1. An atom has n_p number of protons and n_n number of neutrons in its nucleus and one electron orbiting around them. Obtain the following quantities for this ion. In each case, give both the *direction* and the *magnitude* of each vector quantity. Use

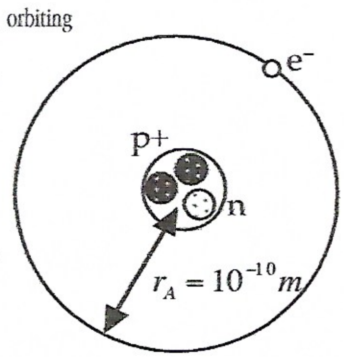
$r_N = 10^{-15} m$ *(radius of the nucleus)*

$r_A = 10^{-10} m$ *(radius of the atom)*

$m_p = m_n = 10^{-27} kg,\ m_e = 10^{-30} kg,$

$e = 10^{-19} C$

$G = 10^{-10}\frac{Nm^2}{kg^2},\ k = 10^{+10}\frac{Nm^2}{C^2}$

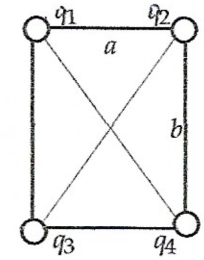


A. The gravitational field created by the nucleus where the electron is. Magnitude & Direction
B. The gravitational force between the nucleus and the electron. Magnitude & Direction
C. The gravitational potential energy of the electron.
D. The electric field created by the nucleus where the electron is. Magnitude & Direction
E. The electric potential (voltage) at the position of the electron.
F. The electric potential energy of the electron in this orbit.
G. The electric force between the nucleus and the electron. Magnitude & Direction
H. The total force between the nucleus and the electron. Which force accounts for the circular motion, electricity or gravity? Why?
I. Use your answers above to obtain the velocity of the electron in this circular orbit. What is its direction?

2. A ring of radius r has a total charge Q distributed uniformly on the ring.
A. Calculate the electric field
   1. at the center of the ring
   2. at a point P along the axis of the ring, a distance z from the plane of the ring. *Remember: All the points on the ring are at the same distance from the point P.*
B. Calculate the electric potential
   1. at the center of the ring
   2. at a point P along the axis of the ring, a distance z from the plane of the ring. *Remember: All the points on the ring are at the same distance from the point P.*

3. Two parallel plates are at a distance d apart from each other, one is negatively charged, the other positively. The magnitude of the electric field inside the plates is E.
A. What is the direction of the electric field inside the plates? Why?
B. What is electric potential (voltage) difference between the plates?
C. If the following particles are put at a distance x away from the negative plate and d-x away from the positive plate, in what direction would they go? Ignore Earth's gravity. (1) electron, (2) proton, (3) neutron
D. Obtain the acceleration of each particle given in part b.
E. Obtain the change in the kinetic energy of eac particle in part B when it hits the plate it is moving toward.

4. Consider the arrangement in the figure.



A. Obtain the electric field due to each charge and the net electric field at the location of q_4
B. Obtain the force due to each charge and the net force on q_4
C. Obtain the potential energy of this arrangement.

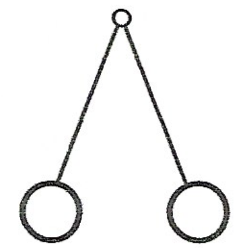
Now, assume all four charges are equal to *q*.

D. Obtain the electric potential V at the center
E. Obtain E_{net} at the center, the magnitude & direction..

Now, a charge q_o is placed at the center.

F. Obtain its potential energy
G. Obtain F_{net} on it., the magnitude & direction.

5. Two objects of mass *m* and charge *q* are connected by two strings of length *l* as shown in the figure. The distance between the centers of the two charges is $2r$ in equilibrium.



A. Draw a free body diagram for each object and show all the forces acting on it.
B. Obtain the gravitational force due to the earth on each object. What is the direction of this force?
C. Obtain the gravitational force on each object due to the other object. What is the direction of this force?
D. Obtain the electric force on each object due to the other object. What is the direction of this force?
E. Obtain the net tension on each string. What is its direction?
F. What has to be the relation between the masses *m* and the charges *q* so that each string makes an angle θ with the vertical? Include all the forces.
G. What would happen if one of the objects is pulled slightly away from the other one? Why?
H. What would happened if one of the objects is pushed slightly in towards the other one? Why?
I. What are the gravitaitional and electric potentail energies of this arrangement?

6. A charged particle of mass *m* and charge *q* is fired with an initial velocity $\vec{v}$ at an angle θ pointing below the horizontal where there is an electric field $\vec{E}$ pointing upward. Answer the questions below in terms of the given quantities and the known constants. *Include the effect of gravity, but assume $F_E > F_g$*

A. What are the x- and y-components of the initial velocity?
B. What are its initial KE & PE?
C. What is the net acceleration of the particle?
D. What are its KE & PE at its iminimum height ?
E. What is the minimum height the particle reaches?
F. What is the range of this projectile before it returns to its initial h?

Continued on the back.

7- Use Gauss' law to obtain (1) the electric field E and (2) the *electric potential* V at at the specified locations from the center of the object for the configurations below. Assume charge densities are uniform and positive. **Show** your calculations. To get partial credit, you must calculate each quantity in

Flux* = *Field* x *SurfaceArea

Flux* = *Constant* x *SourceEnclosed

You can answer these questions without using calculus.

A. A point charge Q.

B. A spherical shell of radius a with a surface charge density σ and charge Q: Obtain E produced bye the sphere at a distance
(i) r<a, (ii) r>a, (iii) r=a

C. A solid sphere with a uniform volume charge density ρ, radius R, charge Q.

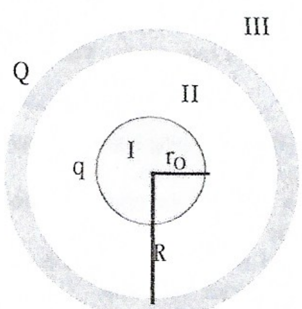
D. A line charge of length ℓ and line charge density λ and charge Q. Assume ℓ is very large.

E. A cylindrical shell of radius a and height h_0 (>>a) with a uniform surface charge density σ, charge Q: Obtain E produced bye the cylindrical shell (as $h_0 \to \infty$) at a distance
(i) r<a, (ii) r>a, (iii) r=a

F. A solid cylinder of radius a and height h_0 (>>a) with a uniform volume charge density ρ, charge Q: Obtain E produced bye the cylindrical shell (as $h_0 \to \infty$) at a distance
(i) r<a, (ii) r>a, (iii) r=a

G. How would your answers change if the charge densities were negative?

H. How would your answers change if you were calculating gravitational fields due to mass densities?



8. A hollow spherical conductor of radius R has electric charge Q. Inside the cavity and concentric with the shell is another conductor of radius $r_0 < R$ with a charge of q as shown in the figure.

A. What is the electric field in region I inside the inner conductor? Hint: Use Gauss' law.

B. 1. What is the electric potential inside the inner conductor?
2. What is the electric potential on the surface of the inner conductor?

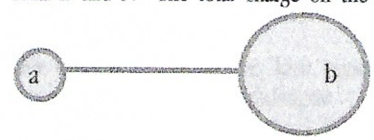
C. What is the electric field in region II between the inner and the outer conductors?

D. Use the result of (c) and $V_f - V_i = -\int_i^f \vec{E}d\vec{r}$ to show that the potential difference between the two spheres is $V_{r_0} - V_R = (?)\left(\frac{1}{r_0} - \frac{1}{R}\right)$.

Do not fudge! You must findthecoefficient (?)

Hint: You are looking for the potential difference between the inside conductor and the outside conductor. You may not have to deal with ∞. I will show you an easier way to get this answer in class.

9. A long thin conducting wire connects two conducting spheres of radii *a* and *b*. The total charge on the connected pair is Q_T.



A. What is the electric field inside the wire?

B. What is the difference in electric potential between the ends of the wire?

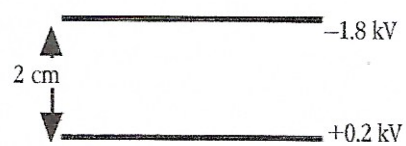
C. What is the ratio of the charge on the larger sphere of radius *b* to the charge on the smaller sphere of radius of *a*? Hint: Think about the implications of the connection on the electric potential on each sphere.

10.

A. An insulated rod of length ℓ is bent into a circular arc of radius R that subtends an angle θ. The rod has a charge Q distributed uniformly along its length. Obtain the electric potential at the origin.

B. The rod is stretched along its length so that it forms a complete circle of the same radius R. The total charge Q remains the same. What is the electric potential at the origin?

11. Consider the two conducting sheets shown in the figure.



A. What is the direction of the electric field between the plates?

B. What is the magnitude of the electric field between the plates?

C. What is the electric potential midway between the plates (1cm away from each)?

D. At what distance from the lower sheet is the electric potential equal to zero?

E. If it is placed at the 0 V-location in what direction does a proton go. Neglect gravity.

F. If it is placed at the 0 V-location in what direction does a electron go. Neglect gravity.

G. If it is placed at the 0 V-location in what direction does a neutron go. Neglect gravity.

BLACK 76
BLUE 8
RED 40

~

1) A) $g = \frac{GM}{r^2} = \frac{(10^{-10} \frac{Nm^2}{kg^2})(10^{-27} kg)(n_p + n_n)}{(10^{-10} m)^2}$ +1

$\approx 10^{-17}(n_p + n_n) \frac{N}{kg} \hat{r}$ radially in ~ ~

B) $\vec{F}_g = \frac{GMm}{r^2} = mg = (10^{-30} kg)(10^{-17}(n_p + n_n)) \frac{N}{kg} \hat{r}$ +1

$= 10^{-47} (n_p + n_n) N \ \hat{r}$, radially in +1 +1

c) $PE_g = mgr = (10^{-47} N)(10^{-10} m) = 10^{-57} J$ ~ ~

d) $E = \frac{kQ}{r^2} = \frac{(10^{10} \frac{Nm^2}{C^2})(e(n_p))}{(10^{-10} m)^2}$ $\hat{r}$ outwards +1

$= 10^{11} n_p \frac{N}{C}$ $\hat{r}$ outwards +1

e) $F = qE$ $V = \frac{kQ}{r} = \frac{(10^{10} \frac{Nm^2}{C^2})(e(n_p))}{(10^{-10} m)} = 10 n_p \frac{Nm}{C}$ ~ ~

f) $PE_e = qV = 10^{-18} n_p J$ ~ ~

g) $F_E = \frac{kQq}{r^2} = qE = 10^{-8} n_p N$ radially in +1 +1 +1

h) $\Sigma F = F_E + F_g =$ ~~10^{-47}~~ +1

$10^{-47}(n_p + n_n) N + 10^{-8} n_p N$ +1

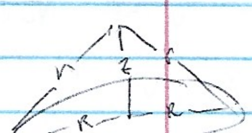
$= 10^{-8} n_p N$ +1 radially in

electricity accounts for circular motion b/c the force is much larger

i) $F_c = \frac{mv^2}{r}$ +1 $v = \sqrt{\frac{rF_c}{m}} = \sqrt{\frac{(10^{-10} m)(10^{-8} n_p N)}{10^{-30} kg}}$

$= 10^{6} \sqrt{n_p}$ m/s ~ ~

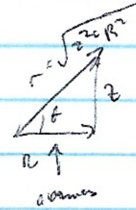
2)



A) E

only z way

A) E at center $= 0$ b/c it cancels out +1 +1



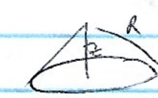
$E_z = E \sin\theta$ +1

$= \frac{kQ}{r^2} \sin\theta = \frac{kQ}{r^2} \cdot \frac{z}{r}$

$= \frac{kQz}{(z^2+R^2)^{3/2}}$ +1

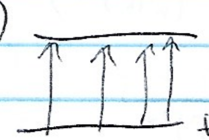
B) at the center

$V = \frac{kQ}{r}$ +1



$V = \frac{kQ}{R} = \frac{kQ}{\sqrt{R^2+z^2}}$ +1

3)



a) towards negative, a (+) test charge will go toward the negative if placed b/w the plates +1

b) $V = rE = dE$ +1

c) (1) towards (+) plate +1

(2) towards (−) plate +1

(3) doesn't move +1

d) $F = qE$ $\Sigma F = ma$

$a = \frac{qE}{m}$

(1) $a = \frac{-eE}{m_e} = -10^{11} E \frac{m}{s^2}$ ~ no numerical

(2) $a = \frac{eE}{m} = 10^{8} E \frac{m}{s^2}$ ~

(3) $a = 0$ +1

e) $\Delta KE = -\Delta PE = -qV$

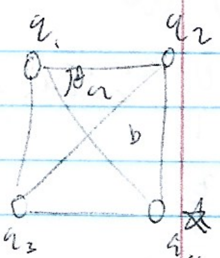
(1) $\Delta KE = eV$ (3) $\Delta KE = 0$

(2) ~ ~ +1

almost

14

13

4) 

a) $E_2 = \frac{kq_2}{b^2}(-\hat{j})$ +1 $\quad E_3 = \frac{kq_3}{a^2}\hat{i}$ +1

$E_1 = \frac{kq_1}{(\sqrt{a^2+b^2})^2}\,\hat{i}\cos\theta\ \ -\hat{j}\sin\theta$ $\quad \cos\theta = \frac{a}{\sqrt{a^2+b^2}}$ $\quad \sin\theta = \frac{b}{\sqrt{a^2+b^2}}$ +1

$E_{Total} = \left(\frac{kq_3}{a^2} + \frac{kq_1 a}{(a^2+b^2)^{3/2}}\right)\hat{i} - \left(\frac{kq_2}{b^2} + \frac{kq_1 b}{(a^2+b^2)^{3/2}}\right)\hat{j}$ +1

b) $F_1 = q_4 E_1 = \frac{kq_1 q_4 a}{(a^2+b^2)^{3/2}}\hat{i} - \frac{kq_1 q_4 b}{(a^2+b^2)^{3/2}}\hat{j}$ +1

$F_2 = q_4 E_2 = -\frac{kq_2 q_4}{b^2}\hat{j}$ +1

$F_3 = q_4 E_3 = \frac{kq_3 q_4}{a^2}\hat{i}$ +1

$F_{total} = \left(\frac{kq_1 q_4 a}{(a^2+b^2)^{3/2}} + \frac{kq_3 q_4}{a^2}\right)\hat{i} - \left(\frac{kq_2 q_4}{b^2} + \frac{kq_1 q_4 b}{(a^2+b^2)^{3/2}}\right)\hat{j}$

c) ~~$PE_c = \Delta V\ \Sigma$~~ (4c) ~ ~ ~

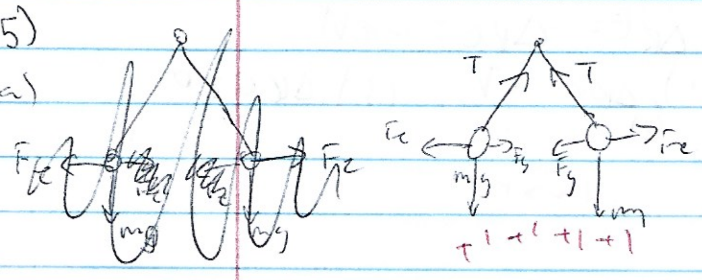
d) $V = 4\frac{kq}{r/2}$ +1 $= 8\frac{kq}{\sqrt{a^2+b^2}}$ +1

e) E_{net} at the center $= 0$? +1

f) $PE_e = qV = \frac{kqq_0}{\sqrt{a^2+b^2}}$ +1

g) $F_{net} = 0$ since $E_{net} = 0$ +1

5)

a) 

+1 +1 +1 +1

b) $F_g = mg$, straight down +1

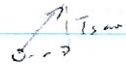
c) $F_g = \frac{Gmm}{(2r)^2} = \frac{Gm^2}{4r^2}$, towards each other +1

d) $F_e = \frac{kqq}{(2r)^2} = \frac{kq^2}{4r^2}$, away from each other +1

e) $\vec{T} = m\vec{g} + \vec{F_e} + \vec{F_g}$ ~ ~ along the string ~

f) $T\cos\theta = F_e - F_g$

$T\sin\theta = mg$



$T = \frac{mg}{\sin\theta}$

$\frac{mg}{\sin\theta}\cos\theta = F_e - F_g$

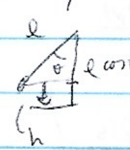
$\tan\theta = \frac{mg}{F_e - F_g}$ ~ $= \frac{mg}{\frac{kq^2 - Gm^2}{4r^2}}$

$\tan\theta = \frac{4mgr^2}{kq^2 - Gm^2}$ upside down

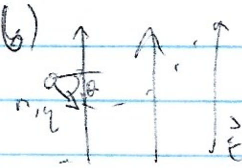
g) the other one would decrease θ b/c the repulsion forces are stronger than the attraction ones +1

h) the other one would increase θ b/c repulsion force is stronger +1

i) $PE_g = mgl(1-\cos\theta)$ +1 $\quad PE_G$ ~



$PE_e = qV = \frac{kq^2}{2r}$ +1

6) 

$V = \frac{kq}{r}$ $\quad PE = \frac{kqq}{r}$

$PE = qV$

$F = qE$

A) $v_x = v\cos\theta$ +1

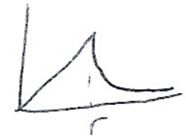
$v_y = v\sin\theta$ +1

B) $KE_0 = \frac{1}{2}mv^2$ +1

$PE_{e_0} = qV = qE \cdot d$ ~

16

18



6) c) $\Sigma F = ma$

$F_E - F_g = ma$

$qE - mg = ma$

$a = \frac{qE}{m} - g$ +1

d) $KE = \frac{1}{2} m (v \cos\theta)^2$

$= \frac{1}{2} m v^2 \cos^2\theta$ +1

$PE = qE \cdot d_{max}$ ~

e) $\Sigma F_y = mg - F_E = 0$ ~

$mg - qEh = 0$ ~

$h = \frac{mg}{qE}$ ~

f) $\Delta x = v\cos\theta t$

$\Delta y = v_0 t + \frac{1}{2} g t^2$

$v_f^2 = v_0^2 + 2a\Delta x$

$v_f = v_0 + at$ $\quad t_{down} = -\frac{v_0}{a}$ +1

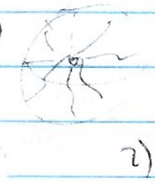
$= \frac{v\sin\theta}{\frac{qE}{m} - g} = \frac{mv\sin\theta}{(qE - mg)}$ +1

$\Delta x = \frac{v\cos\theta \cdot mv\sin\theta}{qE - mg}$ +1

$= \frac{mv^2 \sin\theta\cos\theta}{qE - mg}$ ~ +1

7) a) 1) ~~$E = 0$~~ b) ~~it constant~~ ~

~~2) $V = \frac{kq}{r} = \frac{kQ}{R}$~~

b) 1)  $E = \frac{kq}{r^2}$ +1

2) $V = \frac{kQ}{r}$ +1

b) $E_{outside} \propto \frac{1}{r^2}$ $\quad E_{inside}$ is 0 +1

$E_{a<r<b} \propto r$ ~

E_{a-r} ↗ ~

f) - f)

g) direction would change +1

h) constant would change to G $m_1 q$ would be m, not q +1

8) a) E_{inside} is 0 perfect

b) 1) $V = \frac{kQ}{R} + \frac{kq}{r_0}$ +1

2)

c) $E = 0$ inside the shell? ~

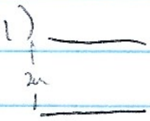
d)

9) A) $E_{inside} = 0$ +1

b) $\Delta V = 0$ since it's conducting +1

c) $\frac{Q_a}{Q_b} = \frac{r_a}{r_b}$ +1 ~ show steps

10) a) $V = \frac{kQ}{R}$ +1 $\quad$ b) $V = \frac{kQ}{R}$ +1

11) 

A) $\Delta V = E \cdot d$ $\quad$ DIRECTION

$E = \frac{\Delta V}{d} = \frac{2.0\,kV}{0.02\,m} = 1 \times 10^5\ N/C$ +1 +1

B) same as A

c) $V = \frac{2.0\,kV}{2} - 1.8\,kV = -0.8\,kV$ +1 +1

d) $d = \frac{\Delta V}{E} = \frac{0.2\,kV}{10^5\,N/C} = 2 \times 10^{-3}\,m$ ~

e) toward top plate +1 f) towards bottom +1

g) nowhere.

8

15

1) Gauss' law?

a) $g = \frac{-Gm}{r^2} = \frac{-(10^{-10} \frac{Nm^2}{kg^2})(n_p + n_n)(10^{-27} kg)}{(10^{-10} m)^2}$ ~

$= -10^{-17} \frac{m}{s^2} \hat{r}$ ~

c) $PE_g = \frac{-GMm}{r} = \frac{-(10^{-10} \frac{Nm^2}{kg^2})(n_p + n_n)(10^{-27} kg)(10^{-30} kg)}{(10^{-10} m)}$

$= -10^{-57} J \hat{r}$ ~

e) $V = \frac{kQ}{r} = \frac{(10^{10} \frac{Nm^2}{C^2})(e)(n_p)}{10^{-10} m}$

$= 10 n_p V$ ~ ~

3) d) 1) $a = \frac{-eE}{m_e}$ ~

2) $a = \frac{+E}{m_e}$ +1

e) 1) $\Delta KE = eV = eEd$ ×1

2) → +1

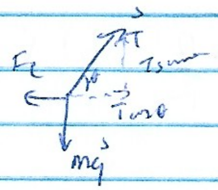
4) c) $PE = qV$

$= 4 \cdot q_0 \cdot \frac{kQ}{r}$

$= 4kq_0 Q$ ~ ~ ~

5k) $F_g >> F_E$

$\vec{T} = \vec{F_g} + \vec{F_E}$



$T\sin\theta = mg$

$T\cos\theta = \frac{kq^2}{4r^2}$ ~

$T = \frac{mg}{\sin\theta} = \frac{kq^2}{4r^2 \cos\theta}$

f) $\frac{mg}{\sin\theta} \cos\theta = F_E - F_g$

f) $\frac{mg}{\cos\theta} \sin\theta = F_E - F_g$

$\tan\theta = \frac{F_E - F_g}{mg} = \frac{\frac{(kq^2 - Gm^2)}{4r^2}}{mg}$ ±1

$= \frac{kq^2 - Gm^2}{4mgr^2}$ +1

i) $PE_G = \frac{-GMm}{2r} = \frac{-Gm^2}{2r}$ +1

7 b) when $a < R$

$E = \frac{kQ_{enclosed}}{r^2}$ $Q_{enc} = \frac{a}{R} Q$

$= \frac{kQa}{r^3}$ ~

when $a = r$ $Q_{enc} = Q$

$E = \frac{kQ}{r^2} = \frac{kQ}{a^2}$ +1

c) $Q_{enc} = Q \cdot \frac{r}{R}$

$E = \frac{kQ_{enc}}{R^2} = \frac{kQr}{R^3}$?

d) $E = \frac{k2\lambda}{r}$? (from textbook)

not found +1

e) f) (sorry, it's really getting too late lol)

i want to go to bed :(

h) A) towards (−) plate +1

1) a) $g = \frac{Gm}{r^2}(-\hat{r}) = (n_p + n_n) \cdot 10^{-7} \frac{m}{s^2} (-\hat{r})$ +2

c) $U_g = \frac{-Gm_e m_n}{r} = -(n_p + n_n) \cdot 10^{-57} J$ +2

e) $V = \frac{ken_p e}{r} = -n_p 10^{-w} J$ +2

3) d) 1) $a = \frac{+E}{m_e}$ +1

4) c) $U = \frac{kq_1q_2}{a} + \frac{kq_1q_3}{b} + \frac{kq_1q_4}{\sqrt{a^2+b^2}} + \frac{kq_2q_3}{\sqrt{a^2+b^2}}$

$+ \frac{kq_2q_4}{b} + \frac{kq_3q_4}{a}$ +3

3) e) $T = \sqrt{m^2g^2 + q^2E^2}$ or $\sqrt{m^2g^2 + (qE - \frac{6m^2}{4\pi r})^2}$ (+1)

7) b) $r > a$, $Q_{en} = Q$ $E = \frac{kQ}{r^2}$ (+1)

c) $r < a$ $Q_{en} = \rho \frac{4}{3}\pi r^3$ $\rho = \frac{Q}{\frac{4}{3}\pi a^3}$

$= Q\frac{r^3}{a^3}$

$4\pi k Q\frac{r^3}{a^3} = E 4\pi r^2$ $E = \frac{kQr}{a^3}$

$r > a$ $Q_{en} = Q$ $E = \frac{kQ}{r^2}$

$r = a$ $Q_{en} = Q$ $E = \frac{kQ}{a^2}$

$r < a$ $V = -\int_\infty^a k\frac{Q}{r^2}dr - \int_a^r k\frac{Q}{a^3}r\,dr$

$= k\frac{Q}{a} + \frac{kQr^2}{a^3} - k\frac{Q}{a}$

$= \frac{kQ}{a^3}r^2$

$r > a$ $V = \frac{kQ}{r}$ $r = a$ $V = \frac{kQ}{a}$ (+8)

d) $E = 2k\frac{\lambda}{r}$

$V = \int_a^r E\,dr = 2k\lambda \ln r + V_\infty$ +1

e) (i) $Q_{en} = 0$ $E = 0$ $r<a$

(ii) $E = 2k\frac{Q}{h_0 r}$

(iii) $E = 2k\frac{Q}{h_0 a}$

(i) $V = \frac{2kQ}{h_0}\ln r + V_\infty$

(ii) $V = 2k\frac{Q}{h_0}\ln r + V_\infty$

(iii) $V = 2k\frac{Q}{h_0}\ln a + V_\infty$ (+6)

f) $Q_{en} = \rho V = Q\frac{r^2}{a^2}$

$E = 2k\frac{Q}{a^2h}r$

(ii) $E = 2k\frac{Q}{h_0 r}$ (iii) $2k\frac{Q}{h_0 a}$

(i) $V = V_\infty + k\frac{Q}{a^2h}r^2$

(ii) $V = V_\infty + 2k\frac{Q}{h_0}\ln r$

(iii) $V = V_\infty + 2k\frac{Q}{h_0}\ln a$ (+7)

8) a) $E = 0$ and $Q_{en} = 0$

b) $V = -k\frac{Q}{R} + k\frac{q}{r_0}$

c) $Q_{en} = q$ $E = \frac{kq}{r^2}$ (+5)

d) $\Delta V = kq\left(\frac{1}{r_0} - \frac{1}{R}\right)$

9) c) $V_a = V_b$ $k\frac{Q_a}{a} = k\frac{Q_b}{b}$

$\frac{Q_a}{Q_b} = \frac{a}{b}$ (+1)

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1 For using Gauss' law anywhere in the question 1pt

21/ $4\pi GM = \vec{g}\cdot 4\pi r^2\,\hat{r}$, $4\pi kQ = \vec{E}\,4\pi r^2\,\hat{r}$

A 3/ $\vec{g}_N = G\dfrac{m_N}{r_A^2}(-\hat{r}) = (n_p+n_n)\times 10^{-7}\,\dfrac{m}{s^2}\,(-\hat{r})$

B 3/ $\vec{F}_G = m_e\,\vec{g}_N = (n_p+n_n)\times 10^{-47}\,N$ attractive toward the nucleus

C 2/ $U_G = -G\dfrac{m_e m_N}{r} = -(n_p+n_n)\times 10^{-57}\,J$

D 3 $\vec{E}_N = k\dfrac{Q}{r_A^2}\hat{r} = n_p\times 10^{11}\,\dfrac{N}{C}\,(\hat{r})$

E 2/ $U_E = -k\dfrac{n_p e\,e}{r} = -n_p\times 10^{-18}\,J$

F 2/ $V_E = k\dfrac{n_p e}{r} = n_p\,10\,V$

G 3/ $\vec{F}_E = e\vec{E}_N = n_p\,10^{-8}\,N$ attractive toward nucleus

H 4/ $\vec{F}_T = \vec{F}_E + \vec{F}_G = n_p\,10^{-8}\,N$ attractive toward nucleus

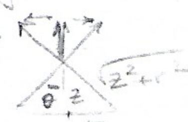
It is the electric force that is responsible.

I 4/ $\dfrac{mv^2}{r} = F_E$ $\quad v = n_p\,1.4\times 10^{6}\,\dfrac{m}{s}$

v is ⊥ to radius & tangent to circle

2 **A** 4/ Because of symmetry all E-fields cancel in pairs $\vec{E}_0 = 0$

2. All E_x & all E_y cancel in pairs, only E_z survives



$E_z = k\dfrac{Q}{r^2+z^2}\cos\theta$

$E_z = k\dfrac{Q\,z}{(z^2+r^2)^{3/2}}$ ↑ or $\hat{j}$

B 1 All the charge is at the same distance from the center $V = k\dfrac{Q}{r}$

2 All the charge is at the same distance from P $V = k\dfrac{Q}{\sqrt{z^2+r^2}}$

3 **A** From + to − b/c E field points from + to −

B $|\Delta V| = |-\vec{E}\cdot\vec{d}| = |-Ed| = Ed$

C (1) e^- toward + plate (3) n^0 stays there

(2) p^+ toward − plate

D 3/ $ma = qE$

(1) $a_e = \dfrac{eE}{m_e}$ (2) $a_p = \dfrac{eE}{m_p}$ (3) $a_n = 0$

E $\Delta KE = -\Delta PE = -qEd$

3/ (1) $\Delta KE_e = eEd$ (2) $\Delta KE = eEd$ (3) 0

4 **A** 4/ $\vec{E}_1 = \dfrac{kq_1}{a^2+b^2}(\hat{i}\cos\theta - \hat{j}\sin\theta) = \dfrac{kq_1}{(a^2+b^2)^{3/2}}(a\hat{i} - b\hat{j})$

$\vec{E}_2 = k\dfrac{q_2}{b^2}(-\hat{j})$, $\vec{E}_3 = k\dfrac{q_3}{a^2}(\hat{i})$

B 3/ $\vec{F}_1 = q_4\vec{E}_1 = k\dfrac{q_1 q_4}{(a^2+b^2)^{3/2}}(a\hat{i} - b\hat{j})$

$\vec{F}_2 = k\dfrac{q_2 q_4}{b^2}(-\hat{j})$, $\vec{F}_3 = k\dfrac{q_3 q_4}{a^2}(\hat{i})$

C 3/ $U = k\dfrac{q_1q_2}{a} + k\dfrac{q_1q_3}{b} + k\dfrac{q_1q_4}{\sqrt{a^2+b^2}} + k\dfrac{q_2q_3}{\sqrt{a^2+b^2}} + k\dfrac{q_2q_4}{b} + k\dfrac{q_3q_4}{a}$

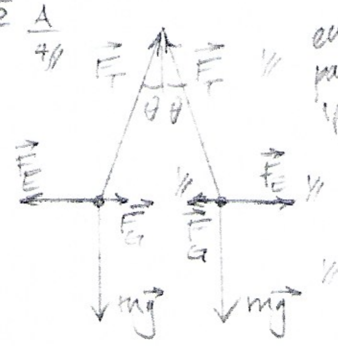
D 3/ $V = 4k\dfrac{q}{\sqrt{a^2+b^2}/2} = 8k\dfrac{q}{\sqrt{a^2+b^2}}$

E All fields cancel in pairs $\vec{E}_0 = 0$

F $U = q_0 V = \dfrac{8kq_0q}{\sqrt{a^2+b^2}}$

G $\vec{F} = q_0\vec{E}_0 = 0$

5 **A** 4/



each part 1pt

B $\vec{F}_g = mg\downarrow$

C $\vec{F}_G = G\dfrac{m^2}{4r^2}$ attraction

D $F_E = k\dfrac{q^2}{4r^2}$ repulsion

E 3/ $\vec{F}_g \gg \vec{F}_G \Rightarrow$

$\vec{F}_{Tot} = \vec{F}_g + \vec{E}$

$\vec{F}_{Tot} = \vec{F}_{Tx} + \vec{F}_{Ty} = mg(\hat{y}) + q\vec{E}(\hat{i})$

$F_T = \sqrt{m^2g^2 + q^2E^2}$

$F_T = \sqrt{m^2g^2 + \left(qE - G\dfrac{m^2}{4r^2}\right)}$ if gravitational attraction is included

F 2/ $\tan\theta = \dfrac{F_x}{F_y} = \dfrac{F_E - F_G}{mg} = \dfrac{(kq^2 - Gm^2)}{4r^2\cdot(mg)}$

G the other one follows b/c the repulsive
1/ E-force decreases

H the other moves away b/c the repulsive
1/ E-force increases

I $U_E = k\frac{q^2}{2r}$, $U_G = -G\frac{m^2}{2r}$, $U_g = mgl(1-\cos\theta)$
3/ 1/ 1/ 1/

6 A $\vec{v}_{0x} = v_0\cos\theta \rightarrow$ 1/
15/ 3/ $\vec{v}_{0y} = v_0\sin\theta \downarrow$ 1/

B $KE_0 = \frac{1}{2}mv_0^2$ 1/ $U_0 = 0$ by choice 1/
2/

C $ma = qE - mg$, $a = \frac{q}{m}E - g$
2/ 1/

D At the minimum h, $v_y = 0$
3/ $KE = \frac{1}{2}mv_x^2 = \frac{1}{2}mv_0^2\cos^2\theta$ 1/
$PE = qEh - mgh$ 1/

E $KE_0 + PE_0 = KE + PE$ 1/
3/ $\frac{1}{2}mv_0^2\sin^2\theta = (qE - mg)h$ 1/
$h = \frac{mv_0^2\sin^2\theta}{2(qE-mg)}$ 1/

F $t = t_{up} + t_{down} = 2t_{max\,h}$ 1/
4/ $v_{av}t_{mh} = \frac{v_{0y}}{2}t_{mh} = h$ 1/
$t_{mh} = \frac{2h}{v_0\sin\theta}$ 1/ $t = \frac{2mv_0\sin\theta}{qE-mg}$
$R = v_x t = \frac{2mv_0^2\sin\theta\cos\theta}{qE-mg}$ 1/

7 Using or stating Gauss' Law anywhere in the problem Const x Source = Field x Area
$4\pi k\, q_{enc} = \vec{E}\vec{A} = \oint \vec{E}\cdot d\vec{A}$ 1 pt//

Using $\Delta V = -\int \vec{E}\cdot d\vec{r}$ anywhere in the problem 1/

A $4\pi k\, q_{enc} = E\,4\pi r^2$
2/ $E = k\frac{Q}{r^2}$ 1/, $V = k\frac{Q}{r}$ 1/

B (i) $r<a$ $q_{enc} = 0$, $\vec{E} = 0$ 1/
6/ (ii) $r>a$ $q_{enc} = Q$, $E = k\frac{Q}{r^2}$ 1/
(iii) $r=a$ $q_{enc} = Q$, $E = k\frac{Q}{a^2}$ 1/
$V = -\int_\infty \vec{E}\cdot d\vec{r} = \frac{kQ}{r}$ (i) $V = kQ/a$ 1/
(ii) $V = k\frac{Q}{r}$, (iii) $V = kQ/a$ 1/

C (i) $r<a$ $q_{enc} = \rho\frac{4}{3}\pi r^3$, $\rho = \frac{Q}{\frac{4}{3}\pi a^3}$
8/ $= Q\frac{r^3}{a^3}$ 1/
$4\pi k\, Q\frac{r^3}{a^3} = E\,4\pi r^2$ $E = \frac{kQ}{a^3}r$ 1/
(ii) $r>a$ $q_{enc} = Q$ $E = k\frac{Q}{r^2}$
(iii) $r=a$ $q_{enc} = Q$ $E = kQ/a^2$ 1/
(i) $r<a$ $V = -\int_\infty^a k\frac{Q}{r^2}dr - \int_a^r k\frac{Q}{a^3}r\,dr$ 1/
$= k\frac{Q}{a} + k\frac{Qr^2}{a^3} - k\frac{Q}{a} = k\frac{Q}{a^3}r^2$ 1/
(ii) $r>a$ $V = k\frac{Q}{r}$ 1/
(iii) $r=a$ $V = kQ/a$ 1/

D $4\pi k\, q_{enc} = E\,2\pi r\,l$, $E = \frac{2kQ}{lr} = 2k\frac{\lambda}{r}$ 1/
2/ $V = -\int_\infty^r E\,dr = -2k\lambda\ln r + V_\infty$ 1/

E (i) $q_{enc} = 0$, $\vec{E} = 0$ $r<a$ 1/
6/ (ii) $4\pi k Q = E\,2\pi r h$ $E = 2k\frac{Q}{h_0 r}$ 1/
(iii) $E = 2k\frac{Q}{h_0 a}$ 1/
(i) $V = -\int_\infty^r E\,dr = -\int_\infty^a 2k\frac{Q}{h_0 r} + \int_a^r 0\,dr = -\frac{2kQ}{h_0}\ln r + V_\infty$ 1/
(ii) $V = -\int_\infty^r E\,dr = -2k\frac{Q}{h_0}\ln r + V_\infty$ 1/
(iii) $V = -\int_\infty^a E\,dr = -2k\frac{Q}{h_0}\ln a + V_\infty$ 1/

F (i) $q_{enc} = \rho V = \frac{Q}{\pi a^2 h_0}\pi r^2 h_0 = Q\frac{r^2}{a^2}$ 1/
7/ $4\pi k\, q_{enc} = E\,2\pi r h$ $E = 2k\frac{Q}{a^2 h}r$ 1/
(ii) $E = 2k\frac{Q}{h_0 r}$ 1/ (iii) $2k\frac{Q}{h_0 a}$ 1/

(i) $V = -\int_{\infty}^{a} E_{out}\,dr - \int_{a}^{r} E_{in}\,dr$

$= V_\infty + \frac{kQ}{a^2 h} r^2$ ½

(ii) $V = -\int_{\infty}^{r} E_{out}\,dr = V_\infty + 2k\frac{Q}{h_0}\ln r$ ½

(iii) $V = -\int_{\infty}^{a} E_{out}\,dr = V_a + 2k\frac{Q}{h_0}\ln a$ ½

G the directions of E would reverse
½ the magnitude of V would -ve.

H Everything remains the same
½ w/ $k \to G$, $q \to -m$

8 A Conductor $E_{in} = 0$ & $Q_{enc} = 0$ ½
5/ B $V = k\frac{q}{r_0} + k\frac{Q}{R}$ superposition ½
for both parts (see below B)

C $Q_{enc} = q$ $E = k\frac{q}{r}$ ½

D $\Delta V = -\int_{R}^{r_0} k\frac{q}{r^2}dr = k\frac{q}{r}\Big|_{R}^{r_0}$ ½

$= kq\left(\frac{1}{r_0} - \frac{1}{R}\right)$ ½

B $V_{r_0} = -\int_{\infty}^{R} k\frac{(q+Q)}{r^2}dr - \int_{R}^{r_0} k\frac{q}{r^2}dr$

$= +k\frac{(q+Q)}{R} + k\frac{q}{r_0} - k\frac{q}{R}$

$= k\frac{Q}{R} + k\frac{q}{r_0}$

9 A $E_{in} = 0$ Conductor ½
4/ B $\Delta V = 0$ ½
C $V_a = V_b$ $k\frac{Q_1}{a} = k\frac{Q_2}{b}$ ½

$\frac{Q_2}{Q_1} = \frac{b}{a}$ ½

10. A $V = k\frac{Q}{R}$ since all the points on the rod are at the same distance from the origin ½

B $V = k\frac{Q}{R}$ the same reason as in A. ½

11. A $E\uparrow$ from + to − plate ½
B $E = \left|-\frac{\Delta V}{\Delta d}\right| = \frac{0.2-(-1.8)}{0.02}\frac{kV}{m} = 10^5\frac{V}{m}$ ½+½
C. $\Delta V = -E\Delta d = 10^5\frac{V}{m} \times 10^{-2}m = 10^3\ V$ ½
$V = 0.2 - 1\ kV = -0.8\ kV$ ½

D $0 = 0.2\times10^3 - 10^5\Delta d \Rightarrow \Delta d = 0.02cm$ ½+½

E. Up towards the − plate ½

F. Down towards + plate ½

G. Stays where it is