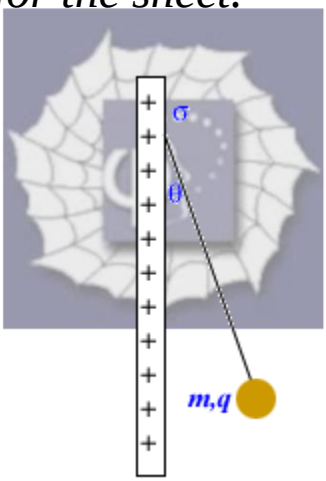
323.

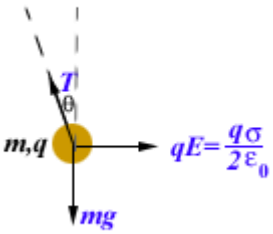
Problem 29.25 (RHK)

A small sphere whose mass m is 1.12 mg *carries a charge* $q = 19.7$ nC. *It hangs in the Earth's gravitational field from a silk thread that makes an angle* $\theta = 27.4^0$ *with a large uniformly charged nonconducting sheet as shown in the figure. We have to calculate the uniform charge density* σ *for the sheet.*



Solution:

We will draw the free-body diagram of forces acting on the charged sphere of mass *m* carrying charge *q* in the electric field produced by a large nonconducting sheet with charge density σ.



It is given that at equilibrium the string with which the spherical ball has been suspended is at an inclination with respect to the vertical. Angle of inclination is

$\theta = 27.4^0$.

Electric field due to a large sheet having charge density σ will be perpendicular to the sheet and its magnitude will be

$$E = \frac{\sigma}{2\varepsilon_0}.$$

Resolving the forces acting on the charged sphere in the horizontal and vertical directions and requiring that at equilibrium the net components will be zero, we get

$T\cos\theta = mg$,

and

$$T\sin\theta = \frac{q\sigma}{2\varepsilon_0}.$$

It is given that

$\theta = 27.4^0$, $m = 1.12\times10^{-6}$ kg, and $q = 19.7\times10^{-9}$ C.

Therefore,

$$\tan\theta = \frac{q\sigma}{2\varepsilon_0 mg}.$$

We therefore find

$$\sigma = 2\times 8.85\times 10^{-12}\times 1.12\times 10^{-6}\times 9.81\times \frac{\tan\left(27.4^0\right)}{19.7\times 10^{-9}} \text{ C m}^{-2}$$

$$= 5.12\times 10^{-9} \text{ C m}^{-2}$$

$$= 5.12 \text{ nC m}^{-2}.$$