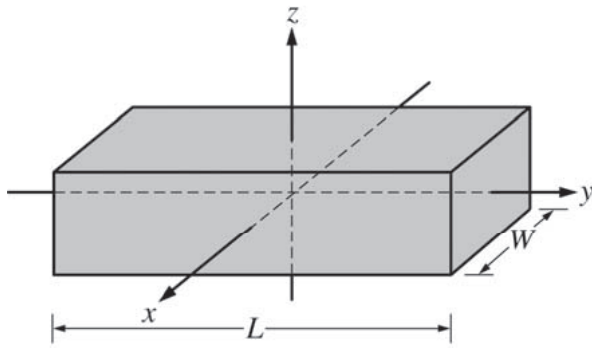
PHYSICS C: ELECTRICITY AND MAGNETISM

SECTION II

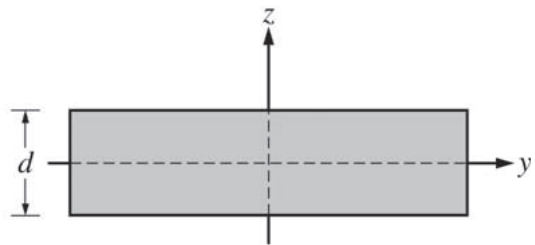
Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



Perspective View

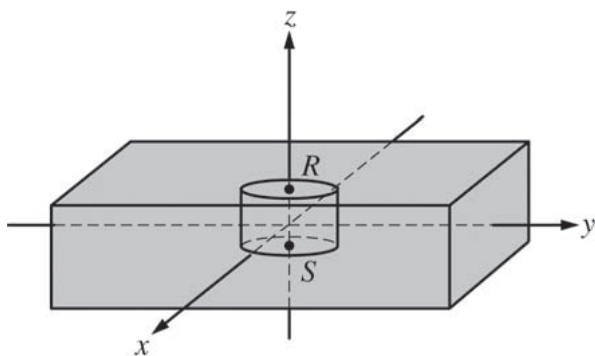


Side View

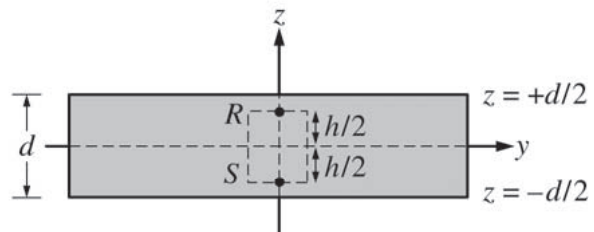
Note: Figures not drawn to scale.

1. A very large nonconducting slab with a uniform positive volume charge density ρ_0 is fixed with the origin of the xyz -axes at its center, as shown in the figure above. The thickness of the slab is d , the length is L , and the width is W , where $L \gg d$ and $W \gg d$. The large faces of the slab are parallel to the xy -plane.

Consider a Gaussian cylinder with a cross-sectional area A and height h that is positioned with its axis along the z -axis, as shown in the figure below.



Perspective View



Side View

Note: Figures not drawn to scale.

- (a) Draw a single vector on each of the dots below representing the direction of the electric field at the given points. If the electric field at either point is zero, write “ $E = 0$ ” next to the point.

i.

ii.

• R

• S

- b) Use Gauss’s law to derive expressions for the following. Express your answers in terms of ρ_0 , A , d , h , z , and physical constants, as appropriate.
 - i. Derive an expression for the total flux Φ through the Gaussian surface shown.
 - ii. Derive an expression for the magnitude of the electric field as a function of z for any position inside the slab, and show that it is equal to $E = \frac{\rho_0 z}{\epsilon_0}$.



Note: Figure not drawn to scale.

The charged slab is now placed between two large metal plates separated by a distance of 0.010 m, which is approximately the thickness of the slab, but the slab does not contact either metal plate. The metal plates are charged, resulting in the surface charge densities $\sigma = \pm 2.0 \times 10^{-6} \text{ C/m}^2$, as shown in the figure above. Assume the charge distribution inside the slab remains unchanged by the presence of the charged plates and that the slab’s volume charge density is $\rho_0 = 1.00 \times 10^{-3} \text{ C/m}^3$.

- (c)
 - i. The magnitude of the electric field inside the slab is zero on the z -axis at position z_0 . Which of the following correctly indicates the value for z_0 ?

☐ $z_0 > 0$ ☐ $z_0 = 0$ ☐ $z_0 < 0$

 Justify your answer.
 - ii. Calculate the value z_0 .

- (d) Calculate the magnitude of the electric potential difference from the center of the slab to the top of the slab.