P24.1 For a uniform electric field passing through a plane surface, $\Phi_E = \vec{\mathbf{E}} \cdot \vec{\mathbf{A}} = EA\cos\theta$, where θ is the angle between the electric field and the normal to the surface.

(a) The electric field is perpendicular to the surface, so θ = 0°:

$$\Phi_E = \left(6.20 \times 10^5 \text{ N/C}\right)\left(3.20 \text{ m}^2\right)\cos 0°$$

$$\Phi_E = \boxed{1.98 \times 10^6 \text{ N} \cdot \text{m}^2/\text{C}}$$

(b) The electric field is parallel to the surface: θ = 90°, so cos θ = 0, and the flux is $\boxed{\text{zero.}}$

P24.2 The electric flux through the bottom of the car is given by

$$\Phi_E = EA\cos\theta = \left(2.00 \times 10^4 \text{ N/C}\right)(3.00 \text{ m})(6.00 \text{ m})\cos 10.0°$$

$$= \boxed{355 \text{ kN} \cdot \text{m}^2/\text{C}}$$

P24.3 For a uniform field the flux is $\Phi = \vec{\mathbf{E}} \cdot \vec{\mathbf{A}} = EA\cos\theta$.

The maximum value of the flux occurs when q = 0, or when the field is in the same direction as the area vector, which is defined as having the direction of the perpendicular to the area. Therefore, we can calculate the field strength at this point as

$$E = \frac{\Phi_{\text{max}}}{A} = \frac{\Phi_{\text{max}}}{\pi r^2}$$

$$E = \frac{5.20 \times 10^5 \text{ N} \cdot \text{m}^2/\text{C}}{\pi(0.200 \text{ m})^2} = 4.14 \times 10^6 \text{ N/C} = \boxed{4.14 \text{ MN/C}}$$

P24.4 (a) For the vertical rectangular surface, the area (shown as A′ in ANS FIG. P24.4) is

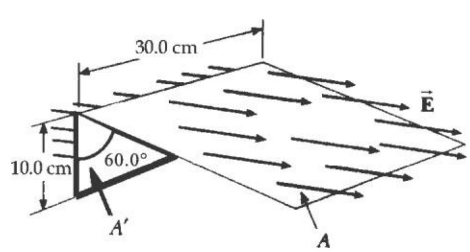
$$A' = (10.0 \text{ cm})(30.0 \text{ cm}) = 300 \text{ cm}^2 = 0.030\,0 \text{ m}^2$$

Since the electric field is perpendicular to the surface and is directed inward, $\theta = 180°$ and

$$\Phi_{E,A'} = EA'\cos\theta$$

$$\Phi_{E,A'} = \left(7.80 \times 10^4 \text{ N/C}\right)\left(0.030\,0 \text{ m}^2\right)\cos 180°$$

$$\Phi_{E,A'} = \boxed{-2.34 \text{ kN} \cdot \text{m}^2/\text{C}}$$



ANS. FIG. P24.4

(b) To find the area A of the slanted surface, we note that the side for which dimensions are not given has length (10.0 cm) $= w \cos 60.0°$, so that

$$A = (30.0\text{ cm})(w) = (30.0\text{ cm})\left(\frac{10.0\text{ cm}}{\cos 60.0°}\right) = 600\text{ cm}^2$$
$$= 0.060\,0\text{ m}^2$$

The flux through this surface is then

$$\Phi_{E,A} = EA\cos\theta = \left(7.80\times10^4\right)(A)\cos 60.0°$$
$$= \left(7.80\times10^4\text{ N/C}\right)\left(0.060\,0\text{ m}^2\right)\cos 60.0°$$
$$= \boxed{+2.34\text{ kN}\cdot\text{m}^2/\text{C}}$$

(c) The bottom and the two triangular sides all lie *parallel* to $\vec{\mathbf{E}}$, so $\Phi_E = 0$ for each of these. Thus,

$$\Phi_{E,\text{ total}} = -2.34\text{ kN}\cdot\text{m}^2/\text{C} + 2.34\text{ kN}\cdot\text{m}^2/\text{C} + 0 + 0 + 0 = \boxed{0}$$

P24.5 For a uniform electric field passing through a plane surface, $\Phi_E = \vec{\mathbf{E}}\cdot\vec{\mathbf{A}} = EA\cos\theta$, where θ is the angle between the electric field and the normal to the surface.

(a) The electric field is perpendicular to the surface, so $\theta = 0°$:

$$\Phi_E = \left(3.50\times10^3\text{ N/C}\right)\left[(0.350\text{ m})(0.700\text{ m})\right]\cos 0°$$
$$= \boxed{858\text{ N}\cdot\text{m}^2/\text{C}}$$

(b) The electric field is parallel to the surface: $\theta = 90°$, so $\cos\theta = 0$, and the flux is $\boxed{\text{zero}}$.

(c) For the specified plane,

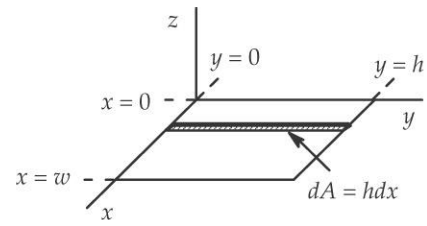
$$\Phi_E = \left(3.50\times10^3\text{ N/C}\right)\left[(0.350\text{ m})(0.700\text{ m})\right]\cos 40.0°$$
$$= \boxed{657\text{ N}\cdot\text{m}^2/\text{C}}$$

P24.6 We are given an electric field in the general form

$$\vec{\mathbf{E}} = ay\hat{\mathbf{i}} + bz\hat{\mathbf{j}} + cx\hat{\mathbf{k}}$$

In the xy plane, $z = 0$ so that the electric field reduces to

$$\vec{\mathbf{E}} = ay\hat{\mathbf{i}} + cx\hat{\mathbf{k}}$$



ANS. FIG. P24.6

To obtain the flux, we integrate (see ANS. FIG. P24.6 for the definition of dA):

$$\Phi_E = \int \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \int \left(ay\hat{\mathbf{i}} + cx\hat{\mathbf{k}} \right) \cdot \hat{\mathbf{k}}\, dA$$

$$\Phi_E = ch \int_{x=0}^{w} x\, dx = ch \frac{x^2}{2} \bigg|_{x=0}^{w} = \boxed{\frac{chw^2}{2}}$$

Where the $\hat{\mathbf{k}}$ term was eliminated since $\hat{\mathbf{k}} \cdot \hat{\mathbf{k}} = 0$.

P24.7 The electric flux through the hole is given by Gauss's Law (Equation 24.6) as

$$\Phi_{E,\,\text{hole}} = \vec{\mathbf{E}} \cdot \vec{\mathbf{A}}_{\text{hole}} = \left(\frac{k_e Q}{R^2} \right) \left(\pi r^2 \right)$$

$$= \left(\frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(10.0 \times 10^{-6} \text{ C}\right)}{(0.100 \text{ m})^2} \right)$$

$$\times \pi \left(1.00 \times 10^{-3} \text{ m}\right)^2$$

$$= \boxed{28.2 \text{ N} \cdot \text{m}^2/\text{C}}$$

P24.8 The gaussian surface encloses the +1.00-nC and –3.00-nC charges, but not the +2.00-nC charge. The electric flux is therefore

$$\Phi_E = \frac{q_{\text{in}}}{\epsilon_0} = \frac{\left(1.00 \times 10^{-9} \text{ C} - 3.00 \times 10^{-9} \text{ C}\right)}{8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2} = \boxed{-226 \text{ N} \cdot \text{m}^2/\text{C}}$$

P24.9 The total charge within the closed surface is

$$5.00\ \mu\text{C} - 9.00\ \mu\text{C} + 27.0\ \mu\text{C} - 84.0\ \mu\text{C} = -61.0\ \mu\text{C}$$

(a) So, from Equation 24.6, the total electric flux is

$$\Phi_E = \frac{q}{\epsilon_0} = \frac{-61.0 \times 10^{-6}\ \text{C}}{\left(8.85 \times 10^{-12}\ \text{C}^2/\text{N} \cdot \text{m}^2\right)} = \boxed{-6.89\ \text{MN} \cdot \text{m}^2/\text{C}}$$

(b) $\boxed{\text{Since the net electric flux is negative, more lines enter than leave the surface.}}$

P24.11 The electric flux through each of the surfaces is given by $\Phi_E = \dfrac{q_{\text{in}}}{\epsilon_0}$.

Flux through S_1: $\Phi_E = \dfrac{-2Q + Q}{\epsilon_0} = \boxed{-\dfrac{Q}{\epsilon_0}}$

Flux through S_2: $\Phi_E = \dfrac{+Q - Q}{\epsilon_0} = \boxed{0}$

Flux through S_3: $\Phi_E = \dfrac{-2Q + Q - Q}{\epsilon_0} = \boxed{-\dfrac{2Q}{\epsilon_0}}$

Flux through S_4: $\Phi_E = \boxed{0}$

P24.48 The electric field makes an angle of 70.0° to the normal. The square has side $d = 5.00$ cm.

$$\Phi_E = EA\cos\theta = Ed^2\cos\theta$$

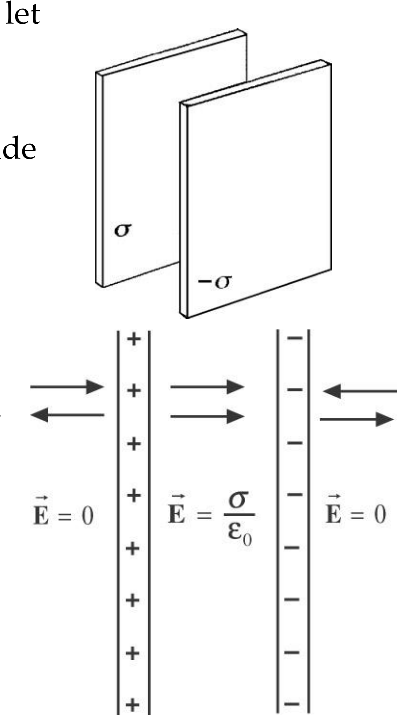
$$\rightarrow E = \frac{\Phi_E}{d^2\cos\theta} = \frac{6.00\ \text{N} \cdot \text{m}^2/\text{C}}{(0.150\ \text{m})^2\cos 70.0°} = \boxed{780\ \text{N/C}}$$

P24.49 The electric field makes an angle of 60.0° with to the normal. The square has side d = 5.00 cm.

$$\Phi_E = EA\cos\theta = \left(3.50\times10^{2}\ \text{N/C}\right)\left(5.00\times10^{-2}\ \text{m}\right)^2\cos 60.0°$$
$$= \boxed{0.438\ \text{N}\cdot\text{m}^2/\text{C}}$$

P24.56 Consider the field due to a single sheet and let E_+ and E_- represent the fields due to the positive and negative sheets. The field at any distance from each sheet has a magnitude given by the textbook equation

$$|E_+| = |E_-| = \frac{\sigma}{2\epsilon_0}$$



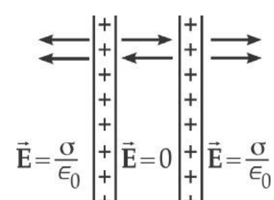
ANS. FIG. P24.56(a-c)

(a) To the left of the positive sheet, E_+ is directed toward the left and E_- toward the right and the net field over this region is $\vec{\mathbf{E}} = \boxed{0}$.

(b) In the region between the sheets, E_+ and E_- are both directed toward the right and the net field is

$$\vec{\mathbf{E}} = \boxed{\frac{\sigma}{\epsilon_0}\ \text{to the right}}$$

(c) To the right of the negative sheet, E_+ and E_- are again oppositely directed and $\vec{\mathbf{E}} = \boxed{0}$.



ANS. FIG. P24.56(d)

(d) Now, both sheets are positively charged. We find that

(1) To the left of both sheets, both fields are directed toward the left:

$$\vec{\mathbf{E}} = \boxed{2\frac{\sigma}{\epsilon_0}\ \text{to the left}}$$

(2) Between the sheets, the fields cancel because they are opposite to each other: $\vec{\mathbf{E}} = \boxed{0}$.

(3) To the right of both sheets, both fields are directed toward the right:

$$\vec{\mathbf{E}} = \boxed{2\frac{\sigma}{\epsilon_0}\ \text{to the right}}$$