Ch 8, 17

1. An object is sliding down an inclined surface of length d (the angle of incline is θ). The coefficients of static and kinetic friction are μ_s and μ_k respectively between the object and the surface.
   A. Draw a free body diagram representing the situation. Label all forces. Do not include any extreneous force or force components.
   B. In terms of the distance d down the incline, g, θ, and μ_s, obtain the work done by (i) static and kinetic friction, (ii) normal force, (iii) gravity, (iv) net force. (v) Is the sum of the work in (i) – (iii) equal to (iv). Why or why not?

2. A block of mass has an initial velocity of v_o as it leaves a spring at the spring's equilibrium position on an inclined plane at θ. The spring constant of the spring is k. Assume that the coefficient of kinetic friction between the block and the plane is zero (μ_k=0)
   A. Use the conservation of energy and the work done by gravity to obtain how far above ***along the incline*** the block will come to a stop.
   B. How much time will it take for the block to come to a stop?
   C. Obtain the average power in this time interval.
   D. On the way down, how far will the spring be compressed before the block comes to a full stop due to the spring?
   E. Draw a free body diagram and label all the forces acting on the block as the block comes to a full stop.
   Now assume that the coefficient of kinetic friction between the block and the plane is μ.
   F. Use the conservation of energy and the net work done to obtain how far above the incline the block will come to a stop.
   G. On the way down how far will the spring be compressed before the block comes to a full stop due to the spring and friction?

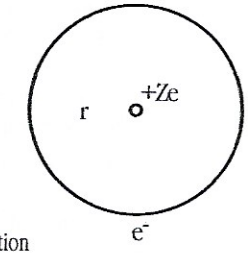
3. The force due to a spring acting on an object is given by $\vec{F}_r = ax^3\vec{i}$ where x is the expansion of the spring and $\vec{i}$ is the direction along the expansion of the spring.
   A. Obtain the work done on the object due to this force as the object moves a displacement $\vec{d}$ at an angle θ with respect to $\vec{i}$.
   B. What are the units of a?
   C. Consider the force $\vec{F}_r = (-\alpha x^3\vec{i} + \beta y^3\vec{j})$ where α and β are constants.. Obtain the work done on the object due to this force as the object moves a displacement $\vec{d}$ at an angle θ with respect to $\vec{i}$.

4. A mass m is in an orbit of radius r around a planet of mass M and radius R.
   A. Draw a free body diagram showing all the forces acting on the mass.
   B. Obtain the fish's kinetic energy in terms of the given quantities and universal constants. Remember this is a circular motion.
   C. Obtain its potential energy in terms of the given quantities and universal constants
   D. Obtain its total energy in terms of the given quantities and universal constants.

5. An footbal is kicked off a cliff of height h with initial velocity of magnitude v_i at an angle θ with respect to the horizontal. The gravitational acceleration on the surface of the planet is $\vec{g}$ In terms of the given quantities, using the conservation of energy, obtain (A)the x and y components of the initial velocity, (B)the velocity at the maximum height, the maximum height, (C)the impact velocity when the antelope hits the ground.

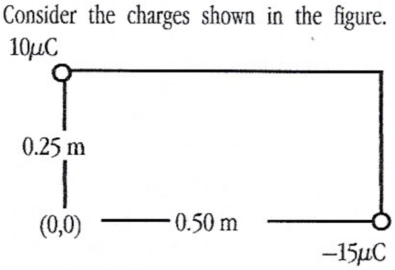
6.
   A. Obtain the work done on an object of mass m due to gravity as the object moves from a point $\vec{r}_1$ to a point $\vec{r}_2$ in terms of m, g, $\vec{r}_1$, $\vec{r}_2$, and the angles with respect to the vertical. Assume that the object is constrained to move in the 2 dimensional vertical plane, and take it to be the x-y plane.
   B. What is the power produced if the object moves in t seconds from $\vec{r}_1$ to $\vec{r}_2$?

7. Consider an atom with a single electron in a circular orbit of radius r about a nuclear charge of +Ze, where Z is the atomic number (the number of protons in the nucleus). Such single-electron atoms are known as hydrogenic atoms.



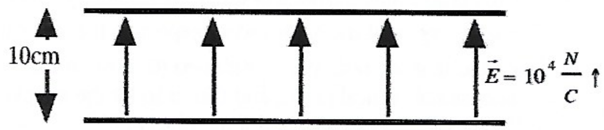
   A. What is the electric potential V produced by the nucleus at the position of the electron?
   B. What is the electric potential energy of the electron at this location?
   C. What is the electrical force on the electron due to the nucleus? (Give magnitude and direction.)
   D. Draw a free body diagram showing all the actual forces acting on the electron and the nucleus–no matter how small they are.
   E. What is the velocity of the electron in this circular orbit? Hint: Use the Newton's second law and the dynamics & kinematics of circular motion.
   F. What is the kinetic energy of the electron?
   G. Use your answer to B and F to show that $KE = -\frac{1}{2}PE$.

8. Consider the charges shown in the figure.



   A. Obtain the total electric potential V_o at the origin (0,0).
   B. Obtain the total electric potential V_∞ at an infinite distance away from the origin.
   C.
      1. What is the electric potential energy of a proton placed at the origin?
      2. What is the electric potential energy of an electron placed at the origin?
      3. What is the electric potential energy of a neutron placed at the origin?
   D. How much work is done by electrical forces if the proton in part C is moved from the origin to infinity under the effect of these electrical forces? How does your answer change if this is an electron or a neutron?
   E. Does your answer in part D depend on the path taken by the proton? Why or why not?
   F. Will the proton placed at the origin go to ∞ on its own or will we have to move it there? Why?

9. Consider the electrically charged plates shown in the figure with $\vec{E}=10^4 \frac{N}{C}\uparrow$ in the region between them.



A. 1. What is the charge distribution on the upper surface?
   2. Is this a positive or negative charge distribution with respect to the lower plate? Why?

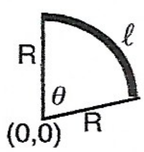
B. What is the electric potential of the upper plate if the lower plate is grounded?

C. A small particle of mass $1\times10^{-5}kg$, placed in the vacuum between the plates, has a charge q and is in equilibrium under the influence of gravitational and electrical forces.
   What is the charge q? Use $g=10\frac{m}{s^2}$.

10. An insulated rod of length ℓ is bent into a circular arc of radius R that subtends an angle θ as shown in the figure. The rod has a charge Q distributed uniformly along its length.

A. 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. An insulated rod of length ℓ is bent into a circle of radius R and placed on the <u>y-z plane</u> where x-axis is its symmetry axis. The rod has a charge Q distributed uniformly along its length. Take the center of the loop to be at (0,0,0).

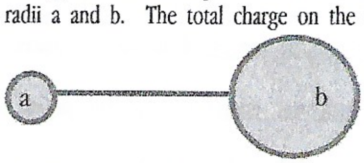
A. 1. Obtain the electric <u>potential</u> at the origin.
   2. Obtain the electric <u>field</u> at the origin. Does this agree with your answer in part i?

B. 1. Obtain the electric <u>potential</u> at a distance x from the origin (perpendicular to the plane of the rod).
   2. Use your answer in (b.i) to obtain all three components of the electric field at that distance x from the origin

C. 1. Obtain the electric field at a distance x from the origin directly. (All three components)
   2. Use your answer in (c.i) to obtain the electric potential at that distance x from the origin.

D. Do your answers in parts (b) and (c) agree? Why or why not?

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

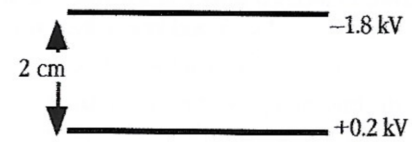


A. What is the electric field inside the wire?

B. What is the difference in electric <u>potential</u> 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.

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



A. What is the direction of the electric <u>field</u> between the plates?

B. What is the magnitude of the electric <u>field</u> between the plates?

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

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

E. Draw the <u>equipotential</u> lines for -0.8 kV and 0V between the plates.

F. If it is placed at the 0 V-location in what direction does (i) a proton, (ii) an electron, (iii) a neutron go. Neglect gravity. (iv) If they move what will be their KE when they get to the plate that they are moving toward?

14. Three equal charges of magnitude Q are fixed initially at the corners of an equilateral triangle with sides ℓ.

A. One charge is released from its position at rest and is allowed to escape to an infinite distance away. What is the final KE of this charge in terms of physical constants and the quantities given?

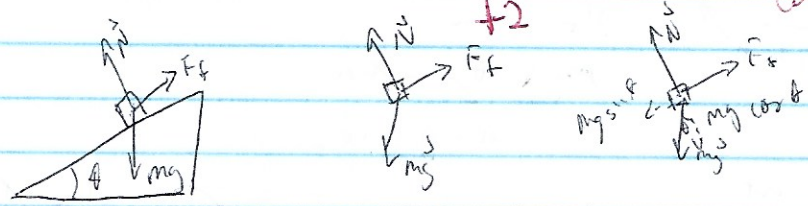
B. The second charge now is released from its position. What is the final KE of this charge after it has escaped to an infinite distance?

C. The third charge is now released. What does it do?
   Hint: Start solving the problem by calculating the electric potential energy of a given particle under the given conditions.

Black 18
Blue 56] 74
Red 14
Total 88

Ch. 8, 17

1) a)



+2

b)(i) $W = \int \vec F \cdot d\vec r = \mu_s N d\cos\phi$, $\phi = 180$

Static friction → $d = 0$; $\boxed{W = 0\,J}$ +1

$W_{kinetic} = \mu_k N d\cos\phi$; $\phi = 180$

$= \mu_k mg\cos\theta\, d\cos\phi$; $\cos\phi = -1$

$= \boxed{-\mu_k d mg\cos\theta}$ +1 +1

(ii) $W = \vec F \cdot \vec d = F_N d\cos\phi$; $\phi = 90^\circ$ ∴ $\cos\phi = 0$

$= \boxed{0\,J}$ +1

(iii) $W = F \cdot d = mg\sin\theta_{\parallel} d_{\parallel}\cos\phi$; $\phi = 0$ ∴ $\cos\phi = 1$

$= \boxed{mgd\sin\theta}$ +1

(iv) $\sum F_{\parallel} = mg\sin\theta_{\swarrow} + \mu_k mg\cos\theta_{\nearrow}$

$W_{net} = \sum F \cdot d$

$= mg\sin\theta_{\swarrow} d_{\swarrow}\cos\phi + \mu_k mg\cos\theta_{\nearrow} d_{\swarrow}\cos\delta$, $\phi = 0$, $\delta = 180$

$= (mg\sin\theta - \mu_k mg\cos\theta)d$

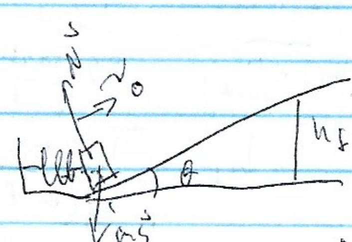
$= \boxed{mgd(\sin\theta - \mu_k\cos\theta)}$ +1

(V) Sum of (i), (ii), (iii) $= 0 + (-\mu_k d mg\cos\theta) + 0 + mgd\sin\theta$

$= mgd(\sin\theta - \mu_k\cos\theta)$ which is =.

This makes sense because W_{net} should be the sum of all the work done on the system. +1

2)



A) $KE_0 + \cancel{PE_{g_0}}^{0} = \cancel{KE_f}^{0} + PE_{g_f} + \cancel{W_{nc}}^{0}$

$\frac{1}{2}\cancel{m} v_0^2 = \cancel{m} g h_f$

$h_f = \frac{v_0^2}{2g}$

$\sin\theta = \frac{h_f}{\Delta x}$

$\Delta x = \frac{h_f}{\sin\theta} = \boxed{\frac{v_0^2}{2g\sin\theta}}$

9

$\left[\frac{m^2}{s^2}\right]\left[\frac{s^2}{m}\right]$ $\left[\frac{m}{s^2}\right]$ $\left[\frac{m}{s}\right]$

b) $\Delta x = \frac{v_0^2}{2g\sin\theta} \nearrow$ $\qquad \Sigma F = ma$

$\cancel{m} g\sin\theta \swarrow = \cancel{m}a$

$a = g\sin\theta \swarrow$

$\cancel{v_f}^{0} = v_0 + at$

$\cancel{t = \frac{v_0}{a} = \frac{\frac{v_0^2}{2g\sin\theta}}{-g\sin\theta} = \frac{v_0^2}{2g^2\sin^2\theta}}$ $\cancel{\left[\frac{m^2}{s^2}\right]\left[\frac{s^4}{m^2}\right]}$

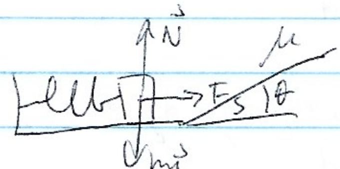
$\cancel{v_f}^{0} = v_0 + at \qquad t = \frac{-v_0}{a} = \frac{-v_0}{-g\sin\theta} = \boxed{\frac{v_0}{g\sin\theta}}$

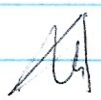
c) $P = \frac{W_{net}}{t} = \frac{-\Delta PE}{t} = -mg\frac{v_0^2}{2g}/t = \boxed{\frac{-m v_0^2}{2t}}$

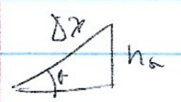
d) $v_f = -v_0 \qquad KE_0 + \cancel{PE_{s_0}}^{0} = \cancel{KE_f}^{0} + PE_{s_f}$

$\cancel{\tfrac{1}{2}} m v_0^2 = \cancel{\tfrac{1}{2}} kx^2$

$x^2 = \frac{m v_0^2}{k} \qquad \boxed{x = v_0\sqrt{\frac{m}{k}}}$

e) 





$\sin\theta = \frac{h_f}{\Delta x}$

$\Delta x = \frac{h_f}{\sin\theta}$

F) $KE_0 + \cancel{PE_{g_0}}^{0} = \cancel{KE_f}^{0} + PE_{g_f} + W_{nc}$

$\frac{1}{2}\cancel{m} v_0^2 = mgh_f + \mu \cancel{m} g\cos\theta\,\Delta x$

$\frac{1}{2}v_0^2 = gh_f + \mu g\cos\theta\frac{h_f}{\sin\theta}$

$gh_f\left(1 + \frac{\mu}{\tan\theta}\right) = \frac{1}{2}v_0^2$

$\cancel{gh_f\left(\frac{\tan\theta + \mu}{\tan\theta}\right) = \frac{1}{2}v_0^2}$

$h_f = \frac{v_0^2}{2g\left(1 + \frac{\mu}{\tan\theta}\right)} = \frac{v_0^2}{\frac{2g(\tan\theta + \mu)}{\tan\theta}}$

$h_f = \boxed{\frac{v_0^2\tan\theta}{2g(\tan\theta + \mu)}}$

$\Delta x = \frac{h_f}{\sin\theta} = \boxed{\frac{v_0^2\cos\theta}{2g(\tan\theta + \mu)}}$

0

g) $PE_{g_0} + \cancel{KE_0}^{0} + \cancel{PE_{s_0}}^{0} = \cancel{PE_{g_f}}^{0} + PE_{s_f} + \cancel{KE_f}^{0} + W_{nc}$

$mgh_f = \frac{1}{2}kx^2 + \mu mg\cos\theta\,\Delta x$

$\frac{m\cancel{g}v_0^2\tan\theta}{2\cancel{g}(\tan\theta+\mu)} = \frac{1}{2}kx^2 + \frac{\mu m\cancel{g}\cos\theta\, v_0^2\cos\theta}{2\cancel{g}(\tan\theta+\mu)}$

$\cancel{\frac{1}{2}}kx^2 = \frac{mv_0^2\tan\theta - \mu m v_0^2\cos^2\theta}{\cancel{2}(\tan\theta+\mu)}$

$kx^2 = \frac{mv_0^2(\tan\theta - \mu\cos^2\theta)}{\tan\theta+\mu}$

$x = \sqrt{\frac{mv_0^2(\tan\theta-\mu\cos^2\theta)}{k(\tan\theta+\mu)}} = \boxed{v_0\sqrt{\frac{m(\tan\theta-\mu\cos^2\theta)}{k(\tan\theta+\mu)}}}$

3) $\vec{F}_r = a x^3\,\hat{\imath}$ $\quad r = \vec{d}$

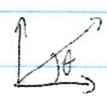
A) $W = \int \vec{F}_r \cdot d\vec{d} = \int \vec{F}_r\, dd\cos\theta = \cos\theta\, a x^3 \int d\vec{d}$

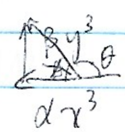
$W = ax^3 d\cos\theta$ ~

B) $\left[kg\frac{m^2}{s^2}\right] = [a][m^3][m]$ ~

$\boxed{[a] = \frac{kg}{m^2 s^2}}$

c)





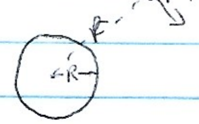
$F_{total} = \sqrt{\alpha^2 x^6 + \beta^2 y^6}$ ~ ~ ~

@ θ

$W = \vec{F}\vec{d}\cos\theta$

$= \boxed{\sqrt{\alpha^2x^6+\beta^2y^6}\ \vec{d}\cos\theta}$

4) A)



+1

b) $KE = \frac{1}{2}mv_t^2$

$\boxed{KE = \frac{GMm}{2r}}$ +1

$F_g = \frac{mv^2}{r}$ +1

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

$= \frac{r\,GMm}{r^2 m}$ +1

$= \frac{GM}{r}$

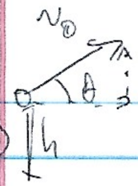
c) $PE_g = mgh = m\frac{GM}{r^2}r$

$= \boxed{\frac{GMm}{r}}$ ~ sign

d) $E_{total} = KE + PE_g$

$= \boxed{\frac{3GMm}{2r}}$ ~

5

5) 

a) $v_{0x} = v_0 \cos\theta$, $v_{0y} = v_0 \sin\theta$ +1

b) $PE_{g_0} + KE_{x_0} + KE_{y_0} = PE_{g_f} + KE_{x_f} + KE_{y_f}$

$\cancel{m}gh + \frac{1}{2}\cancel{m}v_0^2\cos^2\theta + \frac{1}{2}\cancel{m}v_0^2\sin^2\theta = \cancel{m}g(h+\Delta h) + \frac{1}{2}\cancel{m}\cancel{v_{top}^2}$ ~~$+\frac{1}{2}mv_{top}^2$~~

$v_{top}^2 = gh + \frac{1}{2}v_0^2(\sin^2\theta + \cos^2\theta) - g(h+\Delta h)$

$= gh + \frac{1}{2}v_0^2 - \cancel{gh} - g\Delta h$ $\qquad v_{top} = v_{0x} = \boxed{v_0\cos\theta}$ +1

~~$v_{top} = \sqrt{\frac{1}{2}v_0^2 - g\Delta h}$~~

$v_0^2\cos^2\theta = \cancel{gh} + \frac{1}{2}v_0^2 - g(\cancel{h}+\Delta h)$

$v_0^2\cos^2\theta = \frac{1}{2}v_0^2 - g\Delta h$

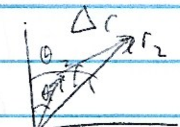
$g\Delta h = \frac{1}{2}v_0^2 - v_0^2\cos^2\theta = v_0^2\left(\frac{1}{2} - \cos^2\theta\right)$

$h_f = h + \Delta h = \boxed{h + \frac{v_0^2}{g}\left(\frac{1}{2} - \cos^2\theta\right)}$ ~ ~

c) $PE_{g_0} + KE_0 = \cancel{PE_{g_f}}^{\,0} + KE_f$

$\cancel{m}gh + \frac{1}{2}\cancel{m}v_0^2 = \frac{1}{2}\cancel{m}v_f^2$

$v_f^2 = 2gh + v_0^2$ $\qquad \boxed{v_f = \sqrt{v_0^2 + 2gh}}$

6) a) 

$W_g = -\Delta PE_g$ +1

$= PE_0 - PE_f$

$PE_{g_0} = r_1\cos\theta_1 mg \qquad PE_{g_f} = r_2\cos\theta_2 mg$

$W_g = \boxed{mg(r_1\cos\theta_1 - r_2\cos\theta_2)}$ ~

b) $P = \frac{W}{t} = \frac{mg(r_1\cos\theta - r_2\cos\theta_2)}{t}$ ~

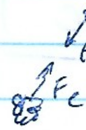
+1

4

7) a) $V_{nucleus} = \frac{kQ}{r} = \boxed{\frac{kZe}{r}}$ +1

b) $PE_{electron} = qV = \frac{kZe \cdot -e}{r} = \boxed{\frac{-kZe^2}{r}}$ +1

c) $F_E = \frac{kq_1q_2}{r^2} = \boxed{\frac{kZe^2}{r^2}, \text{ towards the nucleus}}$ +1

d)  +1 ~

e) $\frac{kZe^2}{r^2} = \frac{mv^2}{r}$ +1 +1

$v^2 = \frac{kZe^2}{rm}$ $\boxed{v = e\sqrt{\frac{kZ}{rm}}}$ +1

f) $KE = \frac{1}{2}mv^2$ +1

$= \boxed{\frac{kZe^2}{2r}}$ +1

g) $PE = -\left(\frac{kZe^2}{r}\right)$ +1

$KE = \frac{1}{2}\left(\frac{kZe^2}{r}\right)$ $\therefore KE = -\frac{1}{2}PE$

8) A) $V_0 = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} = \frac{k(10\mu C)}{0.25m} + \frac{k(-15\mu C)}{0.50m} = \boxed{100 \text{ kV}}$ +1

b) $V_\infty = \lim_{r\to\infty} \frac{kq_2}{r} = \boxed{0V}$ +1

c) 1) $PE_e = \frac{kQq}{r} = qV = (100 \text{ kV})(1.6\times10^{-19} \text{ C}) = \boxed{1.6\times10^{-14} \text{ J}}$

$= \boxed{100 \text{ keV}}$ ~

2) $PE_e = \frac{kQq}{r} = qV = \boxed{100 \text{ keV}}$ ~

3) $PE_e = 0$ +1

D) $W = -\Delta PE = \boxed{-100 \text{ keV}}$ ~, change sign for electron ~ & $W = 0$ for neutron +1

E) doesn't matter because electric force is conservative +1

F) it needs to be moved, since the two charges have opposite signs, so the electric field points towards the negative charge, so the proton will be attracted towards the negative charge. ~

15

9) a) evenly distributed ~

a) Negative w/ respect to the lower plate b/c the field lines point towards it. +1

b) $\Delta U = -E\Delta d = -(10^4 \frac{N}{C})(10\,cm) = \boxed{-1{,}000\,V}$ +1

c) $mg = qE$ +1

F_e

mg

$q = \frac{mg}{E} = \frac{(1\times10^{-5}\,kg)(10\,\frac{m}{s^2})}{(10^4\,\frac{N}{C})} = \boxed{10^{-8}\,C}$ +1

$(= 10\,nC)$

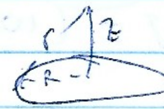
10) a)

$V = k\int \frac{dQ}{R}$

$l = R\theta$

$dl = R\,d\theta$

10) b)



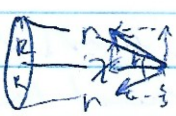
$V = \frac{kQ}{r} = \frac{kQ}{\sqrt{R^2+z^2}}$

$z = 0;\ \boxed{V = \frac{kQ}{R}}$ +1

11) a) 1) $\boxed{V = \frac{kQ}{R}}$ from +1

2) $E_0 = 0$, since all the charge is evenly around the origin, and the vectors cancel out. +1

This agrees since V is scalar and $\vec{E}$ is vector.



b) 1) $V = \frac{kQ}{r} = \boxed{\frac{kQ}{\sqrt{x^2+R^2}}}$ +1

2) horizontal components cancel out b/c of symmetry

$E = \frac{kQ}{r^2}\ ;\ E_x = E\cos\theta = \frac{kQ}{r^2}\cdot\frac{x}{r} = \boxed{\frac{kQx}{(x^2+R^2)^{3/2}}}$

8

11) b) 2) $V = \frac{kQ}{r} = \frac{kQ}{\sqrt{x^2+R^2}}$

$V = -\int \vec{E} \cdot d\vec{r}$

$dV = -\vec{E} \cdot dr$

$E = -\frac{dV}{dr}$ $\quad V = \frac{kQ}{r}$ $\quad \frac{dV}{dr} = -\frac{kQ}{r^2}$

$= kQ(r^{-1})$

$E = -\left(-\frac{kQ}{r^2}\right) = \frac{kQ}{r^2} = \boxed{\frac{kQ}{x^2+R^2}}$

$E_x = E\cos\theta = \frac{kQ}{r^2} \cdot \frac{x}{r} = \boxed{\frac{kQx}{(x^2+R^2)^{3/2}} \hat{i}}$ +1

$E_{y,z} = E\sin\theta$, cancels out b/c symmetry

$E_y, E_z = \boxed{0 \,\hat{j}, \hat{k}}$ +1 +1

c) horiz. cancels out b/c symmetry

$E = E\cos\theta = \frac{kQ}{r^2} \cdot \frac{x}{r} = \boxed{\frac{kQx}{(x^2+R^2)^{3/2}}}$

2) $V = -\int E \cdot dr = -\int \frac{kQx}{r^{3/2}} dr$

$= -kQx \int \frac{dr}{r^{3/2}} = -kQx \int r^{-3/2} dr$

$= \frac{kQx}{2} r^{-1/2} + C, \quad C=0$

$= \boxed{\frac{kQx}{2\sqrt{x^2+R^2}}}$

d) derivation of $\vec{E}$ agrees but not for V.

Can go scalar → vector but not vector → scalar?

12) A) E inside wire = 0 +1

b) $\Delta V = 0$, since everything is conducting +1

c) $V_a = \frac{kq_a}{r_a}$ $\quad V_b = \frac{kq_b}{r_b}$ $\quad \frac{kq_a}{r_a} = \frac{kq_b}{r_b}$ +1

$V_a = V_b$ +1 $\quad \frac{q_a}{r_a} = \frac{q_b}{r_b}$ +1 $\quad \boxed{\frac{q_a}{q_b} = \frac{r_a}{r_b}}$ 8

13)

A) direction - towards the negative plate +1

b) $\Delta U = -\int E \cdot dr$

$dV = E \cdot dr$

$E = -\frac{dU}{dr}$ $\qquad E = -\frac{\Delta V}{r} = -\frac{(-2.0\ kV)}{2\ cm}$ +1

$= \boxed{1.0 \times 10^{5}\ N/C}$ +1

$\Delta U = -Er$ +1

$V_f - V_0 = -Er$

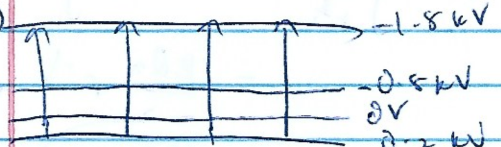
$V_f = -Er + V_0 = -(1.0\times10^{5} N/C)(1\ cm) + 0.2\ kV$

$= \boxed{-1.2\ kV}$ ~

d) $\cancel{V_f} - V_0 = -Er$ +1

$r = \frac{-V_0}{-E} = \frac{-0.2\ kV}{-1.0\times10^{5} N/C} = 0.002\ m = \boxed{0.2\ cm}$ +1

e)



+3

f)(i) proton goes to the -1.8 kV plate, +1

$KE_f = PE_0 = qV = \boxed{1.8\ keV}$ +1

(ii) electron goes to (+) plate,

$KE_f = PE_0 = qV = \boxed{0.2\ keV}$ +1

(iii) neutron doesn't move. +1

14) a) $KE_f = PE_0 = qV$

$= Q\left(\frac{kQ}{l} + \frac{kQ}{l}\right) = \boxed{\frac{2kQ^2}{l}}$ ~

b) $KE_f = PE_0 = qV = Q\left(\frac{kQ}{l}\right) = \boxed{\frac{kQ^2}{l}}$ ~

c) it doesn't do anything since the other charges are infinitely far away. +1

14

3) A) $W = \int F \cdot d\cancel{x} = \int a x^3 \cdot dx = \frac{a}{4} x^4$ ~

b) $[N \cdot m] = [m^4][a]$

$[a] = \left[\frac{N}{m^3}\right]$ +1

c) $W = \int F \cdot dr$

$= \int (-a x^3 + \beta y^3)\, dx, dy$

$= -\frac{1}{4} a x^4 + \frac{1}{4} \beta x^4$ ~ ~ ~

4) c) $PE_g = mgh$

$= m\left(\frac{-GM}{r^2}\right) r$

$= \boxed{\frac{-GMm}{r}}$ +1

d) $E_{total} = PE_g + KE$

$= \frac{GMm}{2r} - \frac{GMm}{r}$

$= \boxed{-\frac{GMm}{2r}}$ ~

5) b) Set top of cliff as $h = 0$

$\frac{1}{2} m v_{0x}^2 + \frac{1}{2} m v_{0y}^2 + \cancel{mgh_0} = mgh_f + \frac{1}{2} m v_{0x}^2 + \cancel{\frac{1}{2} m v_{0y}^2}$ +1

$\frac{1}{2} m v_0^2 \cos^2\theta + \frac{1}{2} m v_0^2 \sin^2\theta = mgh_f + \cancel{\frac{1}{2} m v_0^2 \cos^2\theta}$ ← $v_{top} = v_0 \cos\theta$ +1

$\cancel{m} g h_f = \frac{1}{2} \cancel{m} v_0^2 \sin^2\theta$ +1

$\boxed{h = \frac{v_0^2 \sin^2\theta}{2g}}$ +1

6) a) $W = -\Delta PE_g = PE_0 - PE_f$

$= mgh_1 - mgh_2$

$= mgr_1\cos\theta_1 - mgr_2\cos\theta_2$

$= mg(r_1\cos\theta_1 - r_2\cos\theta_2)$ ~

b) $P = \frac{W}{t} = \frac{mg}{t}(r_1\cos\theta_1 - r_2\cos\theta_2)$ ~

8) c) $PE_e = qV = 10^5\,V \cdot (1.6\times10^{-19}\,C) = 10^5\,eV = 100\,keV$.

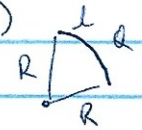
~ ~ ~ ~

f) Proton will go there on its own since it has more PE at the origin. +1

7

9) a) 1) negative charge ~

10) a)



$V \rightarrow$ scalar

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

13) c) $\Delta V = E \Delta r$

$= (1.0 \times 10^5 \frac{N}{C})(0.01\,m) = 1000\,V$

$= 1.0\,kV$

$E_0 + \Delta V = E_f = \boxed{-0.5\,kV}$ +1

14) a)

$KE_f = PE_0 = QV$

$= Q\left(\frac{kQ}{l} + \frac{kQ}{l}\right)$

$= \boxed{\frac{2kQ^2}{l}}$ ~

b) $KE_f = PE_0$

$= QV = \boxed{\frac{kQ^2}{l}}$ ~

2

3) a) $\int F_r \cdot dr = \int_0^{d\cos\theta} a x^3 dx = \frac{1}{4} a x^4 \Big|_0^{d\cos\theta} = \frac{1}{4} a d^4 \cos^4\theta$ +1

c) $\int F_r \cdot dr = \int (-\alpha x^3 \hat{i} + \beta y^3 \hat{j}) \cdot (dx\hat{i} + dy\hat{j})$ +1

$= \int (-\alpha x^3 dx + \beta y^3 dy) = \int_0^{d\cos\theta} -\alpha x^3 dx + \int_0^{d\sin\theta} \beta y^3 dy$ +1

$= -\frac{\alpha}{4}(d\cos\theta)^4 + \frac{\beta}{4}(d\sin\theta)^4$ +1

4) d) $E_{total} = -\frac{GMm}{r}$ +1

6) a) $W_g = \int_{r_1}^{r_2} mg \cdot dr = mg \int_{r_1}^{r_2} mg(r_2 - r_1)\cos\theta$ +1

b) $P_v = \frac{\Delta W_g}{\Delta t} = mg \frac{(r_2 - r_1)}{\Delta t} \cos\theta = mg\bar{v}\cos\theta$ +1

7

8) c) $PE_+ = eV_0 = 10^{-11}$ J $\quad PE_- = -eV_0 = -10^{-11}$ J +2

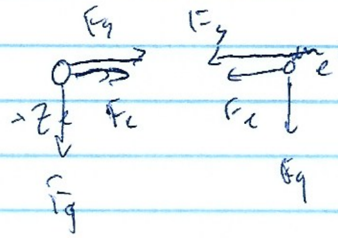
d) $W_+ = -\Delta PE_+ = 10^{-11}$ J $\quad W_- = -10^{-11}$ J +2

9) a) i) $E = \sigma \varepsilon_0 = 10^4\ N/C \quad \sigma = \frac{1}{\varepsilon_0} 10^4\ N/C$ +1

14) a) $KE_f = \frac{2Q}{l}$ $\quad$ b) $KE_{f-} = \frac{Q}{l}$ +2

7

7) d)

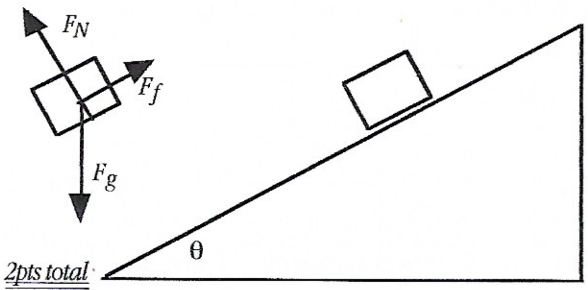


+2

2

90 w/o #2, 106 w/#2

1.



A. 2pts total

1/2 pts for each vector, 1/2 extra if all forces present without any extrenous forces.

$F_g = mg$, $F_N = mg\cos\theta$, $F_f = \mu_k mg\cos\theta$,

$F_{net} = mg(\sin\theta - \mu_k\cos\theta)$

B. (i) $W_{sf} = 0$ static friction does no work since static friction is not present during the displacement. 1pt

$W_{kf} = \vec{F}_{kf} \bullet \vec{d} = -\mu_k mgd\cos\theta$ 1pt

("–" b/c it is against the direction of motion.) 1pt

(ii) $W_N = \vec{F}_N \bullet \vec{d} = F_N d\cos 90° = 0$ 1pt

(iii) $W_g = \vec{F}_g \bullet \vec{d} = mgd\cos(90° - \theta) = mgd\sin\theta$ 1pt

(iv) $W_{net} = \vec{F}_{net} \bullet \vec{d} = mgd(\sin\theta - \mu_k\cos\theta)$ 1pt

(v) Yes, the sum of the work in (i–iii) is equal to (iv). This is because, the net work is a result of the net force. 1pt

/9

2.

A. $W = m\vec{g}\cdot(\vec{r}_2 - \vec{r}_1) = mgr\cos\theta = 10\cdot 10\cdot r\cdot\cos 127° = -60r\ J$ 1pt

$E_{K1} = \frac{1}{2}mv_1^2 = \frac{1}{2}10\cdot 400 = 2000J$ 1pt

$E_{K2} = \frac{1}{2}mv_2^2 = \frac{1}{2}10\cdot 0 = 0$ 1pt

$W = E_{K2} - E_{K1} = -2000J$ 1pt

$-60r = -2000,\ r = \frac{100}{3}m$ 1pt

B. $\vec{v}_2 = \vec{v}_1 + \vec{a}t$, $0 = 20 + 10\cos 127° t$ 1pt, $t = \frac{10}{3}s$ 1pt

C. $P_{av} = \frac{W}{t} = \frac{-2000}{10/3} = -600W$ 1pt

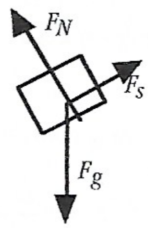
D. $\Delta W = \int_o^r -krdr = \int_{\frac{100}{3}m}^{r} mg\cos 37° dr$, 1pt

$-k\frac{r^2}{2}\Big|_0^r = mg\cos 37° r\Big|_{\frac{100}{3}m}^{r}$

$-500\frac{r^2}{2} = 10\cdot 10\cdot 0.6\,(r - \frac{100}{3})$ 1pt

$250r^2 + 60r - 200 = 0$, $r = -2.95m$ not $2.71m$ 1pt

/11



E. *1/2 pts for each vector, 1/2 extra if all forces present without any extrenous forces.*

F. $\frac{1}{2}mv_2^2 = mgd\sin 37° + \mu_k mgd\cos 37°$ v, $d = 26m$ 1pt

G. Use $mg(d+x)\sin 37° = \frac{1}{2}kx^2 + \mu_k mg(d+x)\cos 37°$ or or

$\frac{1}{2}kx^2 = \frac{1}{2}mv_2^2 - \mu_k mg(2d+x)\cos 37°$ 1pt for either.

$250x^2 + 16x - 1161 = 0$ 1pt $x = -2.19m$, not $x = 2.12m$

If you neglected the fact that the block would stop below the spring's equilibrium positon, you would find $x = -2.77m$. If you assumed that the block would reach as high as the previous height, you would find $x = -2.95m$.

/5

3.

A. $\int \vec{F}_r.d\vec{r} = \int_0^{d\cos\theta} ax^3 dx = \frac{1}{4}ax^4\Big]_0^{d\cos\theta} = \frac{1}{4}ad^4\cos^4\theta$ - 1pt

B. Since W is N.m, ad^4 must be N.m. Therefore, a is $\frac{N}{m^3}$ 1pt

C. $\int \vec{F}_r.d\vec{r} = \int(-\alpha x^3\vec{i} + \beta y^3\vec{j})\bullet(dx\,\vec{i} + dy\vec{j})$ 1pt

$= \int(-\alpha x^3 dx + \beta y^3 dy) = \int_0^{d\cos\theta} -\alpha x^3 dx + \int_0^{d\sin\theta} \beta y^3 dy$ 1pt

$= -\frac{\alpha}{4}(d\cos\theta)^4 + \frac{\beta}{4}(d\sin\theta)^4$ 1pt

/5

4.

A. $\bullet \rightarrow \vec{F}_G$ towards the planet. 1pt

B. $\vec{F}_G = m\vec{a}_c$ 1pt, $G\frac{Mm}{r^2} = m\frac{v^2}{r}$ 1pt, $G\frac{Mm}{r} = mv^2$ 1pt

$E_K = \frac{1}{2}mv^2 = G\frac{Mm}{2r}$ 1pt

C. $E_P = -G\frac{Mm}{r}$ 1pt

D. $E_T = E_K + E_P = G\frac{Mm}{2r} + (-G\frac{Mm}{r}) = -G\frac{Mm}{r}$ 1pt

What does the – sign signify?

5.

A. $v_{ix} = v_i\cos\theta$, $v_{iy} = v_i\sin\theta$ 1pt

B. CoE $\frac{1}{2}mv_i^2 + 0 = \frac{1}{2}mv_h^2 + mgh$ 1pt

C. At the max h, $v_{hy} = 0$, $v_{hx} = v_{ix} = v_i\cos\theta$ 1pt

D. $\frac{1}{2}mv_i^2\sin^2\theta = mgh$ 1pt, $h = \frac{v_i^2}{2g}\sin^2\theta$ 1pt

/12

6.

A. $W_g = \int_{\vec{r}_1}^{\vec{r}_2} m\vec{g} \cdot d\vec{r} = m\vec{g} \cdot \int_{\vec{r}_1}^{\vec{r}_2} d\vec{r} = mg(r_2 - r_1)\cos\theta$ 1pt+1pt

B. $P_v = \frac{\Delta W_g}{\Delta t} = mg\frac{(r_2 - r_1)}{\Delta t}\cos\theta = mgv_{av}\cos\theta$ 1pt+1pt

7. A. $V = k\frac{Ze}{r}$ 1pt B. $E_P = k\frac{Ze^2}{r}$ 1pt C. $\vec{F}_E = k\frac{Ze^2}{r^2}$© 1pt

D. $F_E \xrightarrow{F_G} \xleftarrow{F_G} F_E$ 1/2 for each correctly labeled force. 3pts

$\downarrow F_g \qquad F_g \downarrow$

/10

E.. $F_E = ma_c$ 1pt, $k\frac{Ze^2}{r^2} = m\frac{v^2}{r}$ 1pt, $v = \sqrt{\frac{kZe^2}{mr}}$ 1pt

F. $mv^2 = k\frac{Ze^2}{r}$ 1pt, $E_K = k\frac{Ze^2}{2r}$ 1pt G. $E_P = -k\frac{Ze^2}{r} = -2E_K$ 1pt

8. A. $V_o = 10^{10}\frac{10\times10^{-6}}{0.25} - 10^{10}\frac{15\times10^{-6}}{0.5} = 10^5 V$ 1pt B. $V_\infty = 0$ 1pt /18

C. 1. $U_p = eV_o = 10^{-11} J$ 2. $U_e = -eV_o = -10^{-11} J$ 3. $U_n = 0$ 3pts

D. 1. $W_p = -\Delta U = 10^{-11} J$ 2. $W_e = -10^{-11} J$ 3. $W_n = 0$ 3pts

E. No, because Electricity is a conservative force. 1pt

F. Since its potential energy is more positive at the origin than at ∞ and since W is positive, it will go there on its own. 1pt

9. A. 1. $E = \sigma\varepsilon_o = 10^4\frac{N}{C}$, $\sigma = \frac{1}{\varepsilon_o}10^4\frac{N}{C}$ 1pt

2. (–) since electric field is directed from + to – charges. 1pt /10

B. $E = \frac{\Delta V}{\Delta d}$, $\Delta V = E\Delta d = 10^3 V$ 1pt

C. $mg = qE$ 1pt, $q = \frac{mg}{E} = 10^{-8} C$ 1pt

10. A. $V = k\frac{Q}{R}$ 1pt B. $V = k\frac{Q}{R}$ 1pt

11. A. 1. $V_o = k\frac{Q}{R}$ 1pt 2. $\vec{E}_o = -\nabla V_o = 0$ 1pt

B. 1. $V = \frac{kQ}{\sqrt{x^2 + R^2}}$ 1pt 2. $E_y = -\frac{\partial V}{\partial y} = 0$ 1pt, $E_z = -\frac{\partial V}{\partial z} = 0$ 1pt

$E_x = -\frac{\partial V}{\partial x} = \frac{kQx}{(x^2 + R^2)^{3/2}}$ 1pt

/11

C. and D. We'll do this in a month or so.

12.

A. 0 since this is a conductor. 1pt

B. 0 since this is a conductor; therefore, the voltage must be the same throughout. c 1 pt?

C. Since this is conductor $V_a = V_b$ 1pt; as a result, $\frac{Q_a}{a} = \frac{Q_b}{b}$ 1pt

Therefor, $\frac{Q_b}{Q_a} = \frac{b}{a}$ 1pt

13.

A. + to – 1pt

B. $E = \frac{-\Delta V}{\Delta d}$ 1pt, $\vec{E} = 10^5\frac{V}{m}\uparrow$ 1pt

/7 H

C. $V - V_o = -\vec{E}\cdot\Delta\vec{d}$ 1pt, $V - V_o = -\vec{E}\cdot\Delta\vec{d} = -0.8\ kV$ 1pt

D. $0 = V_o - \vec{E}\cdot\Delta\vec{d}$ 1pt, $d = 0.2\ cm$ 1pt,

/4

E. ______________________

______________________ 1pt per line (3 pts total)

/3

F. (i) p^+ moves towards the (–) plate, up. 1pt

(ii) e^- moves towards the (+) plate, down. 1pt

(iii) n^o stays where it is put since it is neutral and does not experience any electric force. 1pt

(iv) $KE_f = 0 - \Delta PE$. Keep in mind $PE = qV$ 1pt

$p^+: KE_f = 1.8\ keV$ 1pt

$e^-: KE_f = 0.2\ keV$ 1pt

$n^o: KE_f = 0$ 1pt

14. $KE_f = 0 - \Delta PE$

A. $KE_f = \frac{2Q}{\ell}$ 1pt, B. $KE_f = \frac{Q}{\ell}$ 1pt, C. Just stays there. 1pt

/10