Scroll down for Solutions

PHY 2049 Exam 1 NAME____________________

SELECT THE SINGLE BEST RESPONSE FROM THE RESPONSES LISTED. YOU MAY WRITE IN THIS EXAM BOOK. BOTH THE EXAM BOOK AND THE SCAN CARD MUST BE TURNED IN WHEN YOU ARE FINISHED. FAILURE TO DO SO WILL RESULT IN A SCORE OF ZERO FOR THIS EXAM. SIGNIFICANT FIGURES HAVE NOT BEEN CONSIDERED IN THE CALCUALTION OF ANSWERS. CARRY ALL CALCULATIONS TO SIX DIGITS, THEN SELECT THE BEST RESPONSE. DRAW PICTURES TO HELP YOU VISUALIZE THE PROBLEMS.

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1. From the energy that is taken into an engine in each cycle, 500 kJ of work is done and 600 kJ of heat is exhausted into the environment. What is the efficiency of the engine?

(a) 45.5% **(b)** 28.6% **(c)** 90.0% **(d)** 75.0% **(e)** 83.3%

2. A Carnot refrigerator has a COP = 2.5 . It consumes 50 W of power. How much heat is removed from the interior of the refrigerator in 1 hour?

(a) 7.5 kJ **(b)** 4.5×10^5 J **(c)** 1.8×10^5 J **(d)** 7.2×10^5 J **(e)** 72 kJ

3. Your apartment air conditioner has stopped working. Your roommate says "You're the engineering major. Do something!" Fortunately, your electricity is still working. You go to the kitchen and open the refrigerator door. Having done that, the temperature in your kitchen __________.

(a) ultimately decreases as the refrigerator removes heat from the kitchen.
(b) does not change, since the heat taken from the inside of the refrigerator is discharged into the kitchen.
(c) ultimately increases as the heat from the inside of the refrigerator and the energy the refrigerator was pulling from the electrical outlet are discharged as heat into the kitchen.

4. A negatively charged rod is brought near one end of an uncharged metal bar. The end of the metal bar nearest the charged rod will now _______.

(a) have a positive charge.
(b) have a negative charge.
(c) have no net charge.

5. Consider a square in the (x,y) plane which has sides of length 1.0 m. Charges are placed at the corners of the square as follows: +4.0 μC at (0,0), +4.0 μC at (1,1), +3.0 μC at (1,0), -3.0 μC at (0,1). What is the magnitude of the electric field at the square's center?

(a) 1.1×10^5 N/C **(b)** 1.3×10^5 N/C **(c)** 1.5×10^5 N/C **(d)** 1.7×10^5 N/C **(e)** 1.9×10^5 N/C

6. A charge Q_1 is located at coordinates (x = +a, y = +a). A second charge Q_2, which is identical to Q_1, is located in such a way that the net electric field at the origin (x= 0, y = 0) is zero. What are the coordinates of Q_2?

(a) x = -a, y = +a (b) x = +a, y = +a (c) x = 0, y = 0 (d) x = -a, y = -a (e) x = +a, y = -a

7. A metal sphere of radius 2.0 cm carries a charge of 3.0 μC. What is the electric field 6.0 cm from the center of the sphere?

(a) 3.4×10^6 N/C **(b)** 4.2×10^6 N/C **(c)** 5.7×10^6 N/C **(d)** 7.5×10^6 N/C **(e)** 9.3×10^6 N/C

8. An advantage in evaluating surface integrals related to Gauss's Law for symmetric charge distributions is ________.

(a) the flux is outward
(b) the flux is inward
(c) the vector electric field has a constant magnitude over certain surfaces
(d) the charge is always on the surface
(e) the vector electric field is constant over certain surfaces

Magnitude $\boxed{\text{AND}}$ direction

9. Imagine a spherical Gaussian surface of radius R that is centered at the origin. A charge Q is to be placed inside that surface. Where should the charge be located to maximize that magnitude of the electric flux through the imaginary sphere?

(a) at the maximum derived from setting the equation for surface area equal to zero.
(b) at the origin
(c) as close to the surface as possible, while still remaining inside the sphere
(d) outside the sphere
(e) anywhere inside the sphere

10. Consider an electric field **E** = $2x\,\hat{\imath} - 3y\,\hat{\jmath}$. All units are SI. What is the magnitude of the electric flux through a square whose corners are located at the (x,y,z) coordinates (0,2,0), (2,2,0), (0,2,2), (2,2,2)?
HINT: Draw this coordinate system & square so you can visualize the question.

(a) 6 Nm^2/C **(b)** 0 Nm^2/C **(c)** 24 Nm^2/C **(d)** 12 Nm^2/C **(e)** 48 Nm^2/C

11. A line of charge with a uniform charge density +λ lies along the y-axis, extending from y = -2 to y = +5. Consider an observation point that lies on the x-axis at x = -5. Which of the following is the correct expression for dE_y ?

(a) $- k\cdot\lambda\cdot y\cdot dy/(y^2+25)^{3/2}$ **(b)** $k\cdot\lambda\cdot y\cdot dy/(y^2+25)^{3/2}$ **(c)** $5\cdot k\cdot\lambda\cdot dy/(y^2+25)^{3/2}$ **(d)** $k\cdot\lambda\cdot dy/r^2$ **(e)** 0

12. A line of charge with a uniform charge density +λ lies along the y-axis, extending from y = -2 to y = +5. Consider an observation point that lies on the x-axis at x = -5. Which of the following is the correct expression for dE_x ?

(a) $- k\cdot\lambda\cdot y\cdot dy/(y^2+25)^{3/2}$ **(b)** $k\cdot\lambda\cdot y\cdot dy/(y^2+25)^{3/2}$ **(c)** $- 5\cdot k\cdot\lambda\cdot dy/(y^2+25)^{3/2}$

(d) $k\cdot\lambda\cdot dy/r^2$ **(e)** $5\cdot k\cdot\lambda\cdot dy/(y^2+25)^{3/2}$

13. How much heat must be removed from 456 g of water at 25.0 °C to change it into ice at -10 °C? The specific heat of ice is 2090 J/(kg K), the latent heat of fusion for water is 33.5×10^4 J/kg, and the specific heat of water is 4190 J/(kg K).

(a) 105 kJ **(b)** 153 kJ **(c)** 57.3 kJ **(d)** 47.7 kJ **(e)** 210 kJ

14. A region of space contains a non-uniform, time varying electric field **E**(x,y,z,t) = $2xt^2\,\hat{\imath} - 7z\,\hat{\jmath} + 4\,\mathbf{k}$, in SI units. In addition, a point charge of + 2.00 nC is located at the origin. When t = 3.0 seconds, what is the magnitude of the net electric field at the point x = 1 m, y = 0 m, z = 1 m?

(a) 19.6 N/C **(b)** 15 N/C **(c)** 26.1 N/C **(d)** 24.7 N/C **(e)** 0 N/C

15. A region of space contains an electric field **E** = $12\,\hat{\imath}$. A person holding a +10.0 C charge carries that charge from the origin to the point x=3, y = 4? What is the magnitude of the work done on the charge by the electric force as a result of this displacement? All units are SI.

(a) 840 J **(b)** 0 J **(c)** 480 J **(d)** 600 J **(e)** 360 J

16. In the previous question, has the electric potential energy of the charge has ________________.

(a) Increased **(b)** decreased **(c)** not changed

17. A negative charge is being moved by an electric field. That charge is _________.

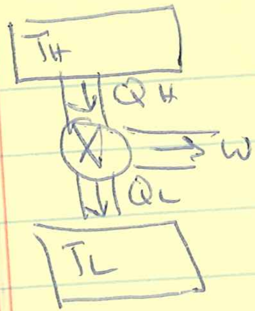
$\vec{F} = (-q)\vec{E}$

(a) moving in the direction of the field and loosing electric potential energy
(b) moving in the direction of the field and gaining electric potential energy
(c) moving opposite to the direction of the field and loosing electric potential energy
(d) moving opposite the direction of the field and gaining electric potential energy
(e) details about the field must be known in order to answer this question.

18. A positive charge is being moved by an electric field. That charge is _________.

(a) moving in the direction of the field and loosing electric potential energy
(b) moving in the direction of the field and gaining electric potential energy
(c) moving opposite to the direction of the field and loosing electric potential energy
(d) moving opposite the direction of the field and gaining electric potential energy
(e) details about the field must be known in order to answer this question.

1)



1^{st} $Q_H = W + Q_L$

$$\varepsilon = \frac{\text{get}}{\text{pay}} = \frac{W}{Q_H}$$

Given: $W = 500 \times 10^3 \, J$
$Q_L = 600 \times 10^3 \, J$

$$Q_H = W + Q_L = 1100 \times 10^3 \, J$$

$$\varepsilon = \frac{W}{Q_H} = \frac{500 \times 10^3}{1100 \times 10^3} = 0.455$$

45.5%

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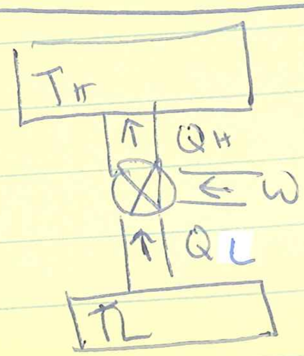
2)



1^{st} $Q_L + W = Q_H$

$$C.O.P. = \frac{\text{get}}{\text{pay}} = \frac{Q_L}{W} = 2.5$$ given

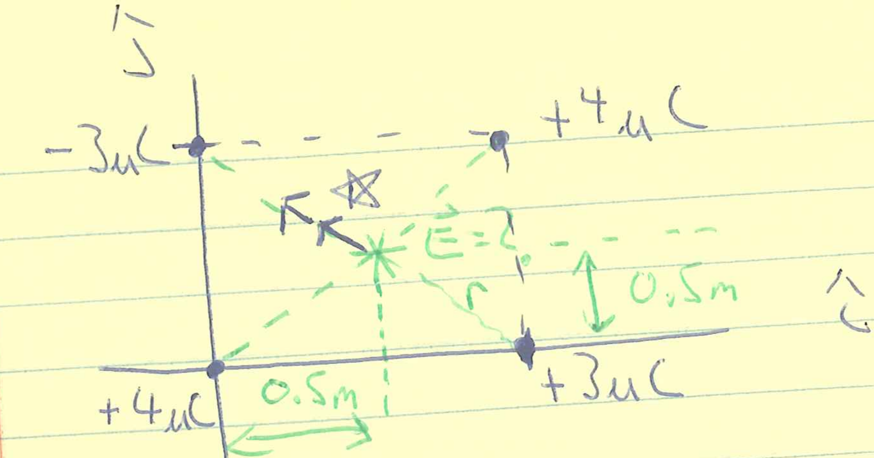
$50 W = 50 \, J/s$ ∴ In 1 hour, $W = 50 \frac{J}{s} \times 3600 s$

$$W = 180 \times 10^3 \, J$$

So we have: $C.O.P. = 2.5 = \dfrac{Q_L}{180 \times 10^3}$

$$Q_L = 450 \times 10^3 \, J$$

5.)



From symmetry, the electric field @ the center from the two $+4\mu C$ charges will cancel.

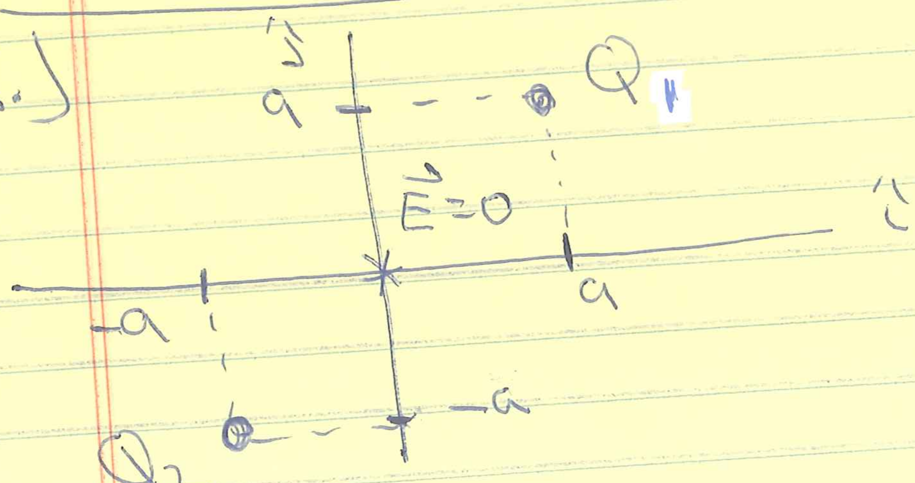
$r = \sqrt{0.5^2 + 0.5^2} = \sqrt{0.5}$

for either $3\mu C$ charge, $|\vec{E}_{center}| = \frac{k|q|}{r^2} = 53940\ N/C$

Both fields will point in same direction!

$\therefore\ |\vec{E}_{center\ TOTAL}| = 107880\ N/C = \underline{1.1 \times 10^5\ N/C}$

6.)

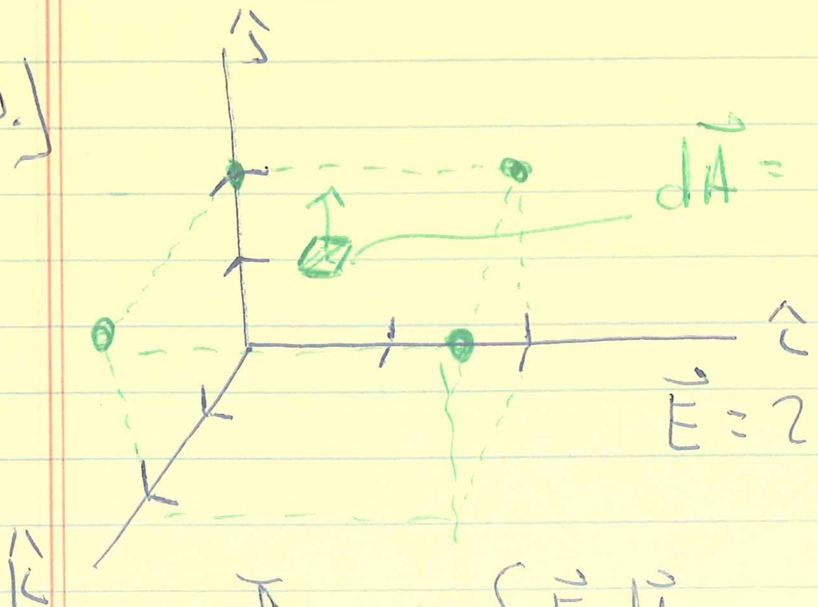


If $Q_1 = Q_2$ as stated, must have symmetric placement of Q_2.

7.) $r = 0.06\ m$ and is <u>outside</u> of the sphere.

$$\therefore |\vec{E}| = \frac{kq}{r^2} = \frac{8.99 \times 10^{9}(3 \times 10^{-6})}{(0.06)^2} = 7.5 \times 10^{6}\ N/C$$

10.)



$$d\vec{A} = dz\,dx\,\hat{j}$$

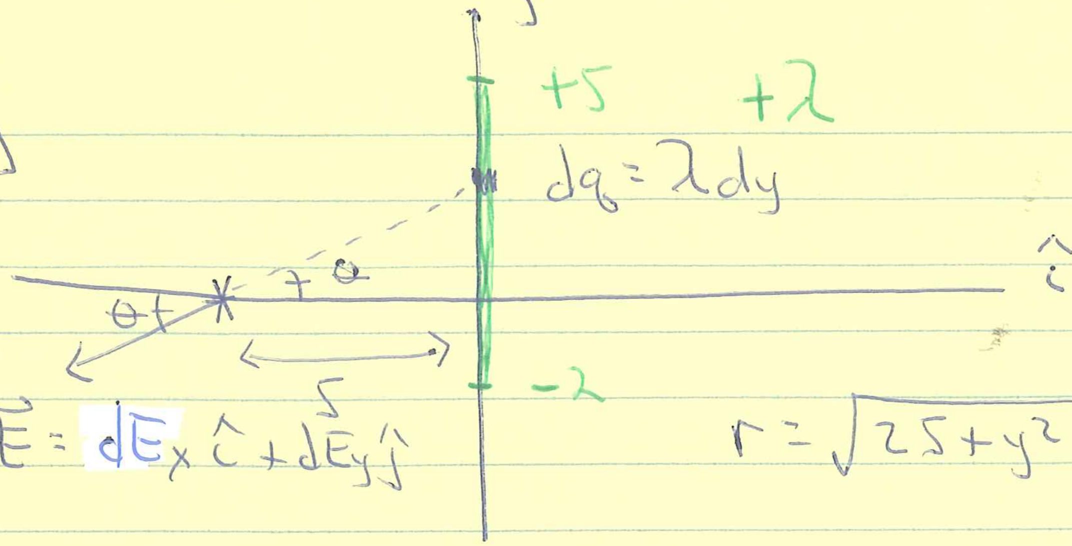
$$\vec{E} = 2x\,\hat{i} - 3y\,\hat{j}$$

$$\Phi_{\text{square}} = \int_{\text{square}} \vec{E} \cdot d\vec{A} = -\int_{\text{square}} 3y\,dz\,dx$$

$$= -3\underset{\substack{\uparrow \\ 2}}{y} \int_0^2 dz \int_0^2 dx = -3(2)(2)(2) = -24\ \frac{Nm^2}{C}$$

"Magnitude" is $24\ \frac{Nm^2}{C}$

11 + 12)



$$d\vec{E} = dE_x \hat{i} + dE_y \hat{j}$$

$$r = \sqrt{25 + y^2}$$

$$dE_y = -|d\vec{E}| \sin(\theta) = -\frac{k\lambda dy}{(25+y^2)} \left(\frac{y}{(25+y^2)^{1/2}} \right)$$

$$dE_y = -\frac{k\lambda y\, dy}{(25+y^2)^{3/2}}$$

REALLY? ☑

Answer #11

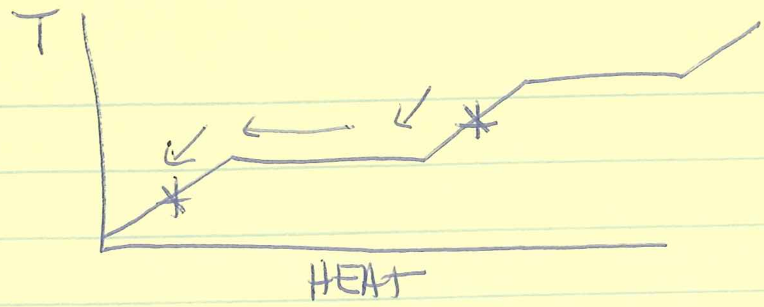
$$dE_x = -|d\vec{E}| \cos\theta = -\frac{k\lambda dy}{(25+y^2)} \left(\frac{5}{(25+y^2)^{1/2}} \right)$$

$$= -\frac{5k\lambda\, dy}{(25+y^2)^{3/2}}$$

REALLY? ☑

Answer #12

13.)



$$Q_{removed} = mC_{water}(0-25) - mL_{f_{water}} + mC_{ice}(-10-0)$$

$$= -47766\,J - 152760\,J - 9530.4$$

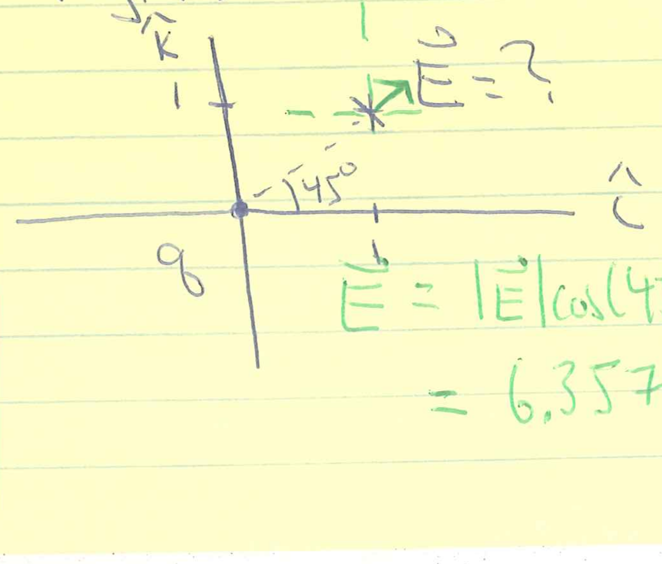
$$= -210056.4 \text{ joules}$$

$\boxed{\approx 210 \text{ kJ must be removed}}$

14.) At $t=3s$, the non-uniform time varying field @ the point $(1,0,1)$ is given by:

$$\vec{E}(1,0,1,t=3) = 18\hat{i} - 7\hat{j} + 4\hat{k}$$

We need to find the electric field @ this point due to a charge of $+2nC$ @ the origin:



$r = \sqrt{2}$ $\quad |\vec{E}| = \dfrac{kq}{r^2}$

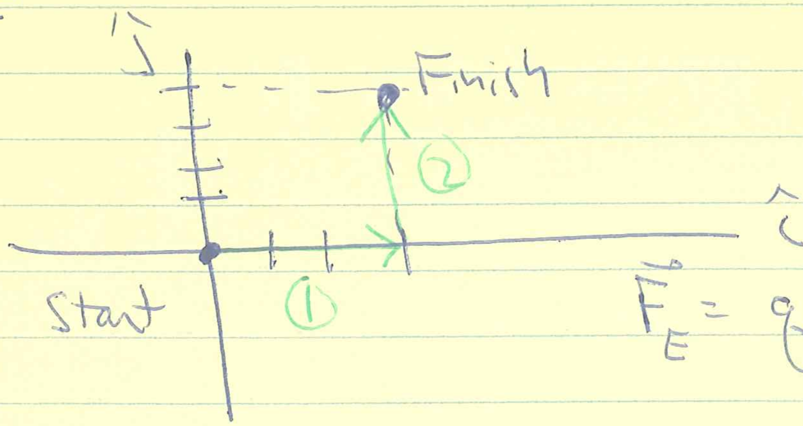
$$\vec{E} = |\vec{E}|\cos(45)\hat{i} + |\vec{E}|\sin(45)\hat{k}$$

$$= 6.357\hat{i} + 6.357\hat{j}$$

So $\vec{E}_{\substack{TOTAL \\ @(1,0,1)}} = \vec{E}_{nonuniform} + \vec{E}_{\substack{pt \\ charge}} = 24.357\,\hat{i} - 0.643\,\hat{j} + 4\,\hat{k}$

$|\vec{E}_{\substack{TOTAL \\ @(1,0,1)}}| = \underline{\underline{24.692 \text{ N/C}}}$ ☆

15)



$q = +10\text{ C}$

$\vec{E} = 12\,\hat{i}$

$\vec{F}_E = q\vec{E} = 120\,\hat{i}$

$W_{①} = \int_{①} \vec{F}_E \cdot d\vec{s} = \int_{①} (120\,\hat{i})\cdot(dx\,\hat{i}) = 120\int_0^3 dx$

$= \underline{\underline{360 \text{ J}}}$

$W_{②} = \int_{②} \vec{F}_E \cdot d\vec{s} = \int_{②} (120\,\hat{i})\cdot(dy\,\hat{j}) \to 0$

$\therefore W_{\substack{Start \to \\ Finish}} = \underline{\underline{+360 \text{ J}}}$ Ans.

16.) Easiest way to see this is to recall that <u>nature</u> (meaning $\vec{F}_{electric}$) moves things "downhill" (to lower P.E.).

This motion is <u>in the direction of</u> $\vec{F}_{electric}$

$\Rightarrow$ "downhill" $\Rightarrow$ <u>lost $PE_{electric}$</u>.

<u>DECREASED</u>

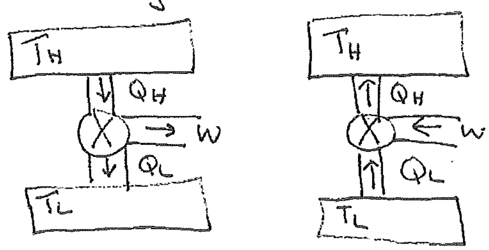
NAME ______________________

Please do not open until instructed to do so.

Make sure you have filled out your SCAN CARD as instructed.

$$Q = mc\Delta T$$
$$Q = mL$$

Heat Engine



$$\text{efficiency} = \frac{\text{get}}{\text{pay}}$$

$$\varepsilon_{\text{Carnot Heat Engine}} = 1 - \frac{T_L}{T_H}$$

$$|\vec{F}| = \frac{k|q_1||q_2|}{r^2} \qquad K = 8.99 * 10^9 \frac{Nm^2}{C^2} \quad \left(\text{Note: } K = \frac{1}{4\pi\varepsilon_0}\right)$$

$$|\vec{E}_{\text{pt. charge}}| = \frac{K|q|}{r^2}$$

$$\vec{F} = q\vec{E}$$

$$\Phi = \int \vec{E} \cdot d\vec{A}$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\varepsilon_0} \qquad \varepsilon_0 = 8.85 * 10^{-12} \frac{C^2}{Nm^2}$$

$$\text{Work} = \int \vec{F} \cdot d\vec{S}$$