PHYS 1320 (Spring 2024) Sonnenfeld Online HW #5: Electric Potential

Problem 1: Two points, point 1 and point 2, are located inside a region with an electric field pointing to the left, as shown in the figure.
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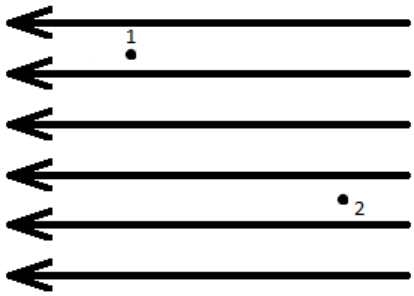

Part (a) If a proton is moved from point 1 to point 2, how will the potential energy of the charge-field system change? How will the potential change?
MultipleChoice :

1) Increases / Increases
2) Increases / Decreases
3) Decreases / Decreases
4) Decreases / Increases

Part (b) If, instead, an electron is moved from point 1 to point 2, how will the potential energy of the charge-field system change? How will the potential change?
MultipleChoice :

1) Decreases / Increases
2) Increases / Decreases
3) Decreases / Decreases
4) Increases / Increases

Problem 2: There are multiple ways to write correct units for the electric field strength.
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Select all options which are correct units for electric field strength.
MultipleSelect :

1) V/m
2) N/C
3) V
4) eV
5) J·s

6) C
7) C·V
8) J/(C·m)
9) kg·m/(C·s^2)

Problem 3: A charge *q* is accelerated from rest up to a speed *v* through a potential difference *V*.
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What speed will the charge have after accelerating through a potential difference equal to 4*V*?
MultipleChoice :

1) 4*v*
2) 2*v*
3) *v*
4) *v*/4
5) *v*/2

Problem 4: A pair of parallel conducting plates have a potential difference of ***3.7***$\times 10^4$ V and a separation of ***0.35*** cm.
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What is the magnitude, in volts per meter, of the electric field strength between the parallel conducting plates?
Numeric : A numeric value is expected and not an expression.
$|E|$ = _____ V/m

Problem 5: The maximum sustainable electric field strength in air is 3.0×10^6 V/m.
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What is the magnitude, in volts, of the maximum potential difference between two parallel conducting plates separated by ***0.41*** cm of air?
Numeric : A numeric value is expected and not an expression.
$|\Delta V|$ = _____ V

Problem 6: The voltage across a membrane forming a cell wall is 80.0 mV and the membrane is 9.00 nm thick.
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What is the magnitude of the electric field strength, in volts per meter, assuming a uniform electric field? (The value is surprisingly large, but correct.)
Numeric : A numeric value is expected and not an expression.
$|E|$ = _____ V/m

Problem 7: A 12.0 V battery-operated bottle warmer heats ***52*** g of glass, ***2.45*** × 10^2 g of baby formula, and ***1.8*** × 10^2 g of aluminum from 20.0 °C to 35.0 °C.
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Part (a) How much charge is moved by the battery in C? You may assume the specific heat of baby formula is approximately the same as for water, and the specific heat of glass is 0.840 J/(g·°C), and the specific heat of aluminium is 0.900 J/(g·°C).
Numeric : A numeric value is expected and not an expression.
q = _____ C

Part (b) How many electrons per second flow if it takes 5.00 min to warm the formula?
Numeric : A numeric value is expected and not an expression.
R = _____ electrons/s

Problem 8: An engineer is designing a process for a new transistor. She uses a vacuum chamber to bombard a thin layer of silicon with ions of phosphorus, each of mass $m_P = 5.18 \times 10^{-26}$ kg. The phosphorus ions are doubly ionized, with each phosphorus ion lacking two electrons. The ions start at rest at one end of the vacuum chamber and are accelerated by an electric field over a distance of r_e = ***34*** cm before they strike the silicon layer with velocity v_P = ***105*** m/s.

Randomized Variables

r_e = ***34*** cm
v_P = ***105*** m/s
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Part (a) Enter an expression for the potential difference ΔV, in volts, between the initial and final points across the vacuum chamber.
Expression :
ΔV = _____

Select from the variables below to write your expression. Note that all variables may not be required.
β, **γ**, **θ**, **d**, **e**, **g**, **h**, **j**, **k**, **m**, $\mathbf{m_P}$, **n**, **P**, **S**, $\mathbf{v_P}$

Part (b) Calculate the average electric field strength E, in volts per meters, across the vacuum chamber.
Numeric : A numeric value is expected and not an expression.
E = _____

Part (c) Calculate the average electric force F, in newtons, that the electric field exerts on each phosphorus ions.
Numeric : A numeric value is expected and not an expression.
F = _____

Problem 9: A battery-operated car utilizes a 120.0 V battery with negligible internal resistance.
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Find the charge, in coulombs, the batteries must be able to store and move in order to accelerate the 740 kg car from rest to 23.5 m/s, make it climb a 1.8×10^2 m high hill while maintaining that speed, and then cause it to travel at a constant 23.5 m/s by exerting a 4.7×10^2 N force for an hour.
Numeric : A numeric value is expected and not an expression.
q = _____ C

Problem 10: Suppose you have two parallel conducting plates that are separated by ***2.1*** mm.
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Part (a) What will the electric field strength between the plates be (in N/C) if they have a potential difference of ***5.2*** × 10^3 V?
Numeric : A numeric value is expected and not an expression.
$\boldsymbol{E}$ = _____

Part (b) The electric breakdown strength for a particular medium, also called the *dielectric strength*, is the point at which electrons bound to the molecules of the medium begin to be stripped off due to the large electric field. How close together must the plates be with this applied voltage in order to achieve breakdown strength for air (3.0×10^6 V/m) in mm?
Numeric : A numeric value is expected and not an expression.
$\boldsymbol{d_{\text{breakdown}}}$ = _____

Problem 11: An evacuated tube uses an accelerating voltage to accelerate electrons from rest.
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Part (a) If the accelerating voltage is ***1.15*** kV, what is the resulting speed, in meters per second, of the electrons?
Numeric : A numeric value is expected and not an expression.
v = _____ m/s

Part (b) Using the same Newtonian mechanics employed in the previous step, what accelerating voltage, in kilovolts, results in a speed that is ten percent of the speed of light? (When speeds approach c, Newtonian mechanics become unreliable, and relativistic corrections are important. When $v/c \approx 0.1$, relativistic corrections are fairly moderate, but they may be observable.)
Numeric : A numeric value is expected and not an expression.
V = _____ kV

Problem 12: Consider a proton in a uniform electric field directed left to right, as shown in the figure. For both paths the initial speed of the proton is the same, but the direction of the initial velocity is different.
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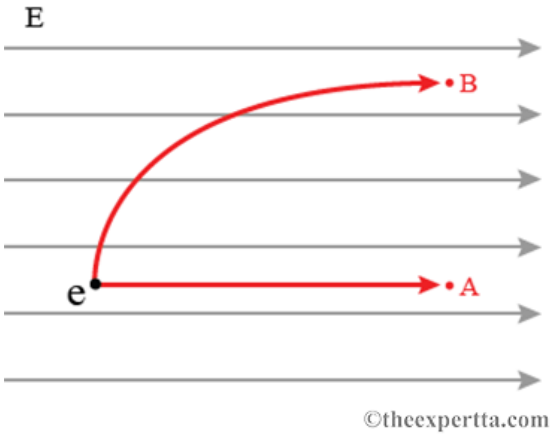

Part (a) Compare the change in electric potential energy along path A to the change in electric potential energy along path B.
MultipleChoice :

1) $\Delta U_A = \Delta U_B$
2) There is not enough information given - we need either the initial speed or the size of the electric field.
3) $\Delta U_A < \Delta U_B$
4) $\Delta U_A > \Delta U_B$

Part (b) Compare the speed of the proton at the end of path A with the speed at the end of path B.
MultipleChoice :

1) $v_A = v_B$
2) It is impossible to tell - you need more information.
3) $v_A > v_B$
4) $v_A < v_B$

Problem 13: Two very large parallel plates are perpendicular to the x axis and have a small separation, d. (The dimensions are distorted for purposes of visualization.) The first plate, located at $x = 0$, has a negative uniform charge density, $-\sigma$, and is designated as the zero of electric potential. The second plate, located at $x = d$, has a positive uniform charge density, $+\sigma$.
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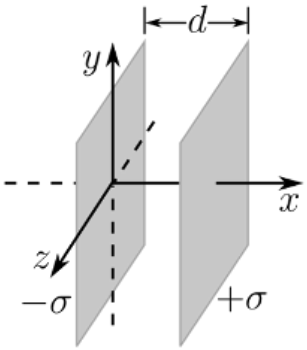

Part (a) In terms of the variables provided in the problem statement, enter a vector expression for the electric field, $\vec{E}$, that is valid in the gap between the two plates.
Expression :
$\vec{E}$ = _____

Select from the variables below to write your expression. Note that all variables may not be required.
ε_0, λ, μ_0, Φ_E, π, ρ, σ, $\hat{\imath}$, $\hat{\jmath}$, $\hat{k}$, e, n, x, y, z

Part (b) In terms of the variables provided in the problem statement, enter an expression for the electric potential that is valid in the gap between the two plates.
Expression :
V = _____

Select from the variables below to write your expression. Note that all variables may not be required.
ε_0, **λ**, **μ_0**, **Φ_E**, **π**, **ρ**, **σ**, **$\hat{\imath}$**, **$\hat{\jmath}$**, **$\hat{k}$**, **e**, **n**, **x**, **y**, **z**

Part (c) Given that the magnitude of the charge density is ***14.1*** $\mu\mathrm{C}/\mathrm{m}^2$, and the plate separation is ***4.27*** mm, what is the magnitude, in volts per meter, of the electric field, E, in the gap between the two plates?
Numeric : A numeric value is expected and not an expression.
E = _____ V/m

Part (d) Given that the magnitude of the charge density is ***14.1*** $\mu\mathrm{C}/\mathrm{m}^2$, and the plate separation is ***4.27*** mm, what is the magnitude, in volts, of the potential difference, ΔV, between the two plates?
Numeric : A numeric value is expected and not an expression.
ΔV = _____ V

Part (e) If an electron is released from rest at the negatively charged plate, what is the maximum speed, in meters per second, that it attains just prior to striking the positively charged plate?
Numeric : A numeric value is expected and not an expression.
v = _____ m/s

Problem 14: An evacuated tube uses a potential difference of ΔV = ***0.58*** kV to accelerate electrons, which then hit a copper plate and produce X-rays.
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Part (a) Write an expression for the non-relativistic speed of these electrons v in terms of e, ΔV, and m, assuming the electrons start from rest.
Expression :
v = _____

Select from the variables below to write your expression. Note that all variables may not be required.
α, **β**, **ΔV**, **θ**, **a**, **b**, **c**, **d**, **e**, **f**, **g**, **h**, **j**, **k**, **m**, **P**, **q**, **S**, **t**, **V**

Part (b) Calculate the non-relativistic speed of these electrons v in m/s.
Numeric : A numeric value is expected and not an expression.
v = _____