# PHYSICS 271
# ELECTRICITY AND MAGNETISM
# FIRST EXAMINATION

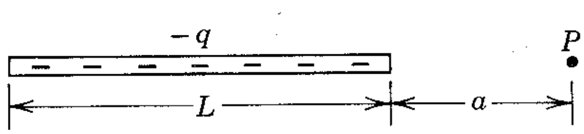
13 October 2000

**INSTRUCTIONS:** Answer all questions on the answer sheet provided, it will be the only paper that is collected. This is a closed book exam.

**1. a)** An insulating rod of length *L* has charge -*q* uniformly distributed along its length, as shown below. What is the linear charge density of the rod?

a) $l = \frac{q}{L+a}$ c) $l = \frac{q}{L}$ e) $l = 0$

b) $l = \frac{-q}{L+a}$ d) $l = \frac{-q}{L}$




**1. b)** What is the direction of the electric field at point ***P***?

a) **E** points up c) **E** points to the right e) **E** is zero

b) **E** points down d) **E** points to the left

**1. c)** The magnitude of the electric field at ***P*** is:

a) $E = \frac{q}{4pe_0 a(L+a)}$ c) $E = \frac{q}{4pe_0 (L+a)^2}$ e) $E = 0$

b) $E = \frac{q}{4pe_0 \left(\frac{L}{2}+a\right)^2}$ d) $E = \frac{q}{4pe_0 (L+a)L}$

**2. a)** Suppose a spherically shaped planet with radius $R$ has an excess positive charge $Q$ uniformly distributed over its surface. The electric field at radial distances $r > R$ from the center of the planet is:

a) $\vec{E} = \dfrac{Q}{4pe_0 r^2}\hat{r}$  c) $\vec{E} = \dfrac{Q}{4pe_0 R^2}\hat{r}$  e) $\vec{E} = 0$

b) $\vec{E} = \dfrac{-Q}{4pe_0 r^2}\hat{r}$  d) $\vec{E} = \dfrac{-Q}{4pe_0 R^2}\hat{r}$

**2. b)** What is the electric field inside the planet?

a) $\vec{E} = \dfrac{Q}{4pe_0 R^2}\hat{r}$  c) $\vec{E} = \dfrac{Q}{4pe_0 r^2}\hat{r}$  e) $\vec{E} = 0$

b) $\vec{E} = \dfrac{-Q}{4pe_0 R^2}\hat{r}$  d) $\vec{E} = \dfrac{-Q}{4pe_0 r^2}\hat{r}$

**2. c)** In addition, the planet is surrounded by a positively charged dust cloud containing total charge $q$ and extending from the surface of the planet out to a radius $R_D$. The cloud has a spherically symmetric charge distribution with volume charge density given by $r(r) = \dfrac{q}{4p(R_D - R)r^2}$ for $R \le r \le R_D$ , and zero otherwise. What is the electric field at radial distances $r > R_D$?

a) $\vec{E} = \dfrac{Q+q}{4pe_0 r^2}\hat{r}$  c) $\vec{E} = \dfrac{Q+q}{4pe_0 R_D^2}\hat{r}$  e) $\vec{E} = 0$

b) $\vec{E} = \dfrac{q}{4pe_0 r^2}\hat{r}$  d) $\vec{E} = \dfrac{-Q-q}{4pe_0 R_D^2}\hat{r}$

**2. d)** What is the electric field at radial distances $R \le r \le R_D$?

a) $\vec{E} = \dfrac{Q+q}{4pe_0 r^2}\hat{r}$  c) $\vec{E} = \dfrac{q}{4pe_0 r^2}\dfrac{(r-R)}{(R_D - R)}\hat{r}$  e) $\vec{E} = 0$

b) $\vec{E} = \dfrac{Q+q}{4pe_0 R^2}\hat{r}$  d) $\vec{E} = \dfrac{Q+q}{4pe_0 r^2}\hat{r} - \dfrac{q}{4pe_0 r^2}\dfrac{(R_D - r)}{(R_D - R)}\hat{r}$

**3. a)** Two conducting spheres are far apart. The smaller sphere carries a total charge of *q*. The larger sphere has a radius that is twice that of the smaller and is neutral. After the two spheres are connected by a conducting wire, the charges on the smaller and larger spheres, respectively, are:

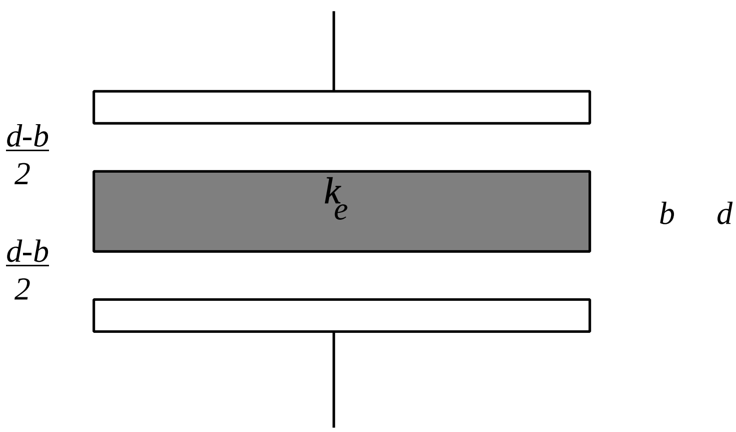

a) $\frac{1}{3}q$ and $\frac{2}{3}q$ c) $-q$ and $+2q$ e) $q$ and $0$

b) $\frac{2}{3}q$ and $\frac{1}{3}q$ d) $\frac{1}{2}q$ and $\frac{1}{2}q$ .

**3. b)** A hollow metal sphere is charged to a potential *V*. The potential at its center is:

a) *0* c) *V* e) *pV*
b) *-V* d) *2V*

**4.** A potential difference $V_0$ is applied to a parallel plate capacitor with plate area *A* and plate separation *d* . The battery is disconnected and then a dielectric slab of thickness *b* and dielectric constant $k_e$ is centrally inserted between the plates as shown below.




**4. a)** What is the magnitude of the electric field $E_0$ in the gaps between the plates and the dielectric slab?

a) $E_0 = \frac{q}{e_0 A}$ c) $E_0 = \frac{V_0}{d}$

b) $E_0 = \frac{q}{e_0 k_e A}$ d) $E_0 = \frac{V_0}{k_e d}$

**4. b)** What is the magnitude of the electric field $E$ in the dielectric slab?

a) $E = E_0$

c) $E = \frac{V_0}{d}$

b) $E = k_e E_0$

d) $E = \frac{1}{k_e} E_0$

**4. c)** What is the potential difference $V$ between the plates after the slab has been inserted?

a) $V = V_0$

c) $V = V_0\left[1 - \frac{b}{d}\left(\frac{k_e - 1}{k_e}\right)\right]$

b) $V = \frac{V_0}{k_e}$

d) $V = E_0(d - b)$

**4. d)** What is the capacitance with the slab in place?

a) $C = \frac{e_0 A}{\left[d + \frac{b}{k_e}\right]}$

c) $C = \frac{q}{V}$

b) $C = \frac{e_0 k_e A}{\left[k_e(d-b) + b\right]}$

d) $C = k_e \frac{e_0 A}{d}$

**4. e)** Find the ratio of the stored energy before to that after the slab is inserted.

a) $\frac{U_0}{U} = 1$, energy is conserved

c) $\frac{U_0}{U} = \frac{d}{k_e(d-b) + b}$

b) $\frac{U_0}{U} = \frac{k_e d}{k_e(d-b) + b}$

d) $\frac{U_0}{U} = k_e$

**4. f)** How much work is done on the slab as it is inserted?

a) $W = 0$, energy is conserved

c) $W = \frac{1}{2}CV_0^2 - \frac{1}{2}C_0V_0^2$

b) $W = \frac{1}{2}C_0V_0^2 - \frac{1}{2}CV^2$

d) $W = \frac{1}{2}CV_0^2$