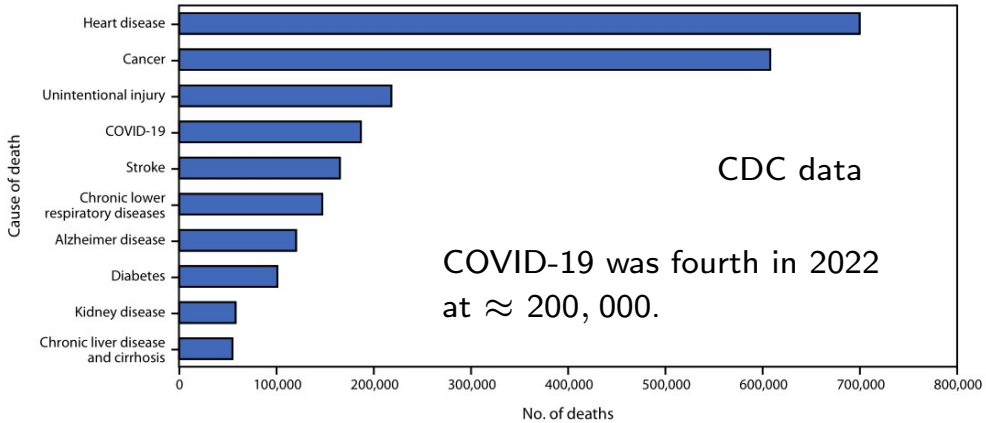
1

New Treatments for Cancer 2

1. The second leading cause death in the US is cancer.



New Treatments for Cancer 3

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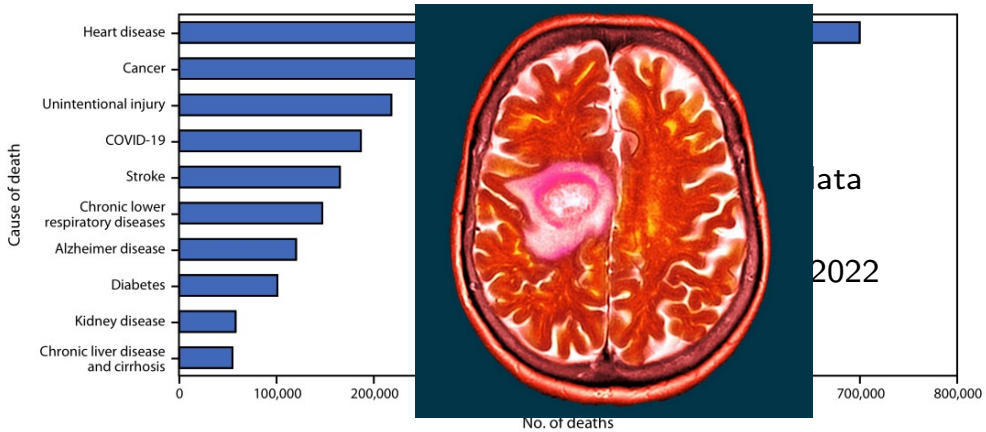
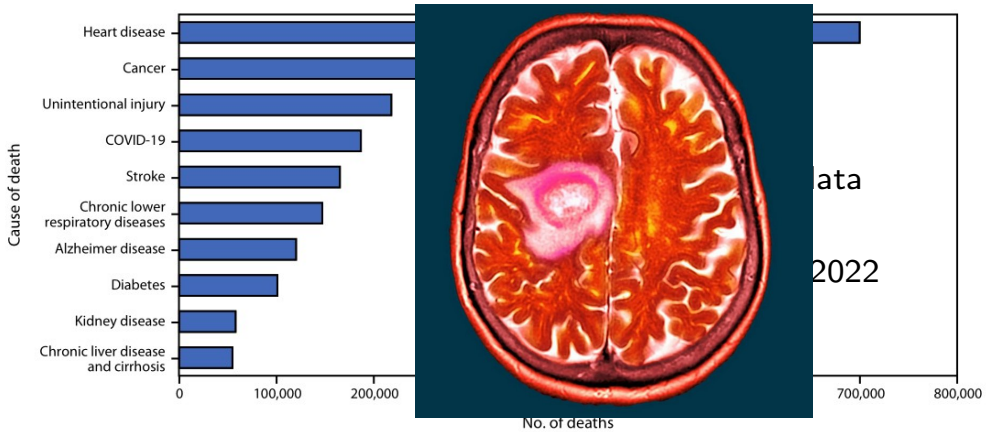


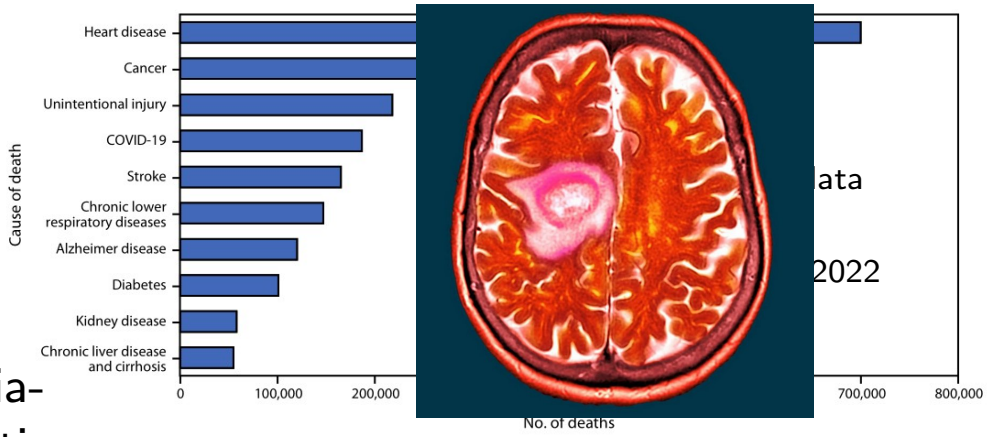
New Treatments for Cancer 4

1. The second leading cause death in the US is cancer.
2. Radiation therapy works by ionizing enough atoms in the tumor to disrupt its growth.



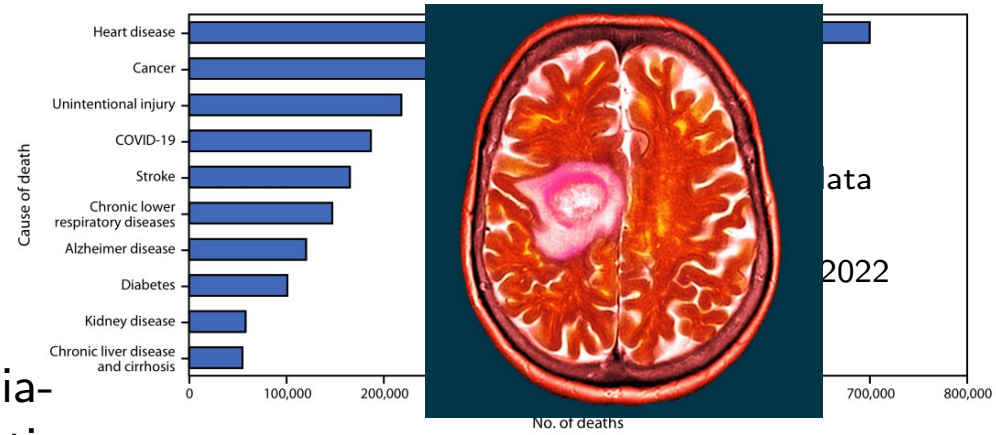
New Treatments for Cancer 5

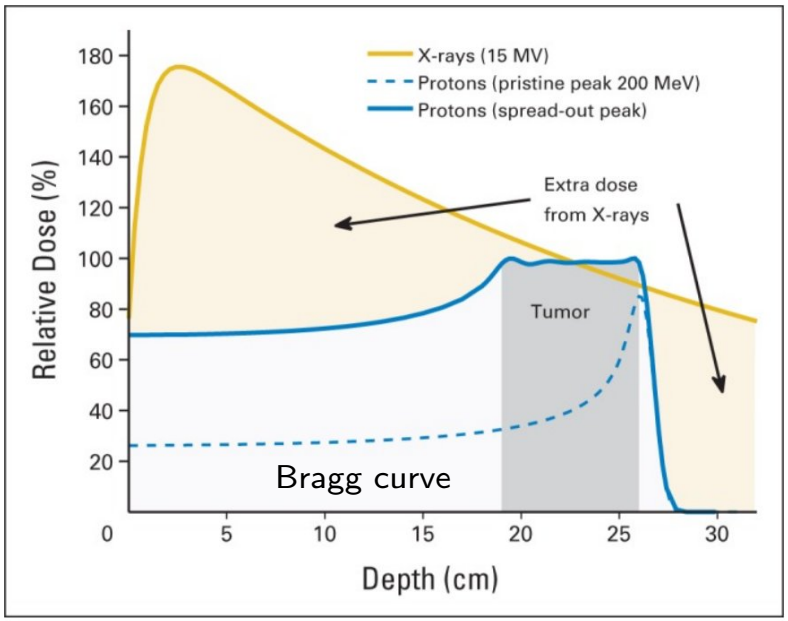
1. The second leading cause death in the US is cancer.
2. Radiation therapy works by ionizing enough atoms in the tumor to disrupt its growth.
3. The most common form of radiation used now are photons (particles of light) like x-rays.



New Treatments for Cancer 6

1. The second leading cause death in the US is cancer.
2. Radiation therapy works by ionizing enough atoms in the tumor to disrupt its growth.
3. The most common form of radiation used now are photons (particles of light) like x-rays.
4. The Bragg curve is the deposited energy E_{dep} per mass (J/kg) as a function of depth in the material.





New Treatments for Cancer 7

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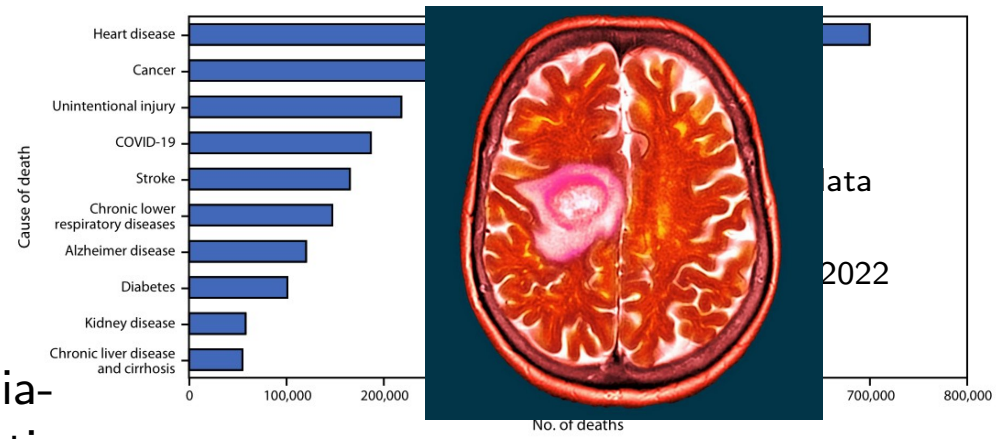
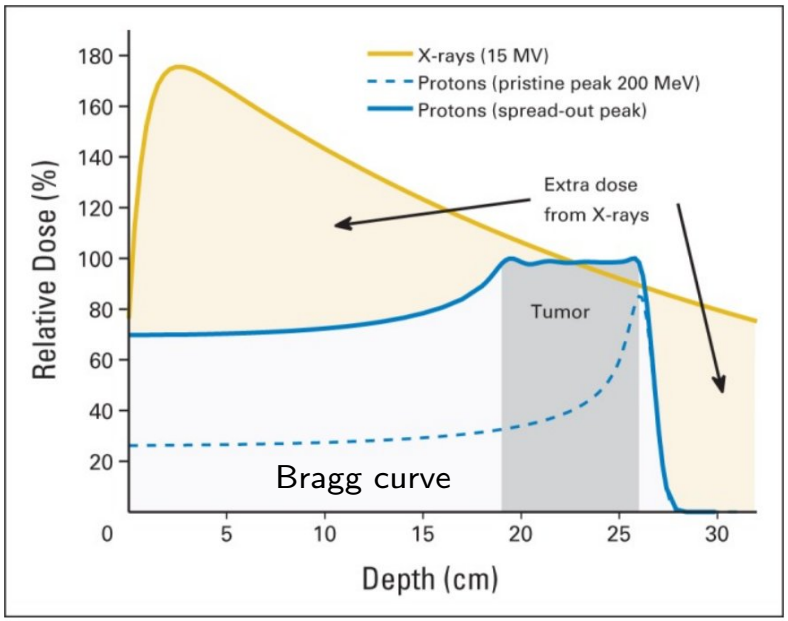
4. The Bragg curve is the deposited energy E_{dep} per mass (J/kg) as a function of depth in the material.
5. Photons have a large E_{dep} all along their path through the patient's body (gold curve).





New Treatments for Cancer 8

1. The second leading cause death in the US is cancer.
2. Radiation therapy works by ionizing enough atoms in the tumor to disrupt its growth.
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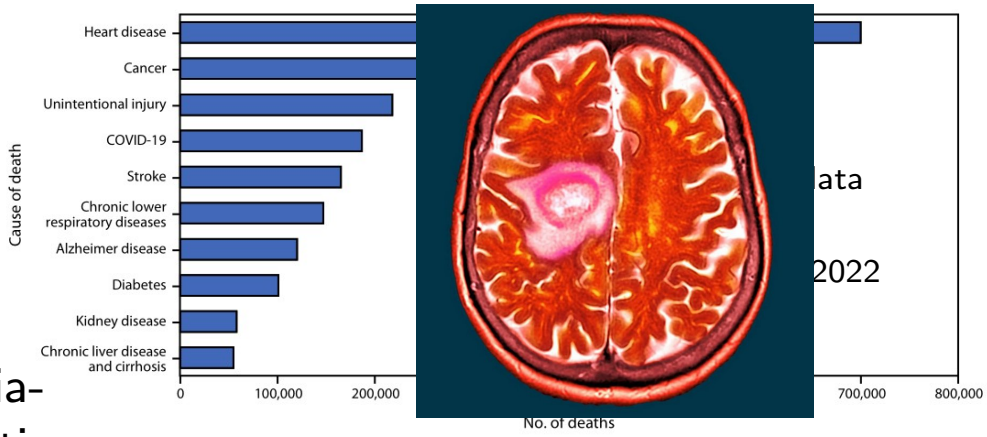
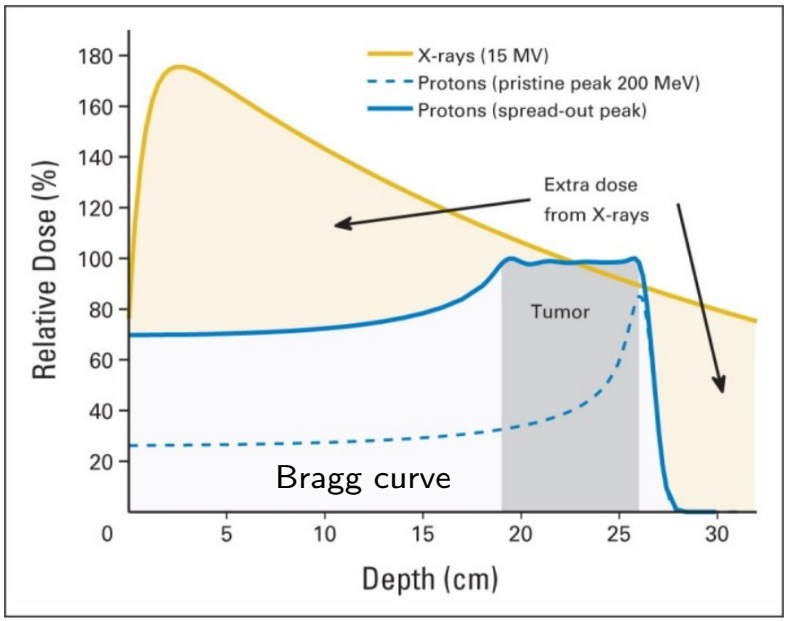
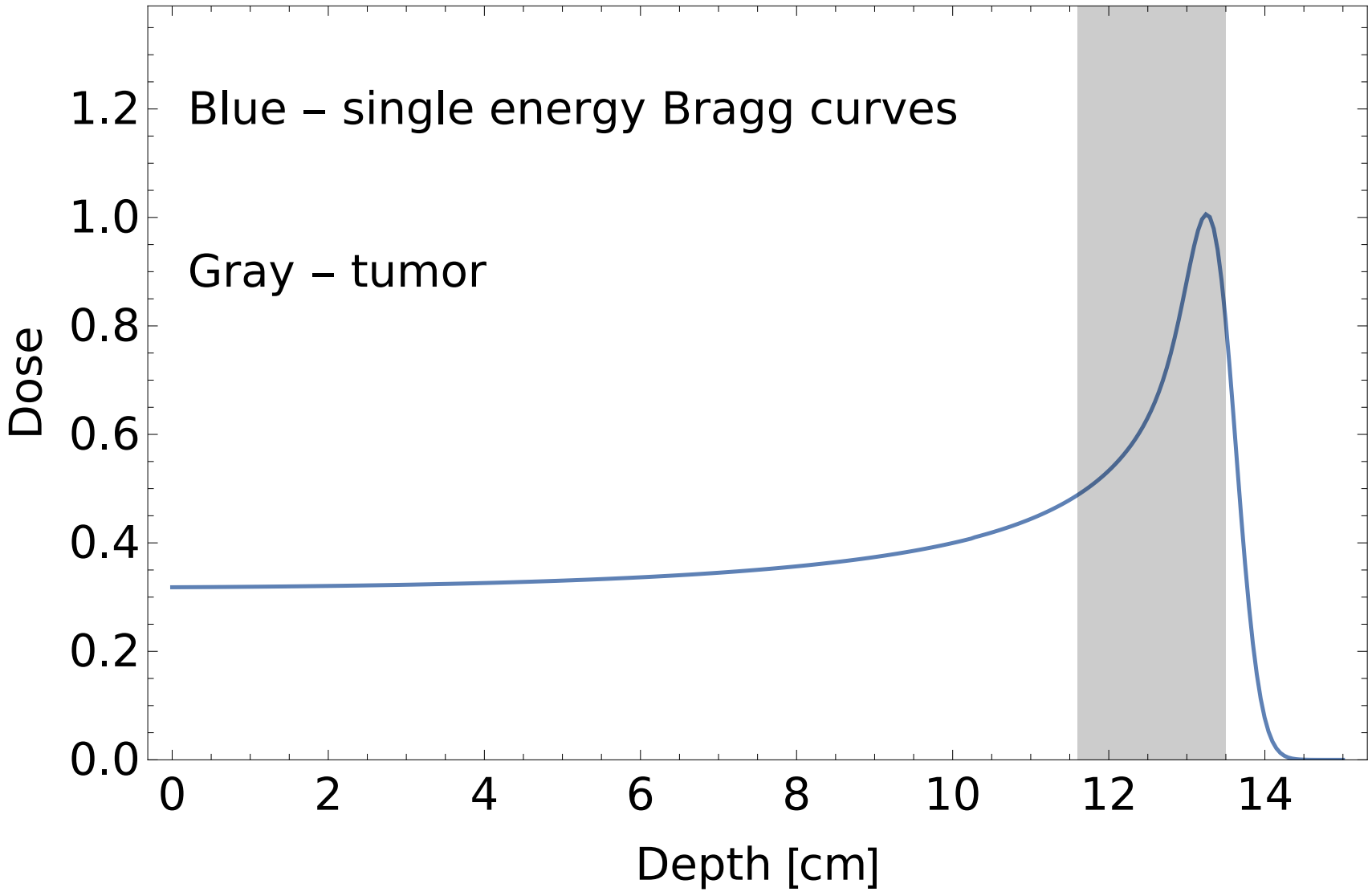
4. The Bragg curve is the deposited energy E_{dep} per mass (J/kg) as a function of depth in the material.
5. Photons have a large E_{dep} all along their path through the patient's body (gold curve).
6. Protons deposit more of their energy in the tumor (blue curve) - reducing the negative impacts associated with photon beams.

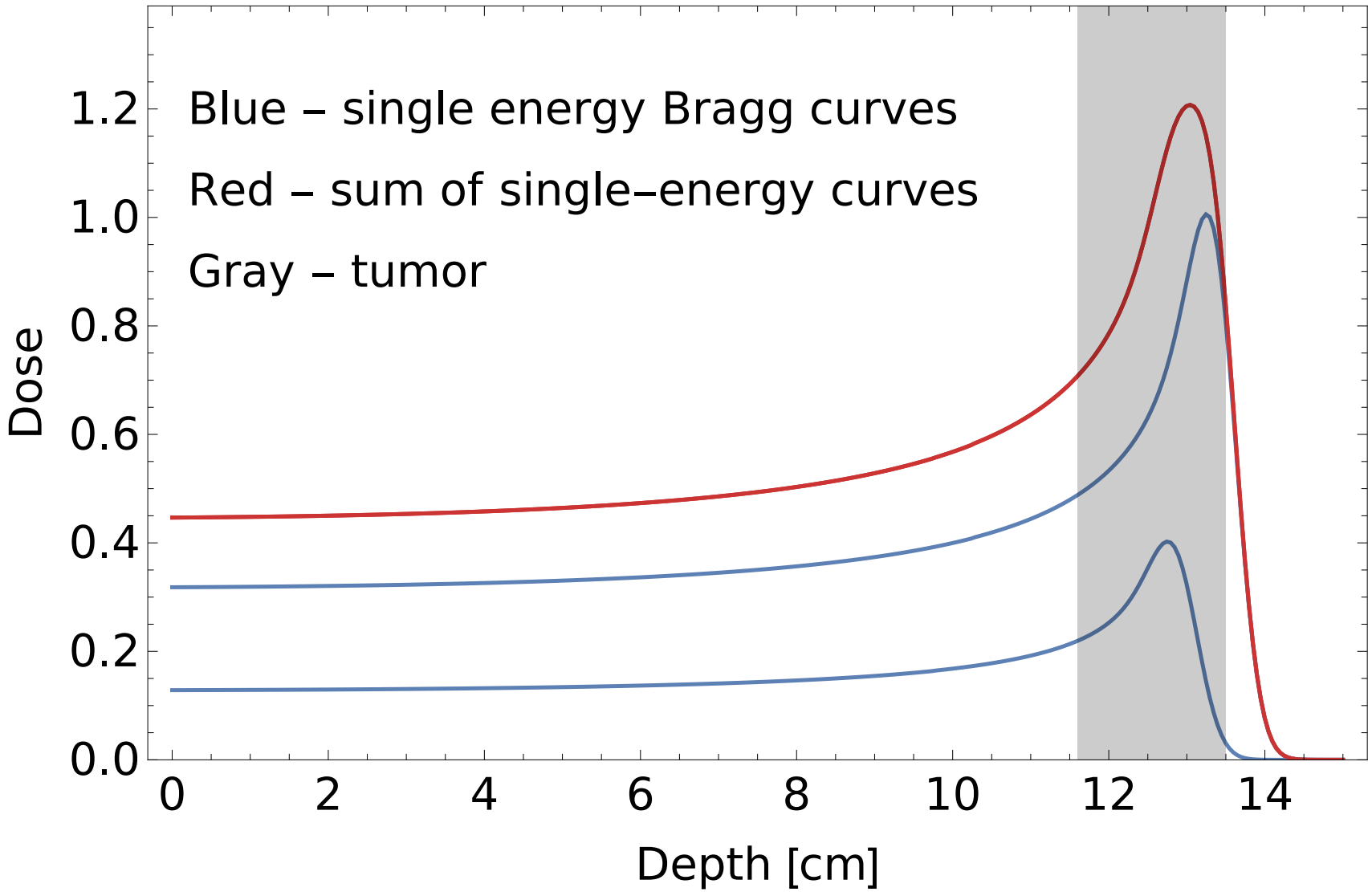




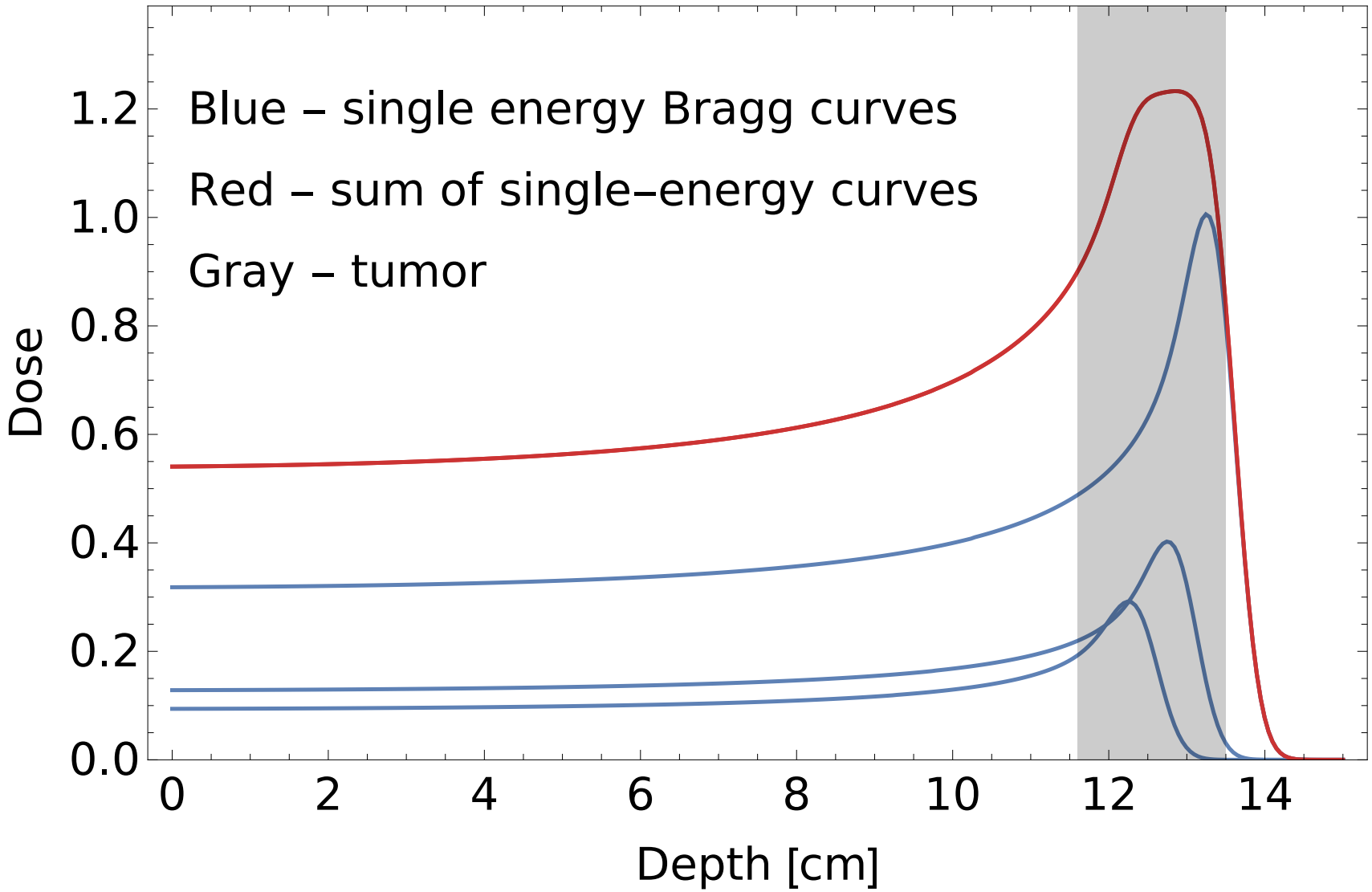
Why Use Protons? 9



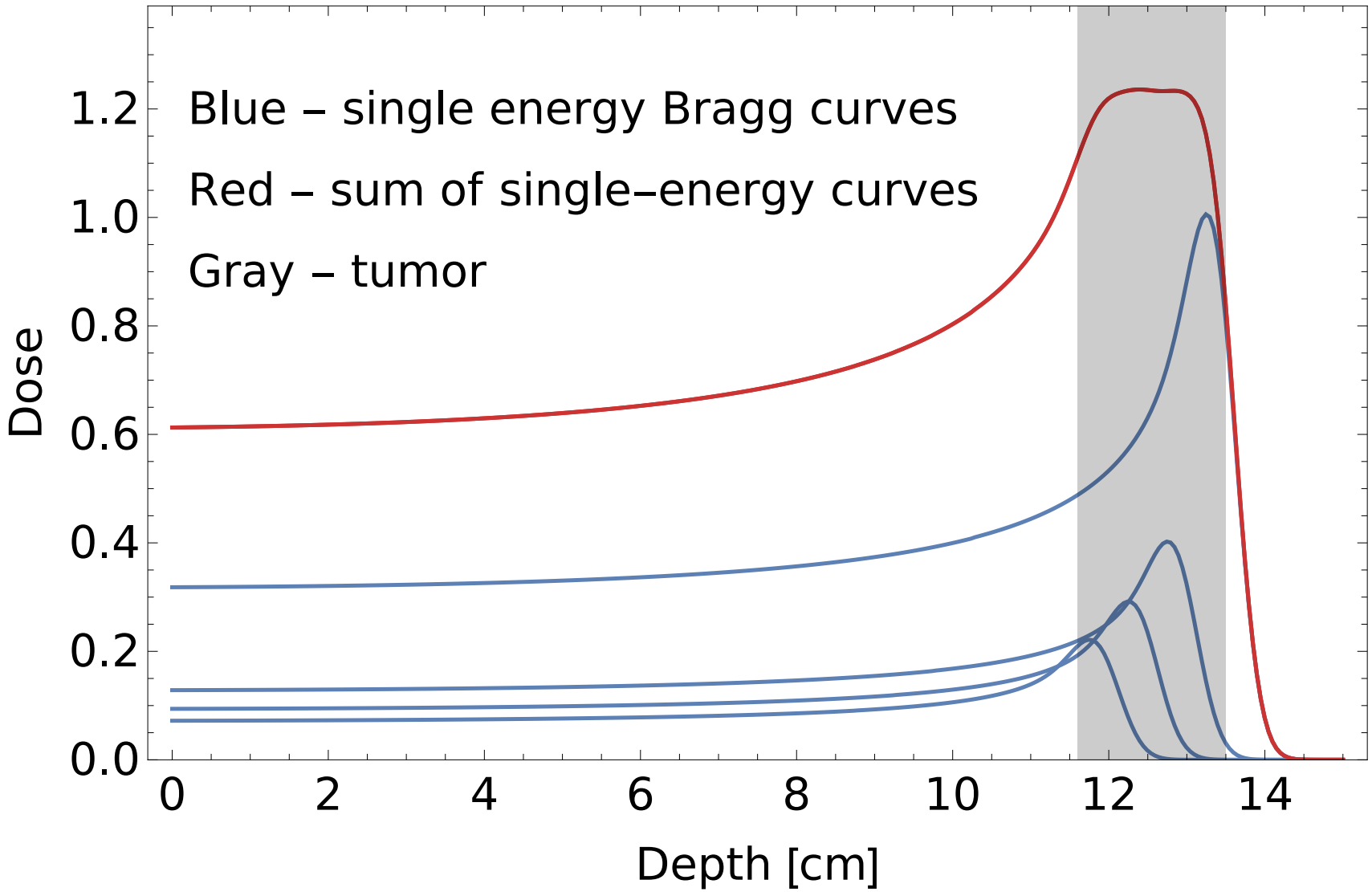
Why Use Protons? 10



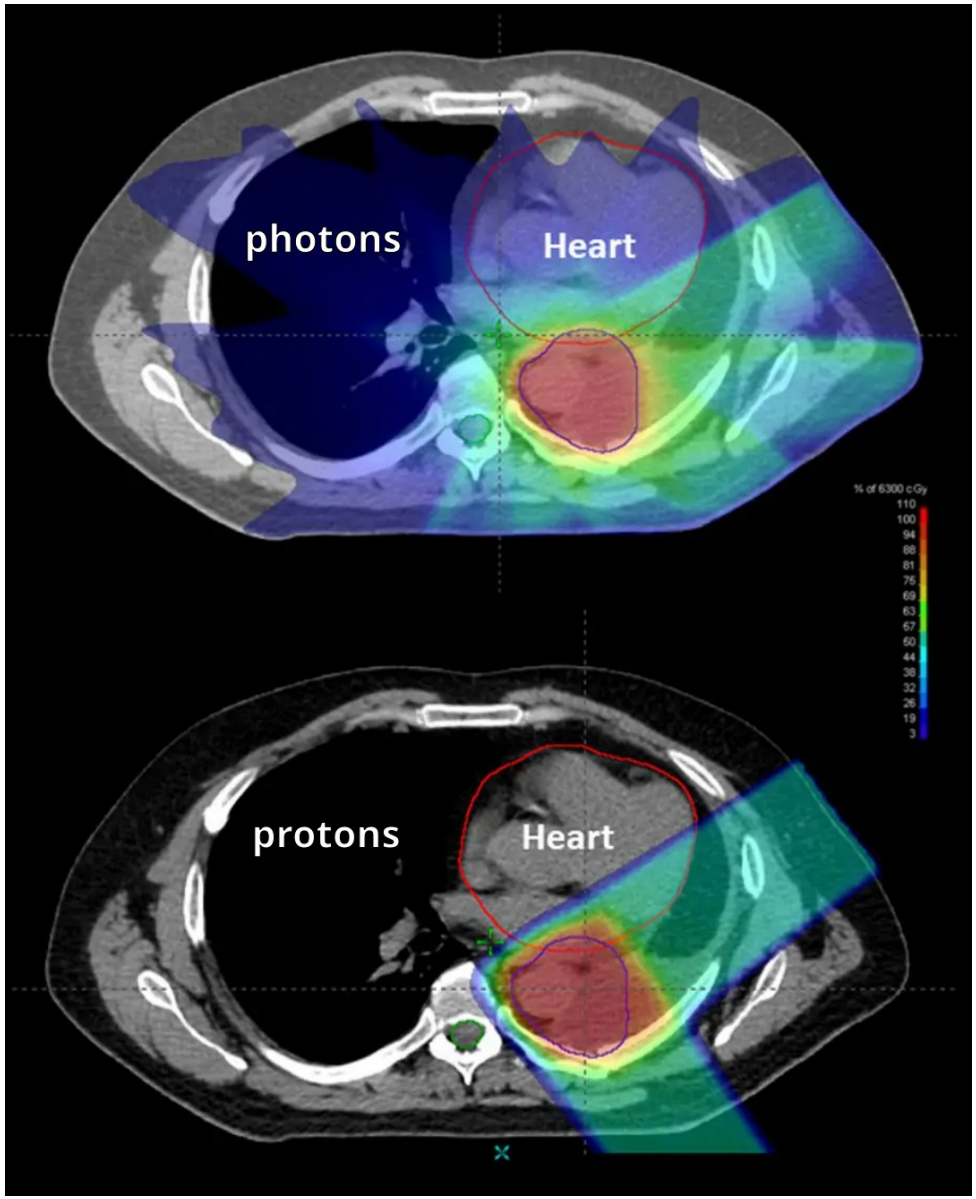
Why Use Protons? 11



Why Use Protons? 12

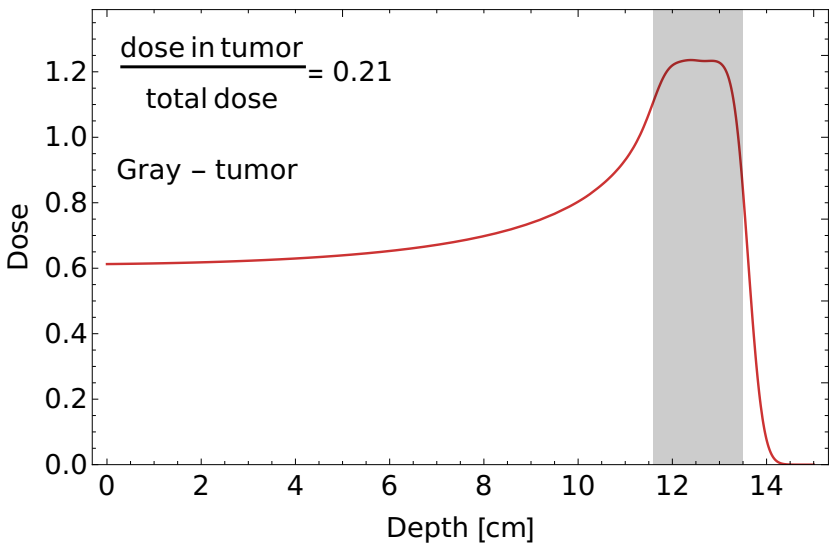


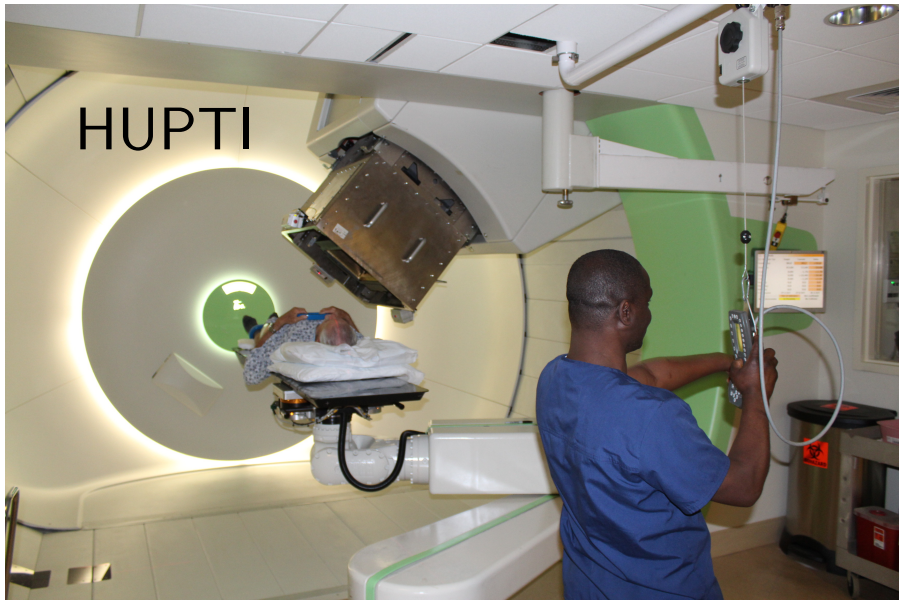
Why Use Protons? 13

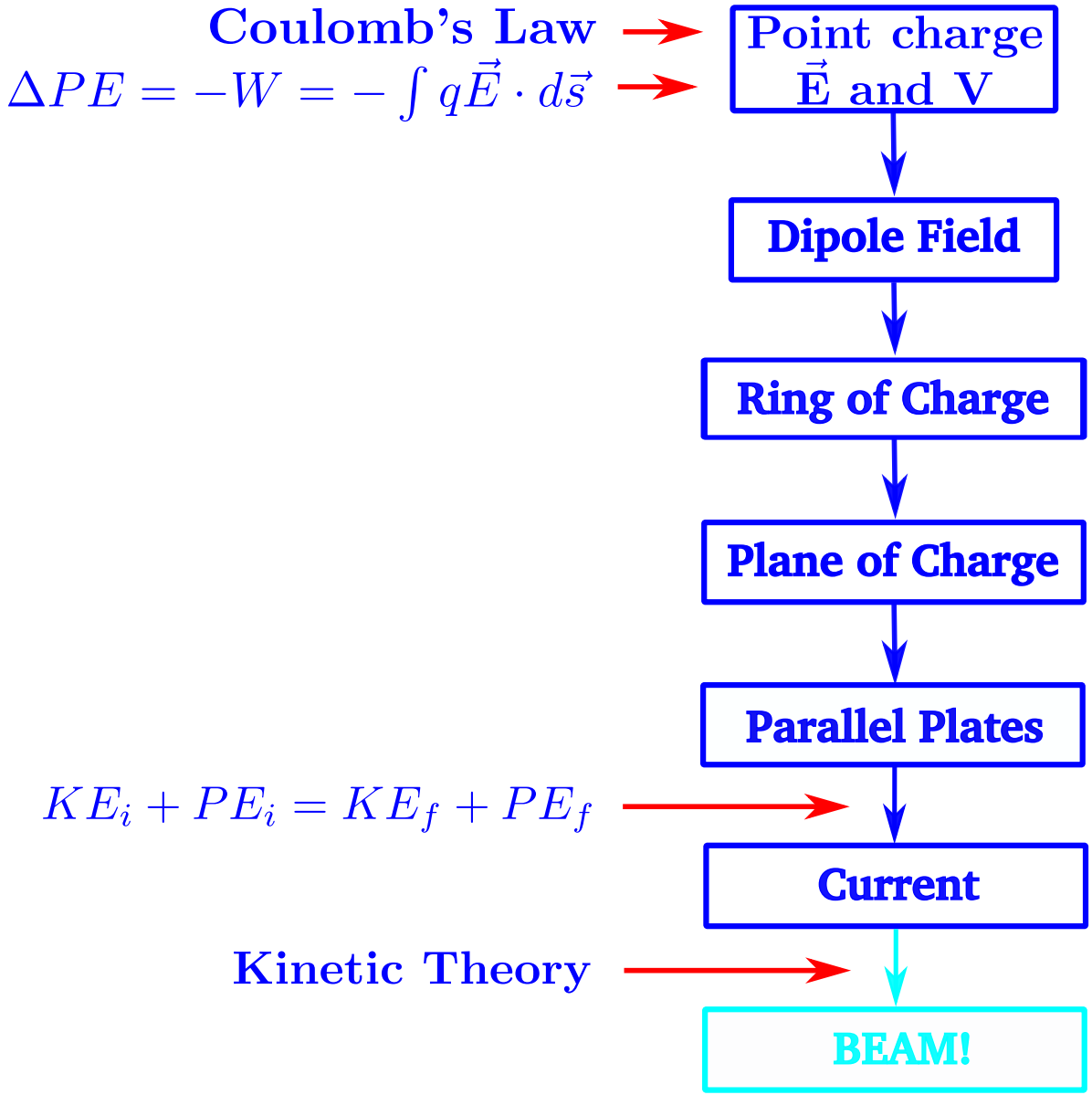


New Treatments for Cancer 14

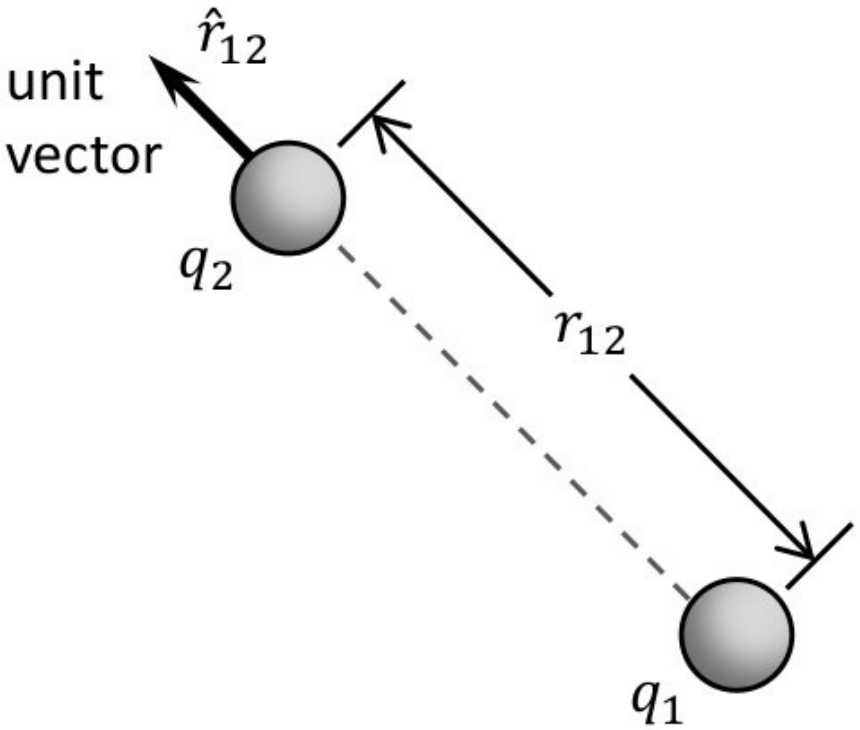
In proton-beam therapy, high-energy protons are used to kill tumors. In one case an energy $E_{dep} = 200\ J$ must be deposited into the tumor. However, only 21% of the incident proton energy E_{inc} actually goes into the tumor. To create the beam, protons are accelerated from rest through an electric potential difference $V_p = 100\ MV = 10^8\ V$. The total exposure time is to be three minutes. What is the electric current during the treatment? If the beam spot is circular with radius $r = 0.1\ m$, what is the beam proton density? Compare this with the proton density of water ($\approx 10^{28}\ m^{-3}$).






Coulomb's Law
$\Delta PE = -W = -\int q\vec{E} \cdot d\vec{s}$
Point charge
$\vec{E}$ and V
Dipole Field
Ring of Charge
Plane of Charge
Parallel Plates
$KE_i + PE_i = KE_f + PE_f$
Current
Kinetic Theory
BEAM!

Coulomb's Law

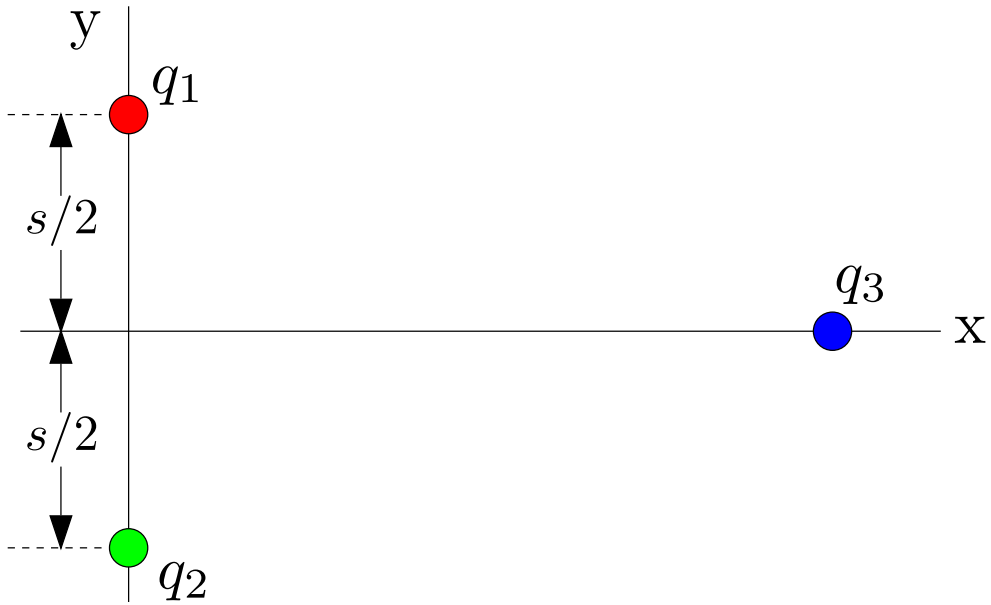


$$\vec{F}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

$$k_e = 8.99 \times 10^9 \ \mathrm{N\,m^2/C^2}$$

Consider the set of charges shown below. What is the force on charge 3 due to charges 1 and 2 given the conditions on the charges shown below? Express the answer in terms of the charge q, the horizontal position x of charge 3, and the separation s of charges 1 and 2. What is the electric field at the position of charge 3 due to the other charges? Demo here.

$$q_1 = q > 0 \qquad q_2 = -q \qquad q_3 > 0$$



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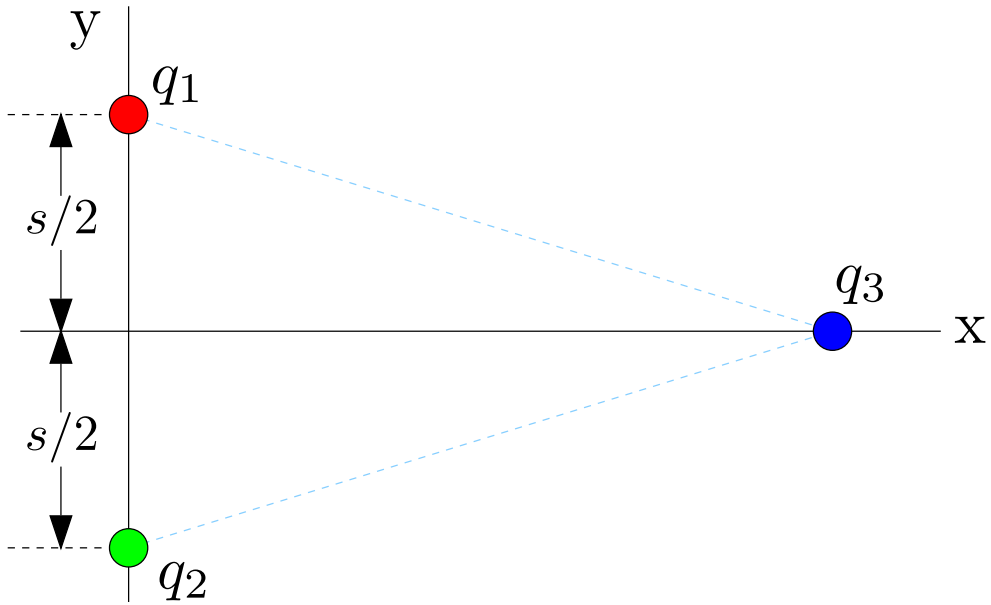

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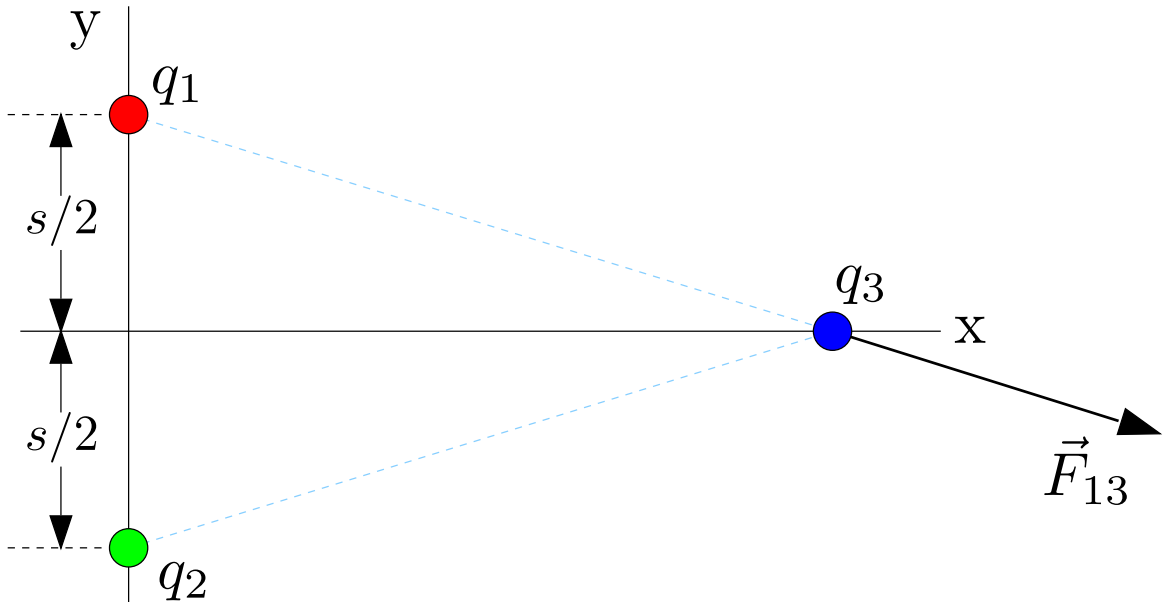

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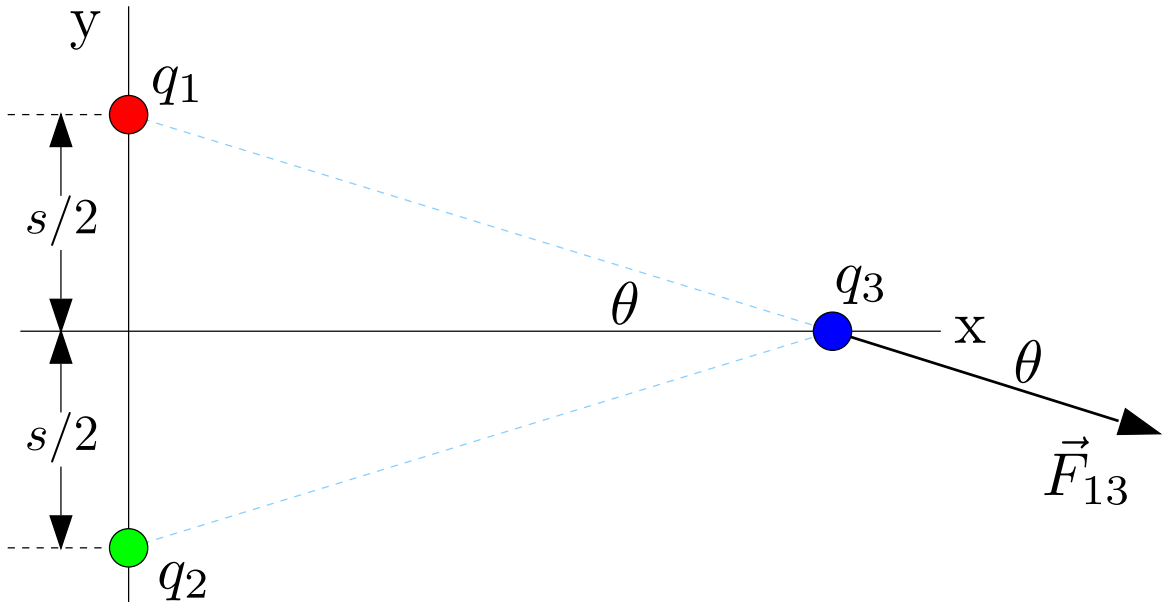

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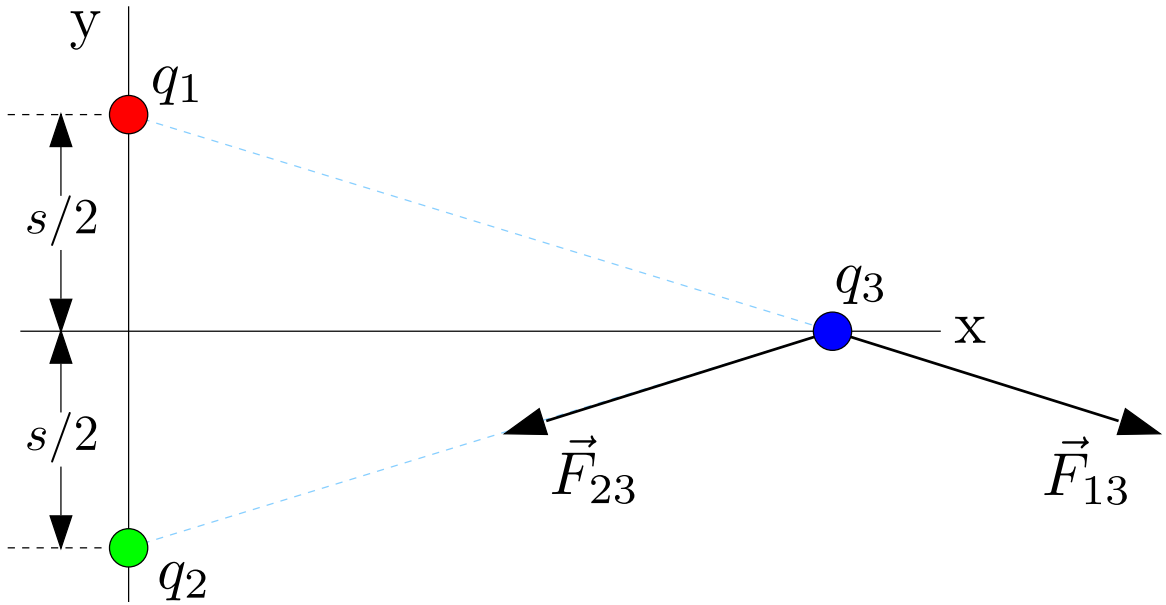

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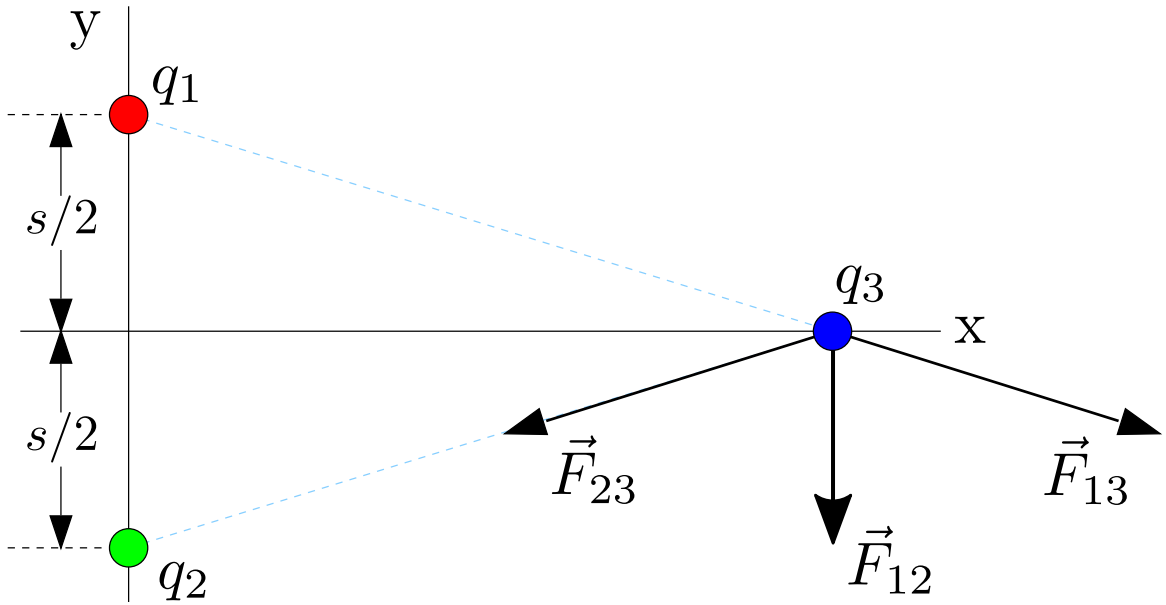

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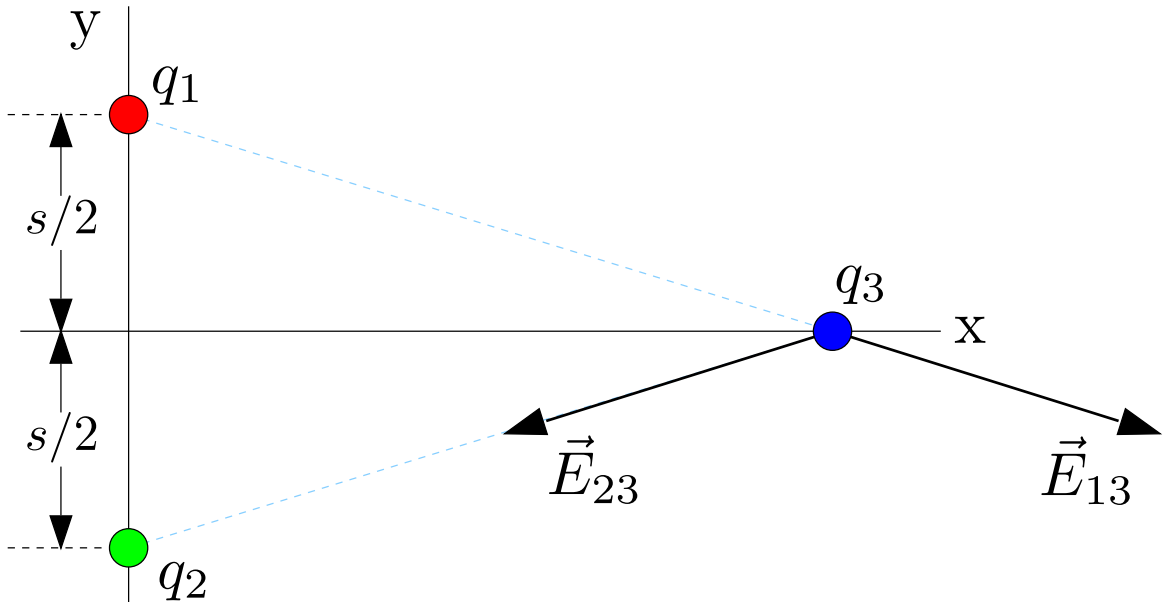

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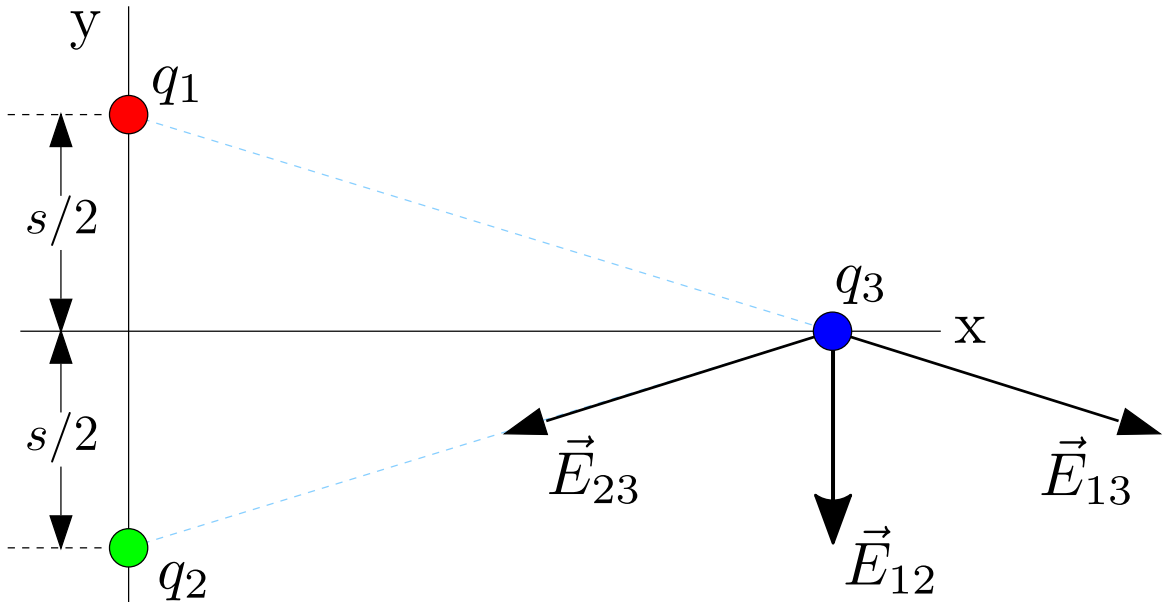
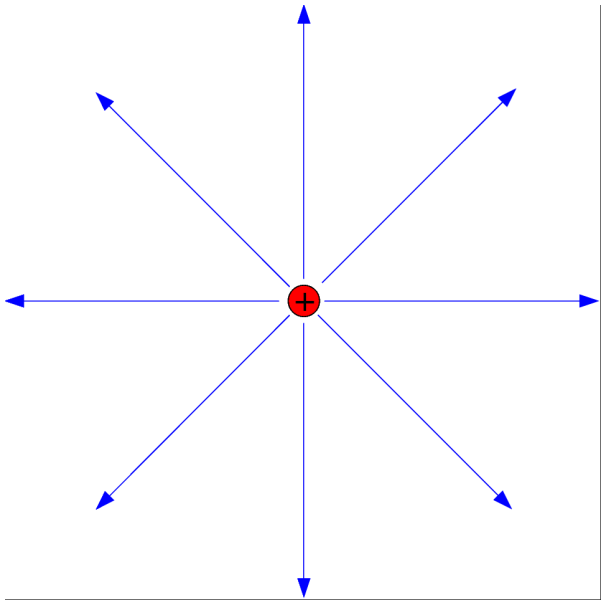
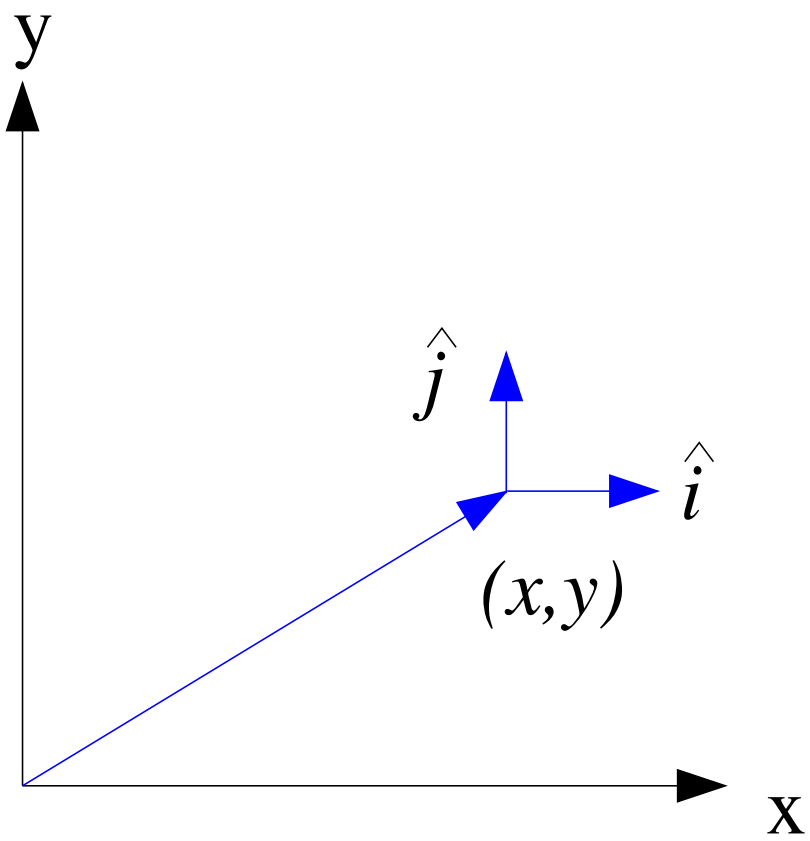
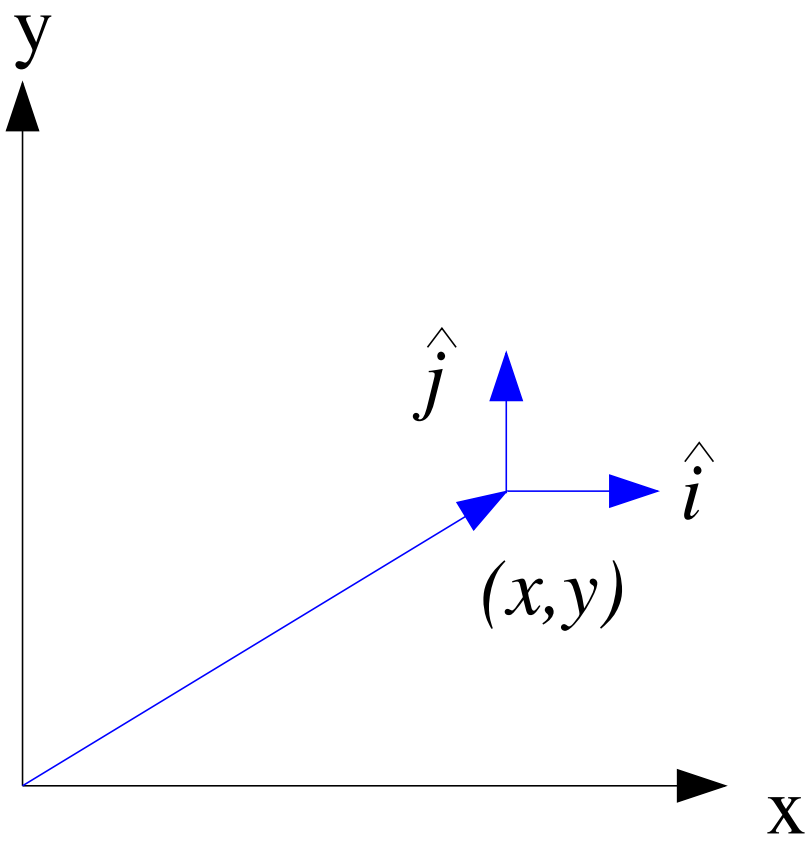


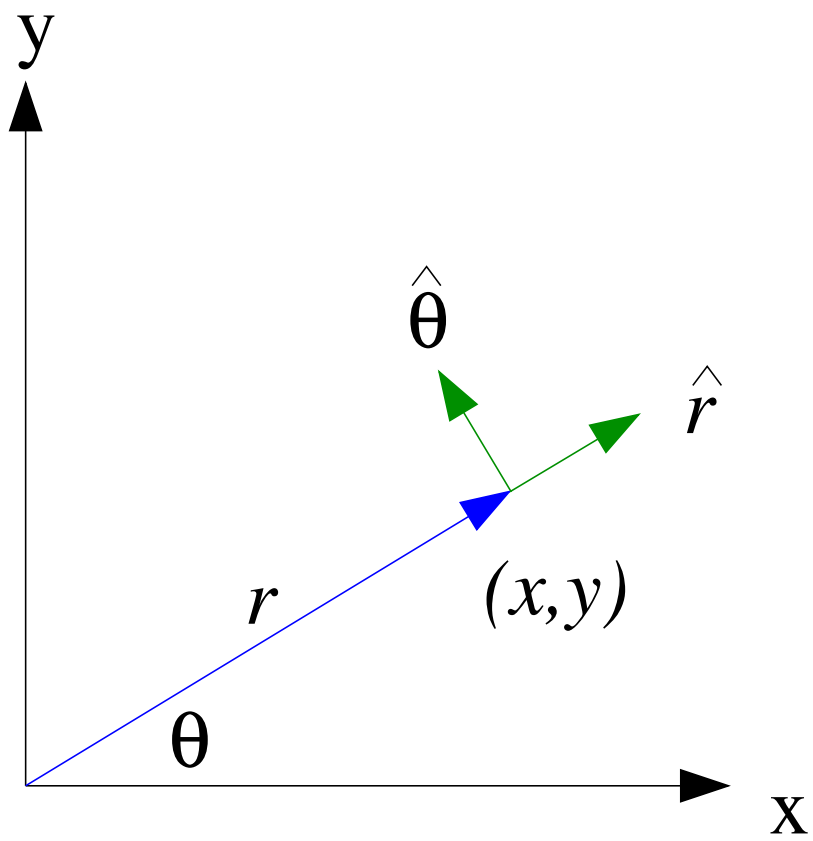
The Electric Potential of a Point Charge - 1 25

Calculate the electric potential due to a point charge in terms of the radial distance from the charge r, the amount of charge q, and any other necessary constants. A plot of the fields lines is shown to the right. Demo here.

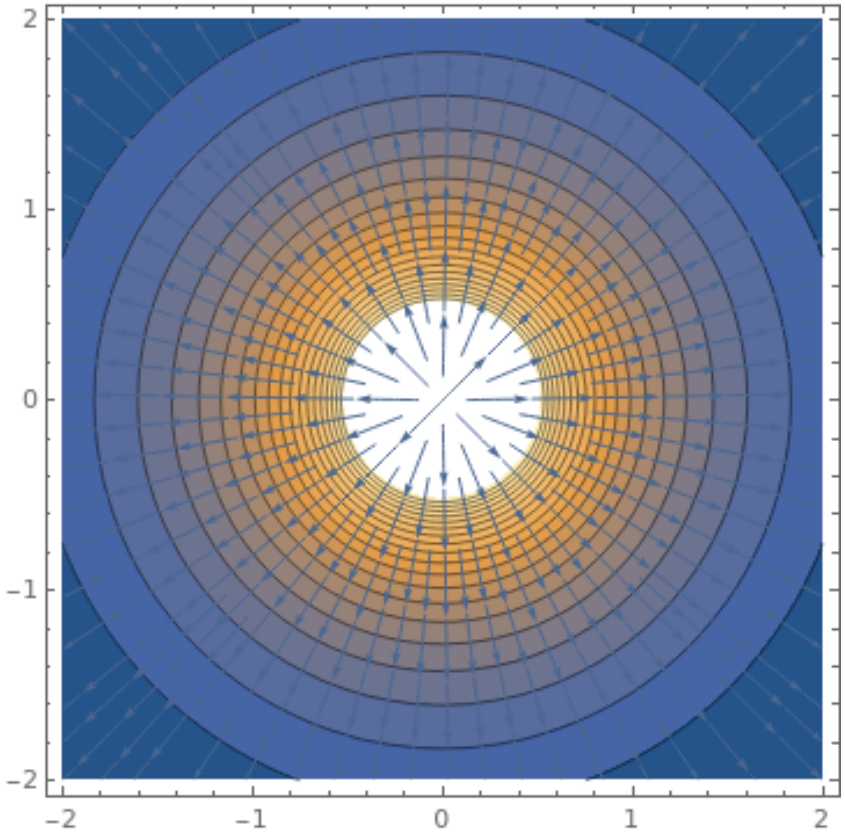


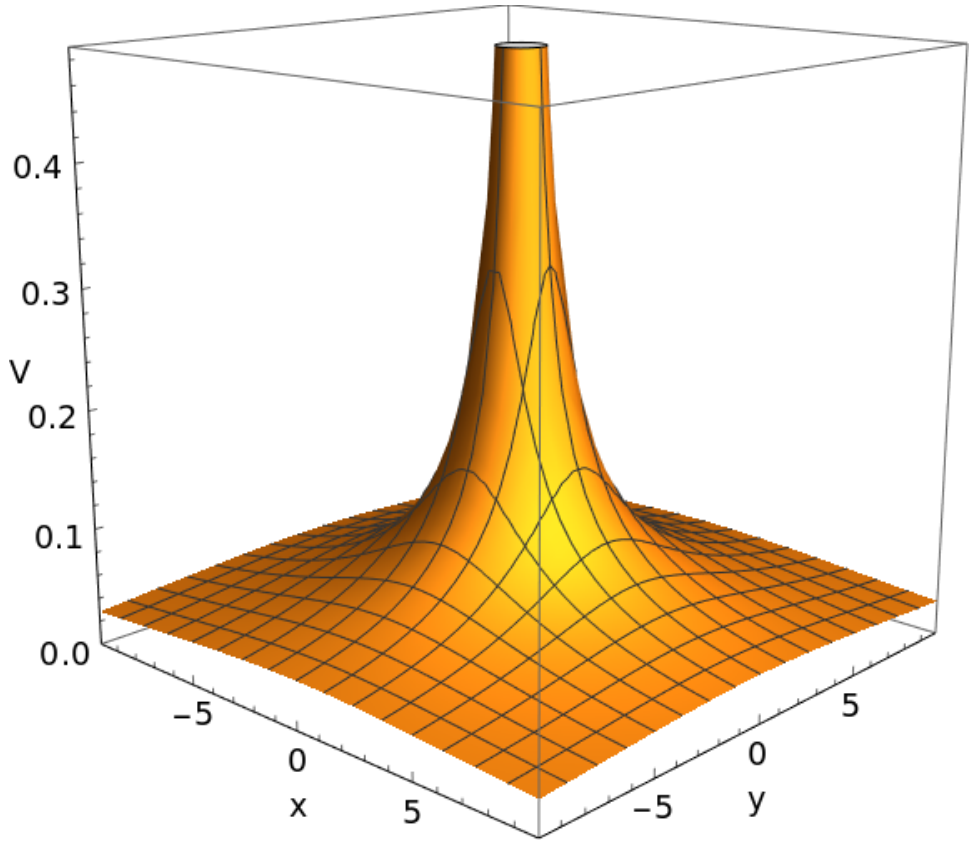

y
$\hat{j}$
$\hat{i}$
(x,y)
x


y
x
$\hat{j}$
$\hat{i}$
(x,y)

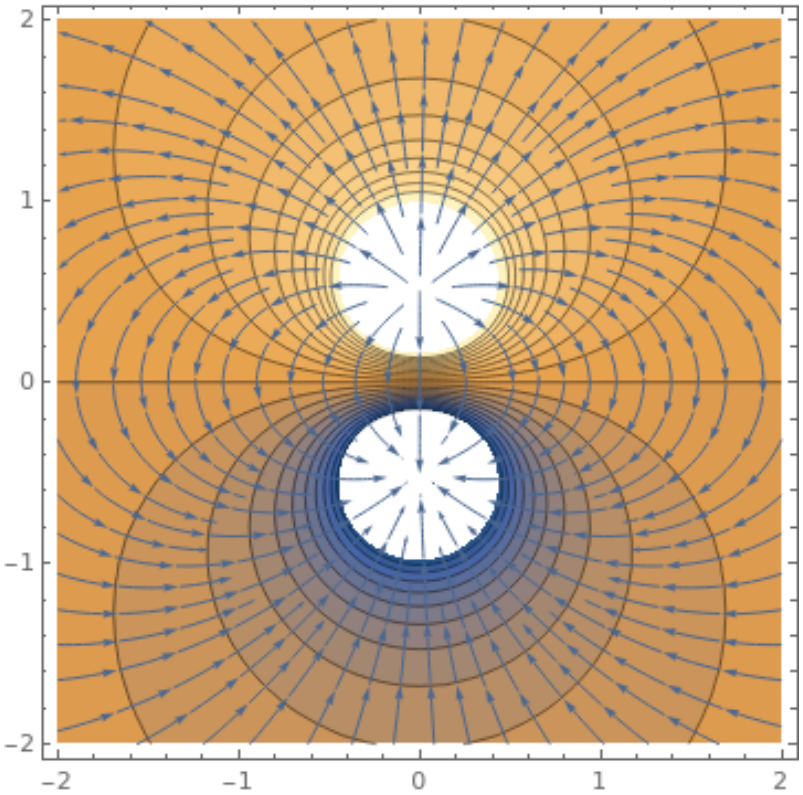

y
x
$\hat{\theta}$
$\hat{r}$
r
θ
(x,y)

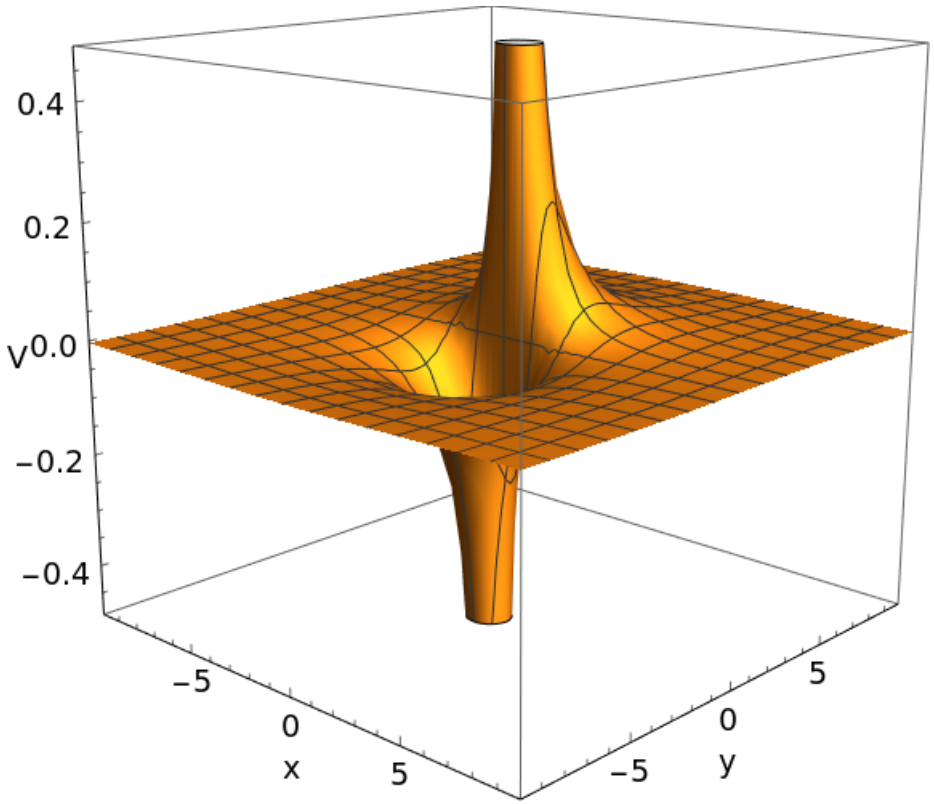
The Electric Potential of a Point Charge - 3 28





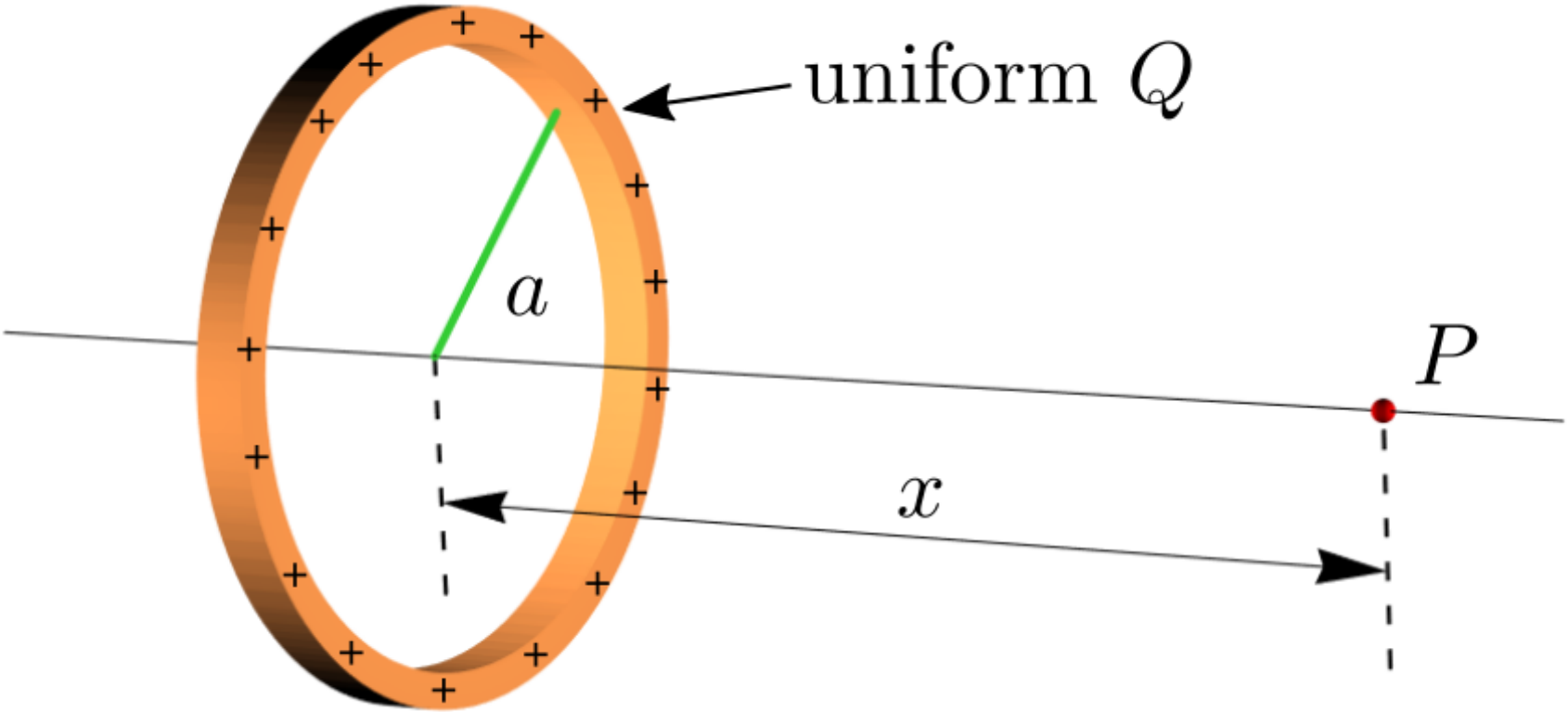
The Electric Dipole Potential 29



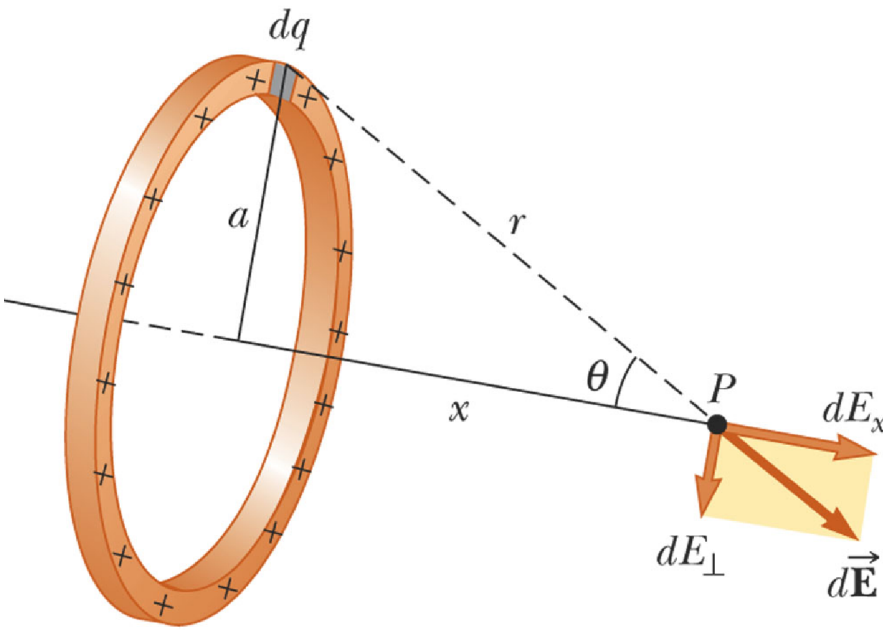


The Charged Ring 30

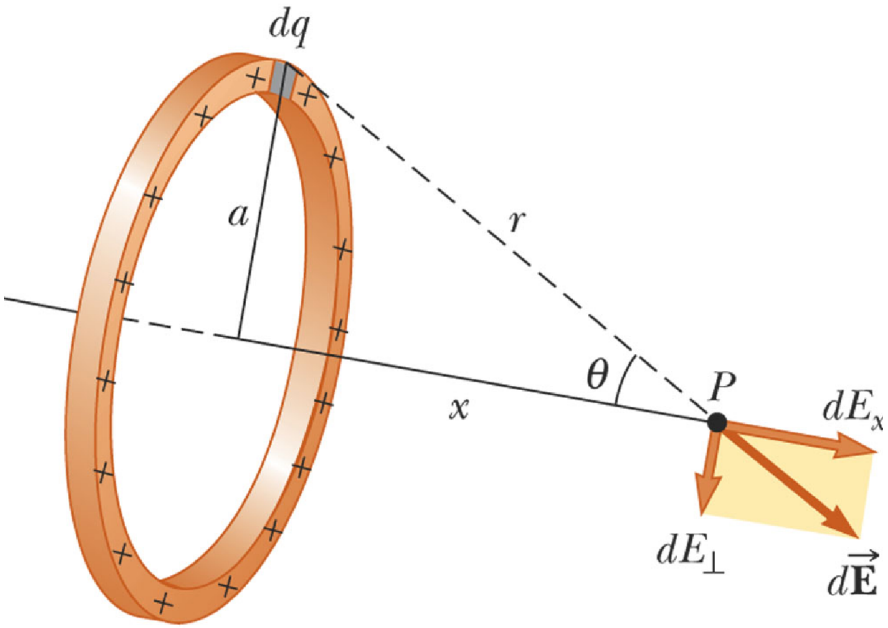
A ring of radius a as shown in the figure has a positive charge distribution per unit length with total charge Q. Calculate the electric field $\vec{E}$ along the axis of the ring at a point lying a distance x from the center of the ring. Get your answer in terms of a, x, Q.

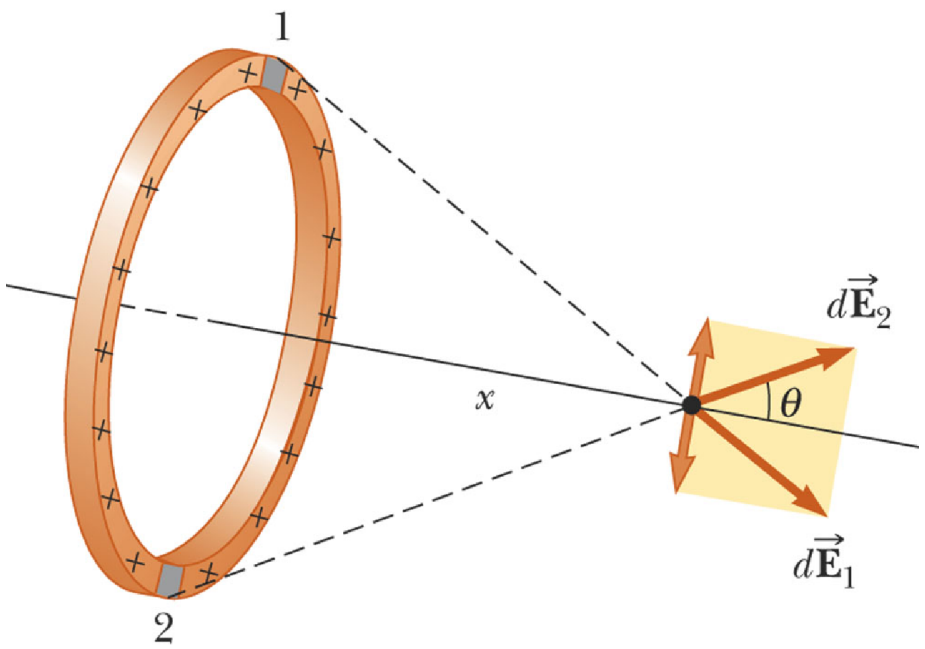


The Charged Ring 31



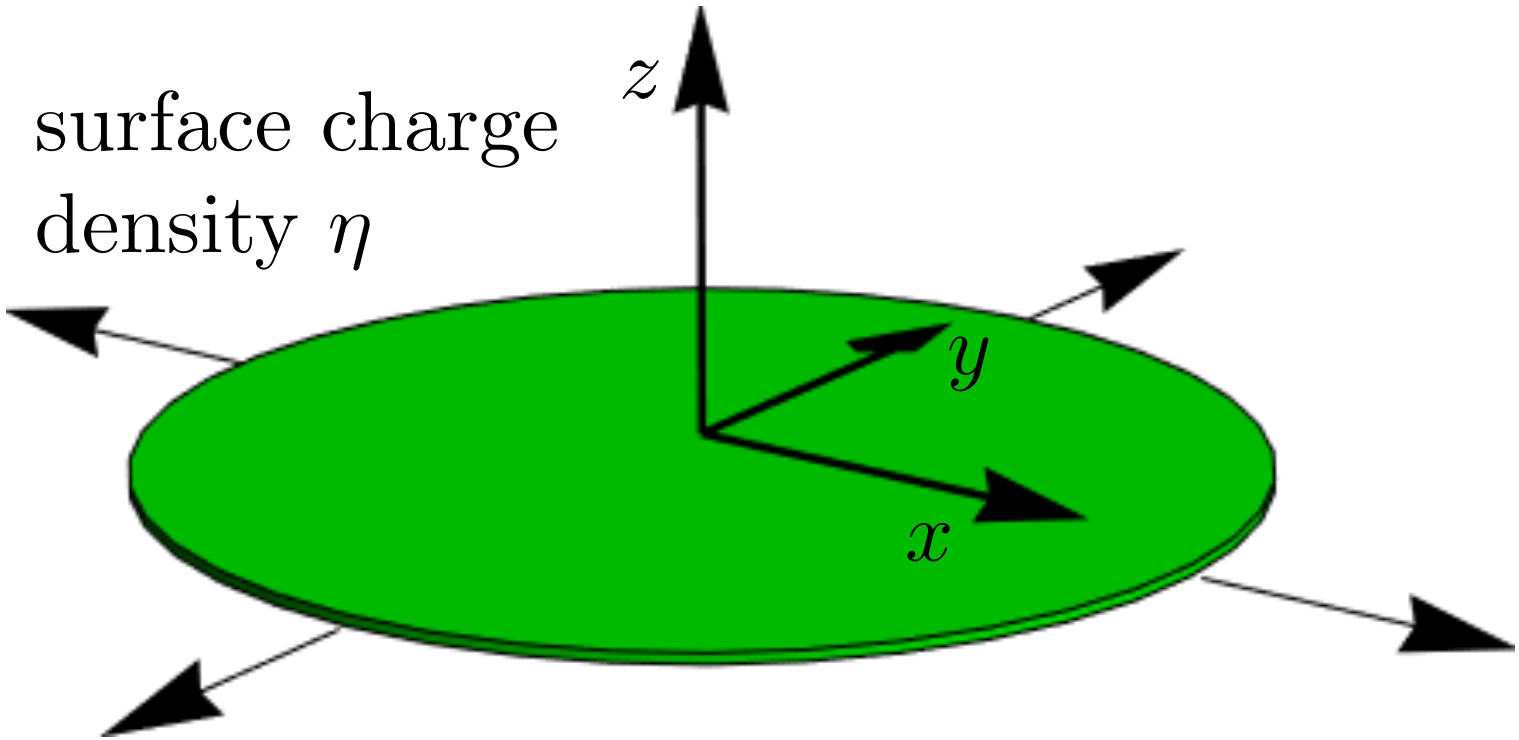
The Charged Ring 32





The Charged Disk - 1 33

Consider an infinitely-large, flat plate covered with a uniform distribution of charge on its surface η. What is the electric field above the plate in terms of this surface charge density η and any other constants? What is the electric potential?



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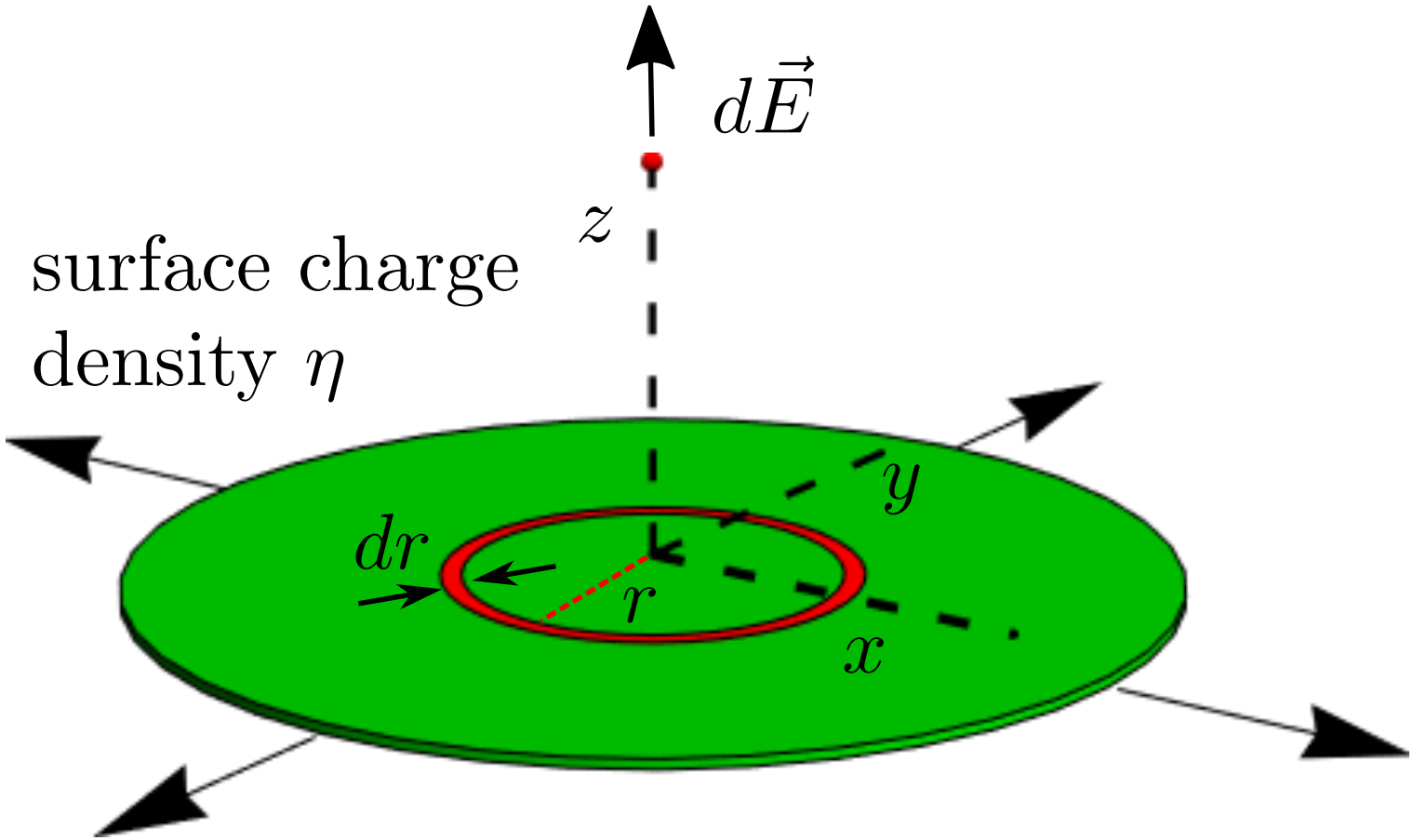
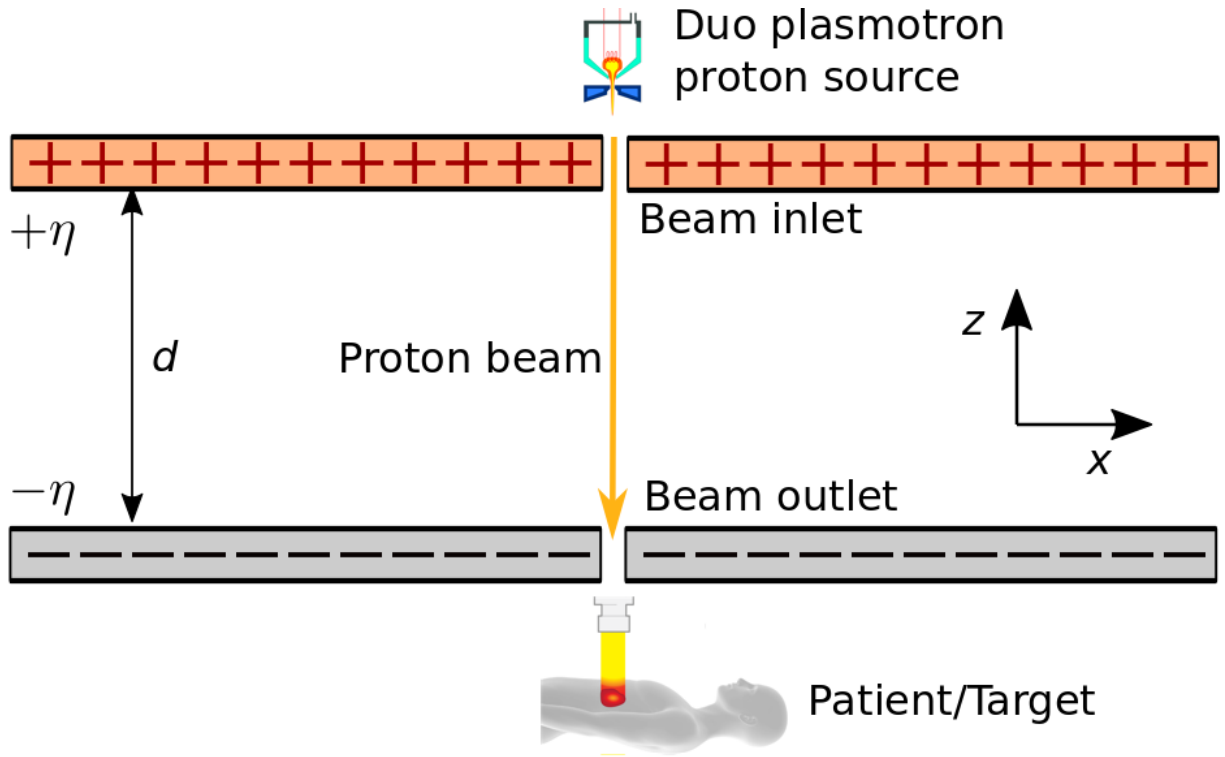


Accelerating Protons 35

To create a particle beam for cancer therapy protons are injected at low velocity between two large, metal plates with surface charge densities $\pm\eta$ and separated by a distance d. The particles speed up as they cross between the plates. What is the field between the plates? What is the electric potential across the plates in terms of the η and d? What is the kinetic energy of the protons after they leave the accelerator? What is the proton velocity?

$d = 0.1\ m$
$\eta = 8.85 \times 10^{-8}\ C/m^2$



Accelerating Protons 36

To create a particle beam for cancer therapy protons are injected at low velocity between two large, metal plates with surface charge densities $\pm\eta$ and separated by a distance d. The particles speed up as they cross between the plates. Wh
electric potential across
kinetic energy of the pro
proton velocity?

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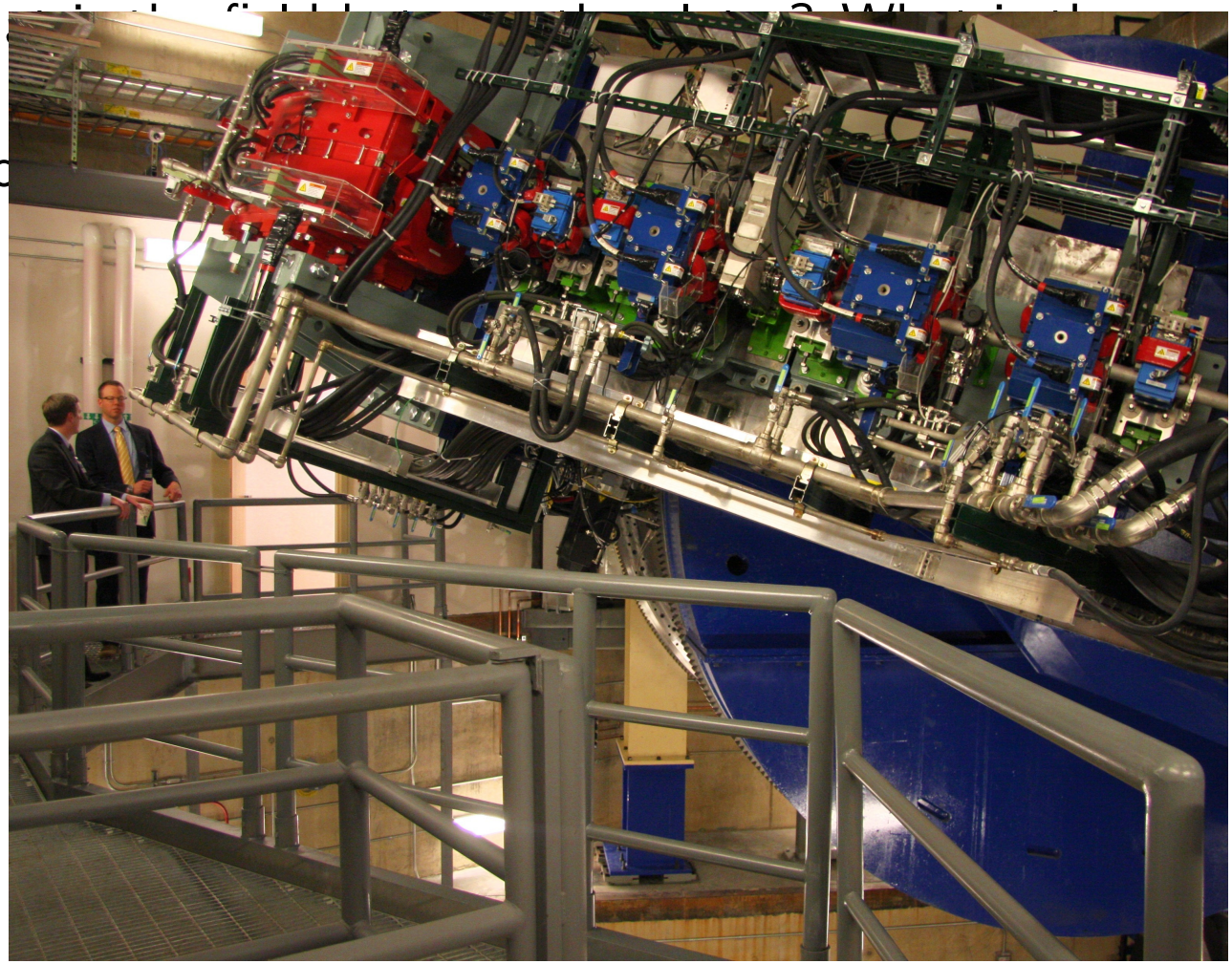
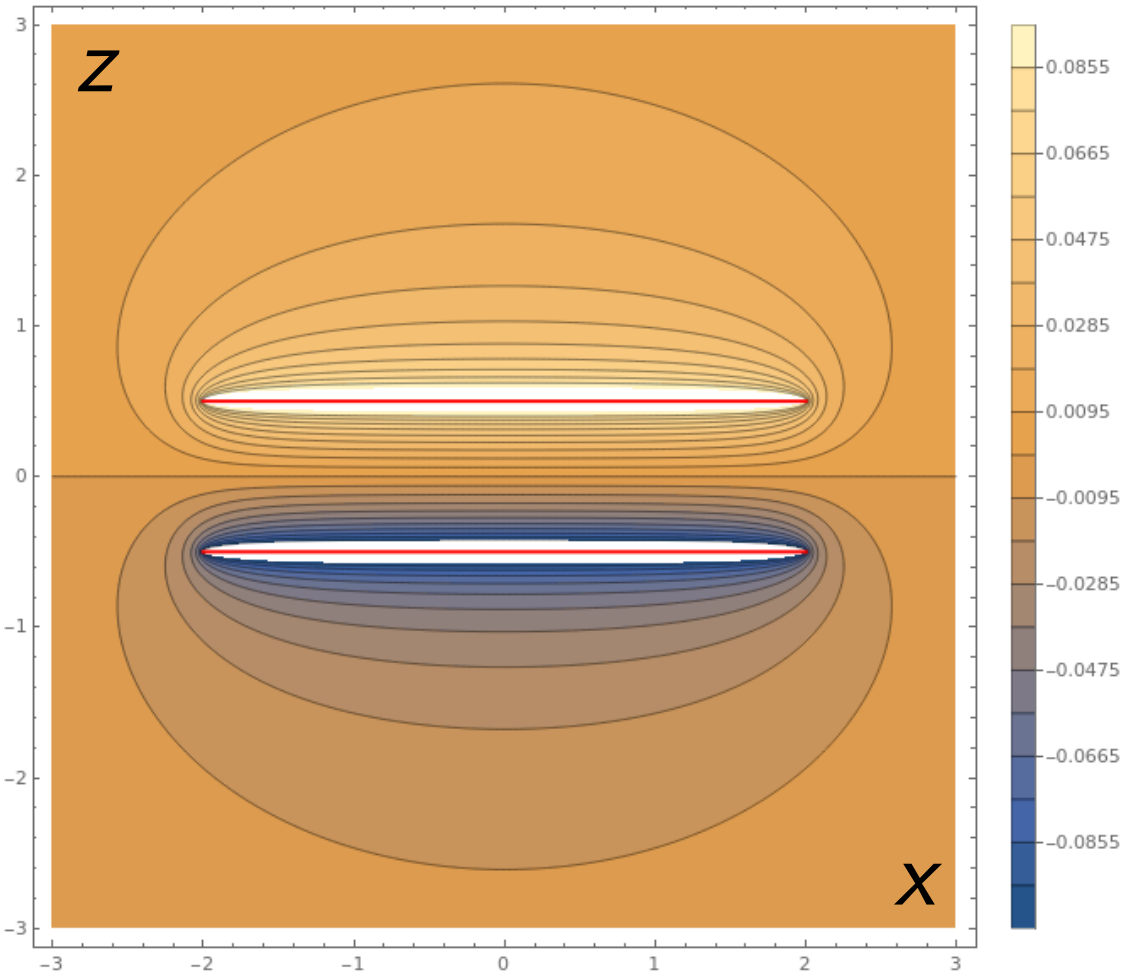


Proton therapy machine at the Mayo Clinic in Rochester, NY.

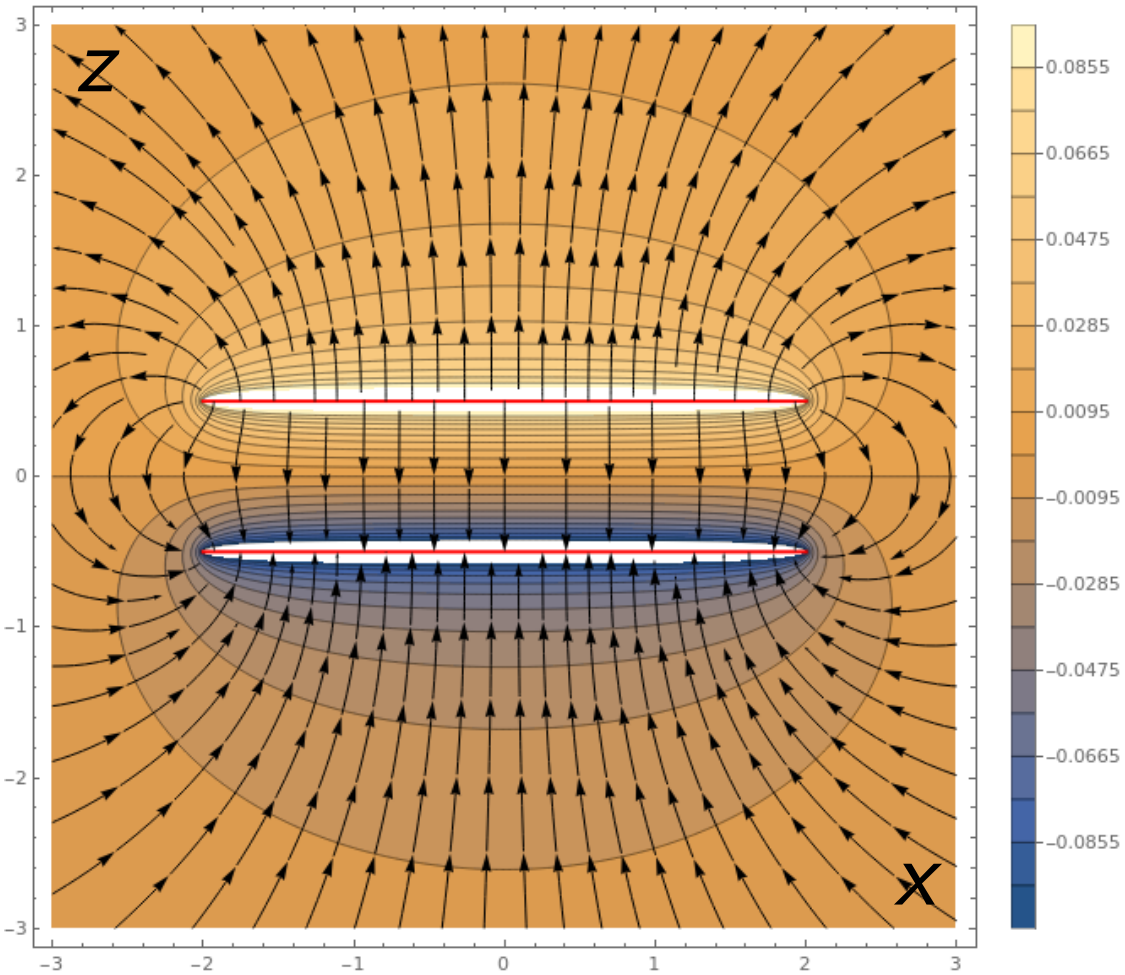
The Parallel Plate Electric Potential and Field 37



- Contours represent values of fixed electric potential - equipotentials.
- Colors also represent the value of the electric potential. See legend.
- White means the plot reached the upper or lower limit.
- Top plate (red) - positive, forms a ridge.
- Bottom plate (red) - negative, forms a valley.
- Electric field lines come out of positive charges (upper plate).
- And go into negative charges (bottom plate).
- Field lines are prependicular to equipotentials.

Units of electric potential (y direction into the plane) are V/C.

The Parallel Plate Electric Potential and Field 38



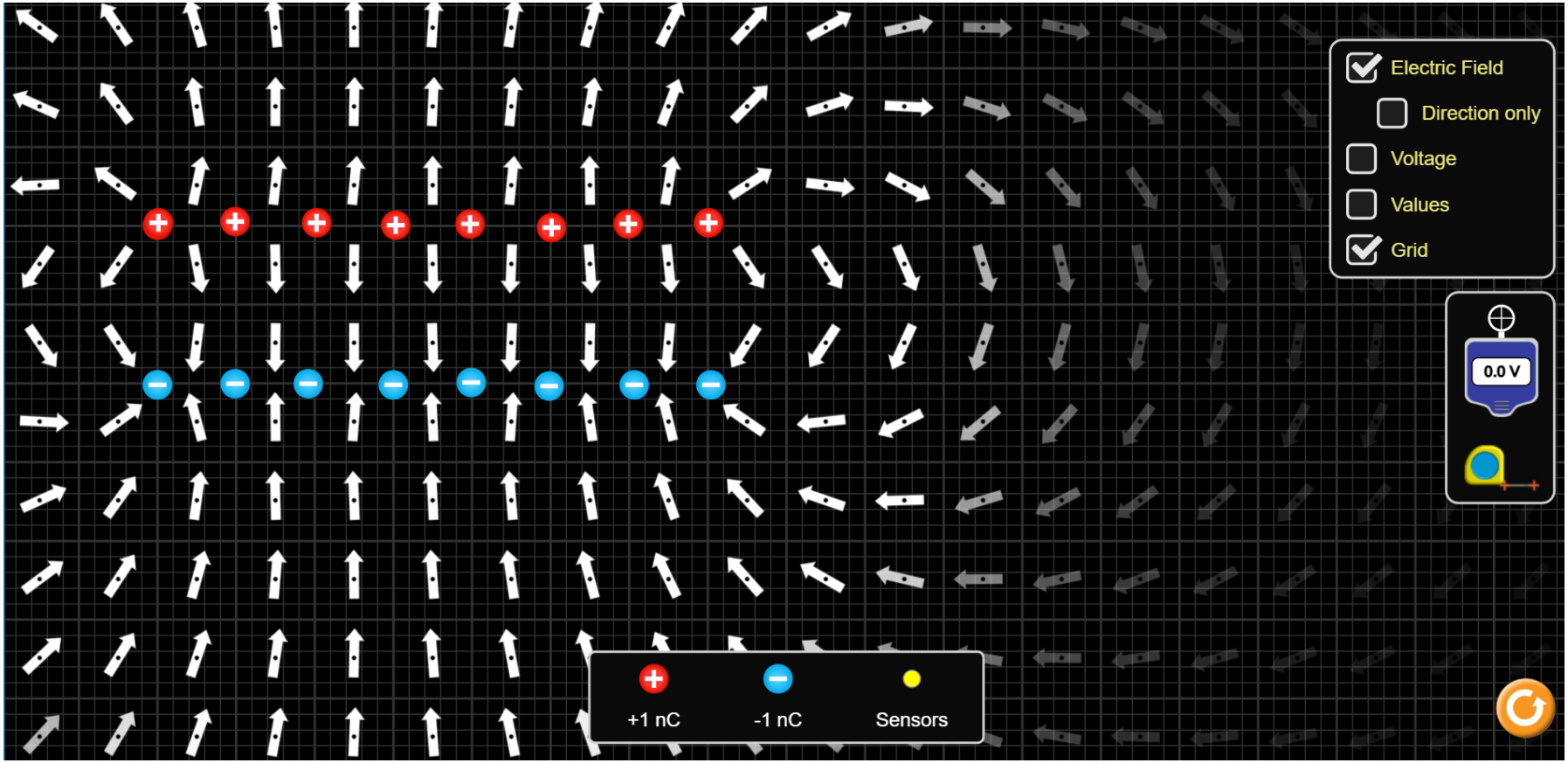
- Contours represent values of fixed electric potential - equipotentials.
- Colors also represent the value of the electric potential. See legend.
- White means the plot reached the upper or lower limit.
- Top plate (red) - positive, forms a ridge.
- Bottom plate (red) - negative, forms a valley.
- Electric field lines come out of positive charges (upper plate).
- And go into negative charges (bottom plate).
- Field lines are prependicular to equipotentials.

Units of electric potential (y direction into the plane) are V/C.

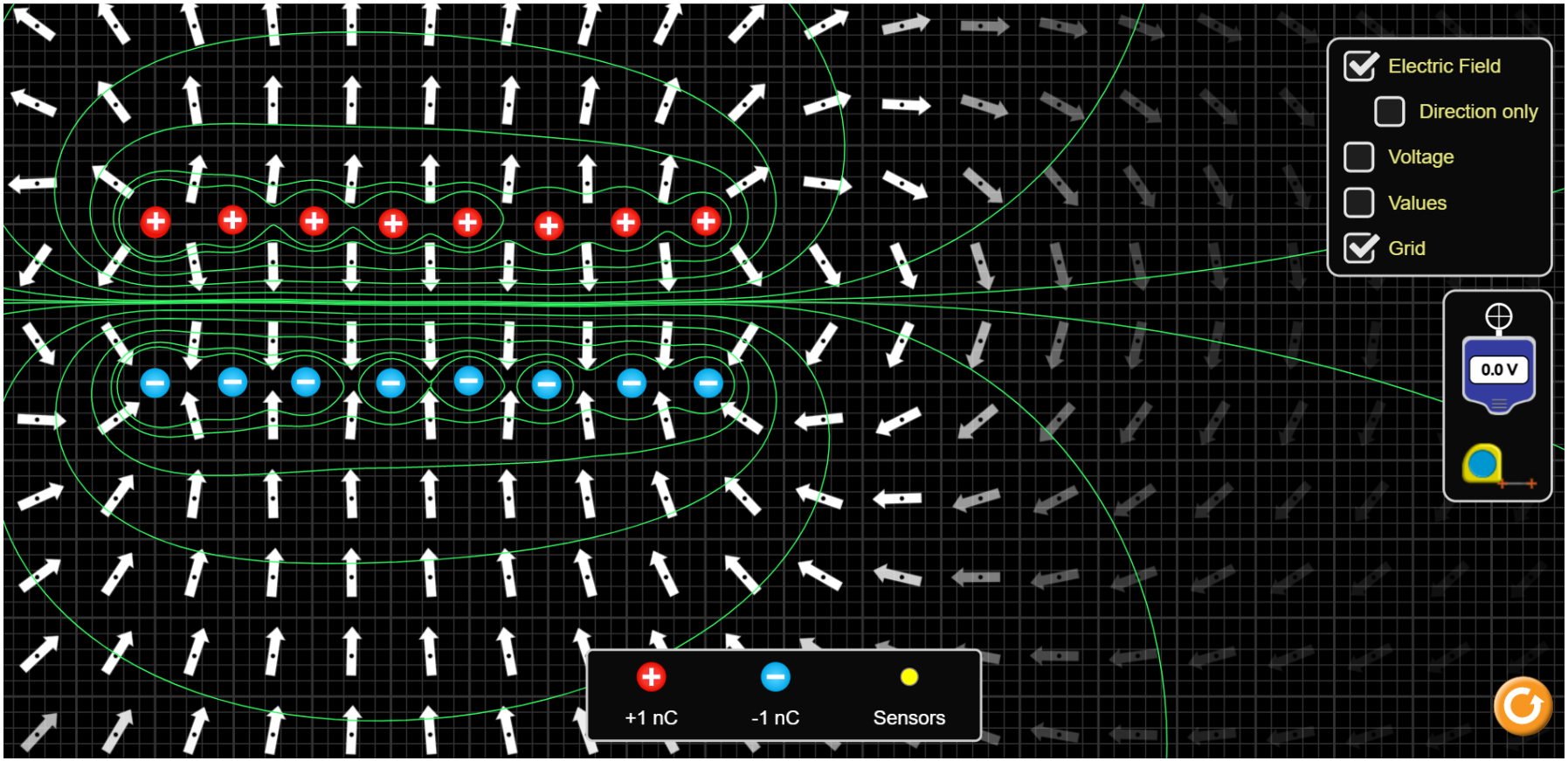
Use of Power Supply 39

1. Before plugging it in make sure it is off. The power switch should be out and the voltage knobs, coarse and fine, turned all the way down (counterclockwise).
2. Plug in the supply.
3. Hook up your circuit.
4. Set the meter switch on the readout to volts.
5. With the voltage knob still turned down, toggle the power switch. The readout should be zero.
6. You can now turn up the voltage as required. You may have to adjust the current limiting knob.

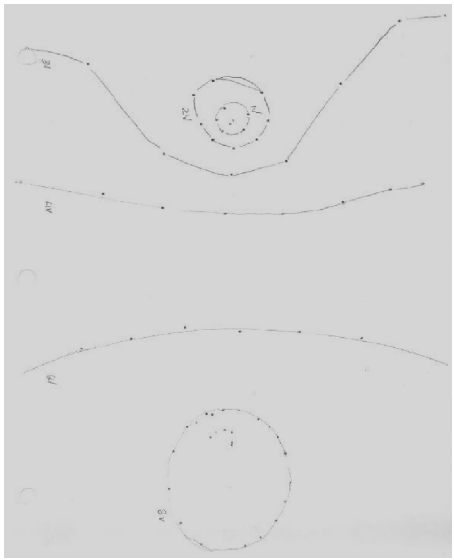
The Parallel Plate Electric Potential and Field 40



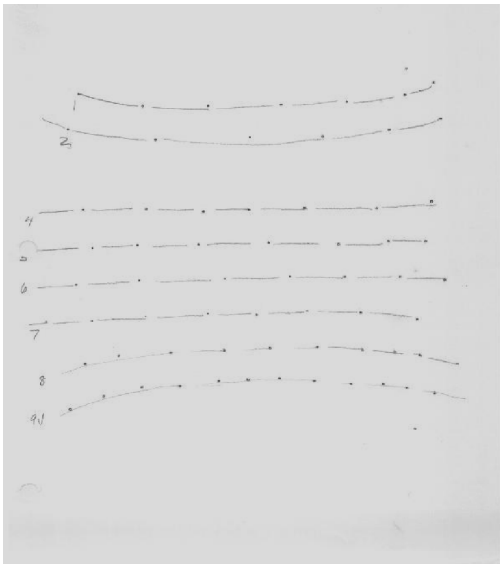
The Parallel Plate Electric Potential and Field 41



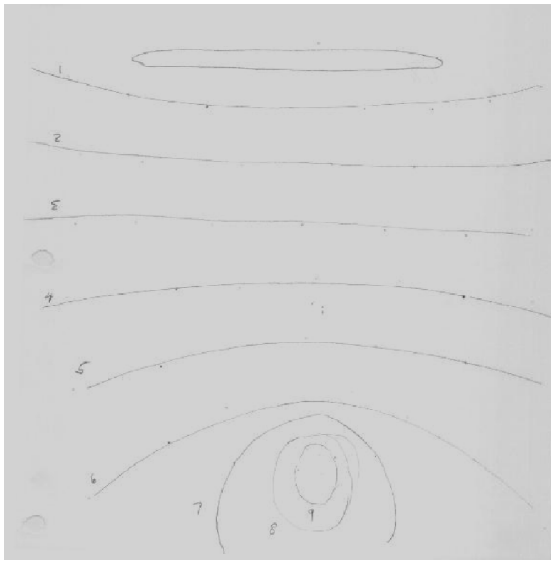
Measuring Equipotential Lines and Electric Fields 42



two point charges



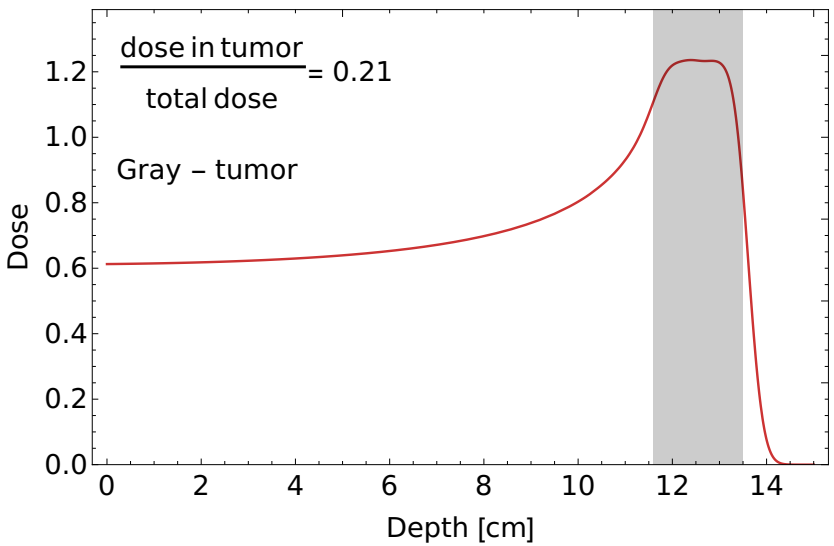
two line charges

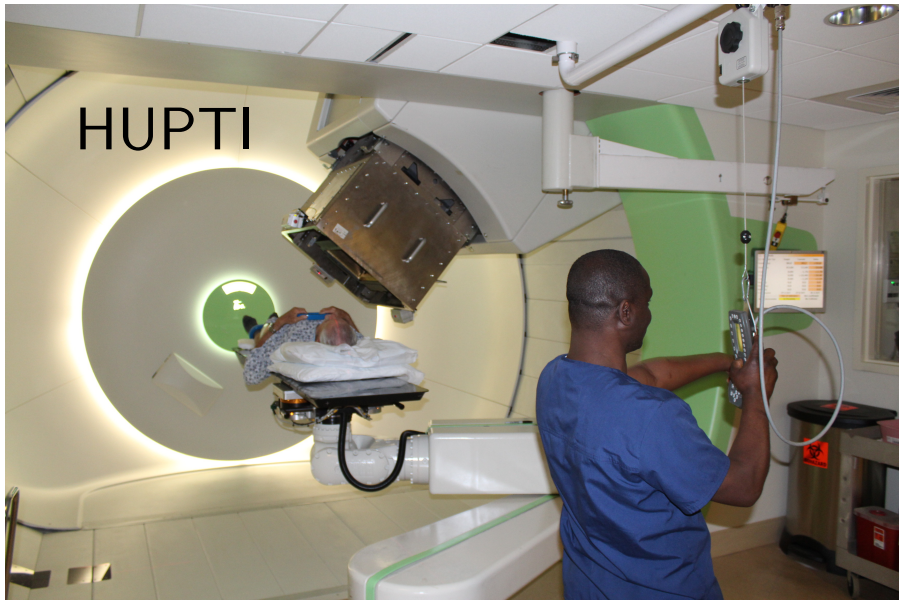


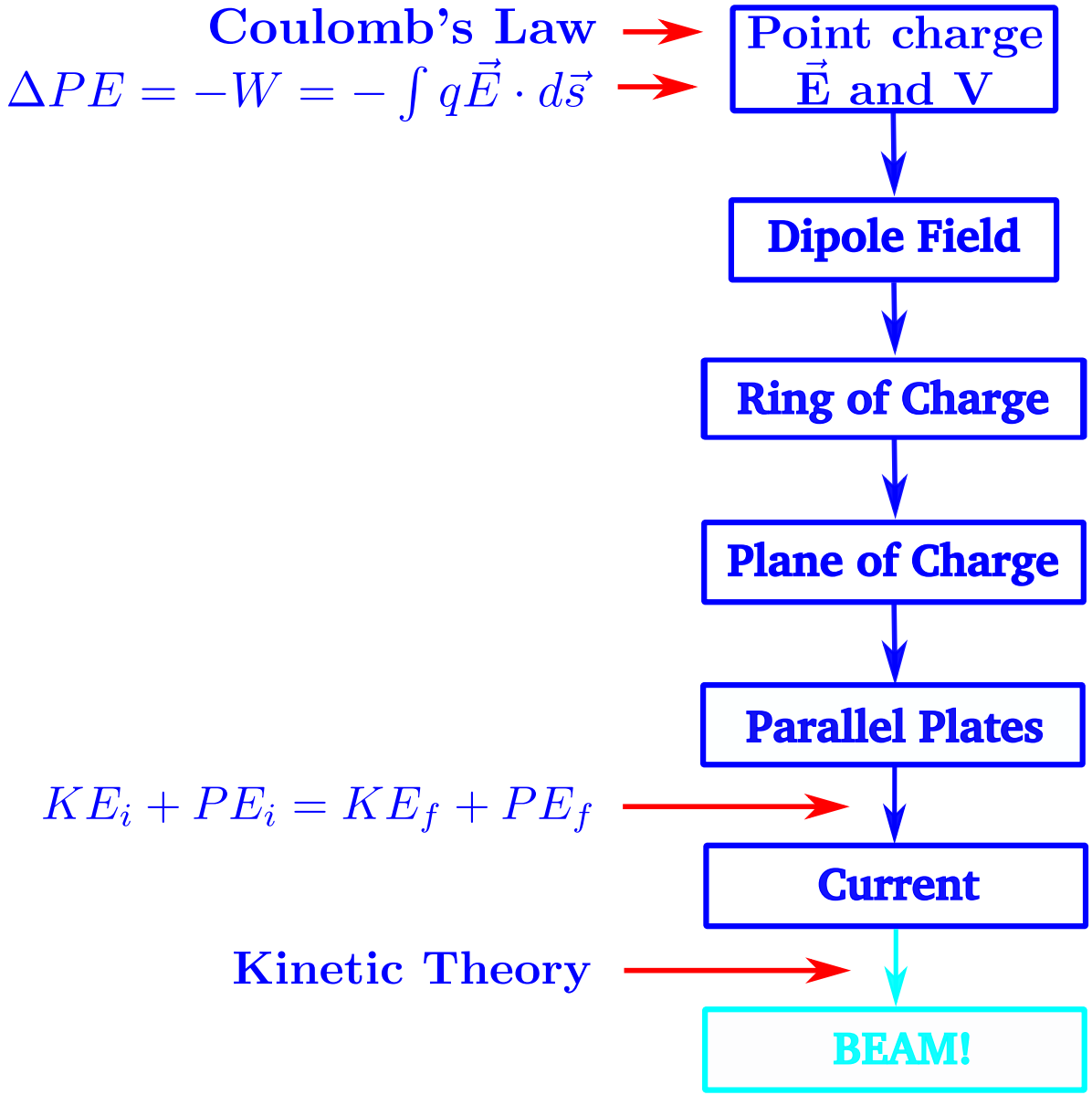
a line and a point charge

New Treatments for Cancer 43

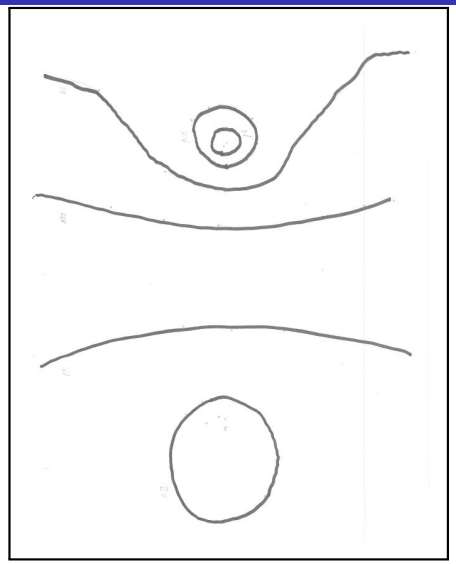
In proton-beam therapy, high-energy protons are used to kill tumors. In one case an energy $E_{dep} = 200\ J$ must be deposited into the tumor. However, only 21% of the incident proton energy E_{inc} actually goes into the tumor. To create the beam, protons are accelerated from rest through an electric potential difference $V_p = 100\ MV = 10^8\ V$. The total exposure time is to be three minutes. What is the electric current during the treatment? If the beam spot is circular with radius $r = 0.1\ m$, what is the beam proton density? Compare this with the proton density of water ($\approx 10^{28}\ m^{-3}$).



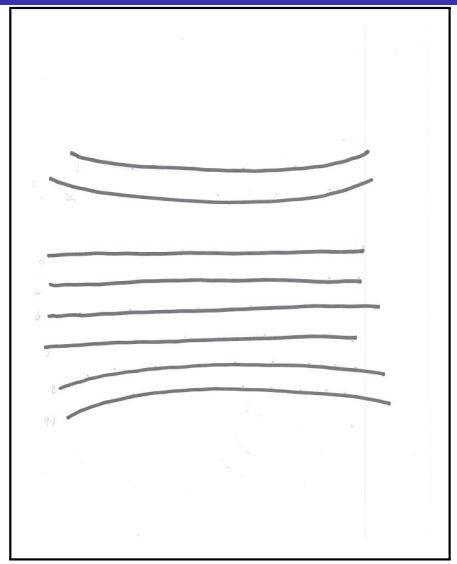



Coulomb's Law
$\Delta PE = -W = -\int q\vec{E} \cdot d\vec{s}$
Point charge
$\vec{E}$ and V
Dipole Field
Ring of Charge
Plane of Charge
Parallel Plates
$KE_i + PE_i = KE_f + PE_f$
Current
Kinetic Theory
BEAM!

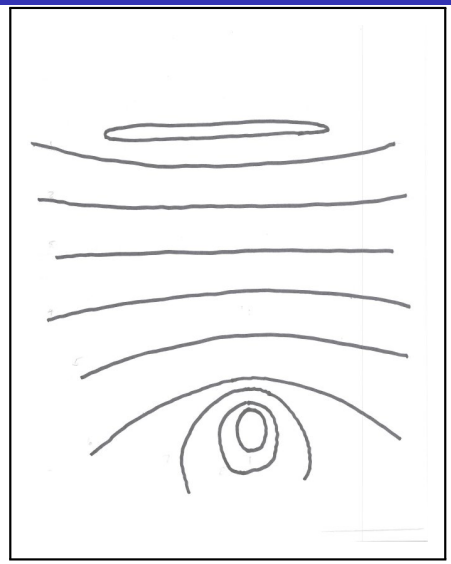
Measuring Equipotential Lines and Electric Fields 45



two point charges

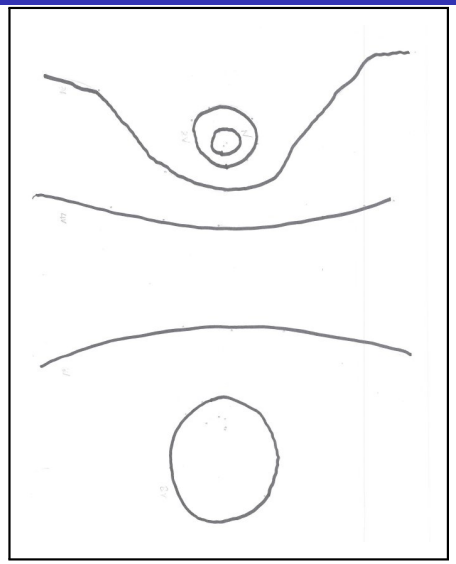


two line charges

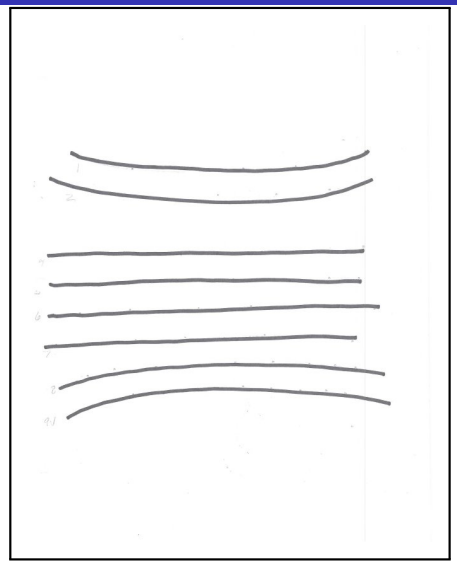


line and point charge

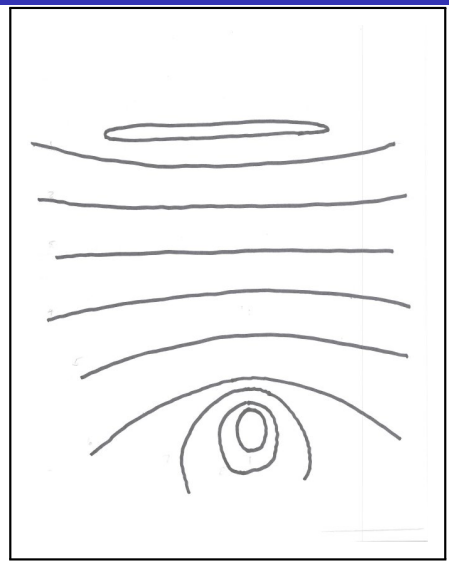
Measuring Equipotential Lines and Electric Fields 46



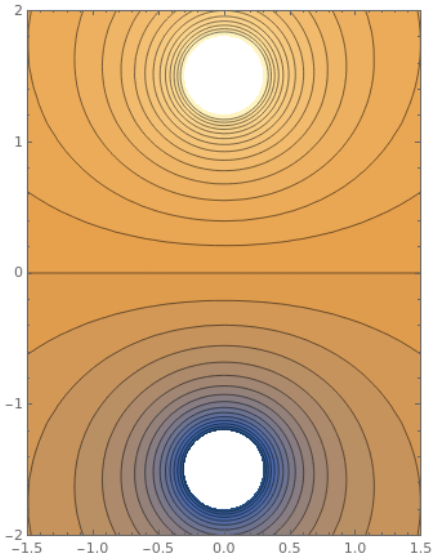
two point charges

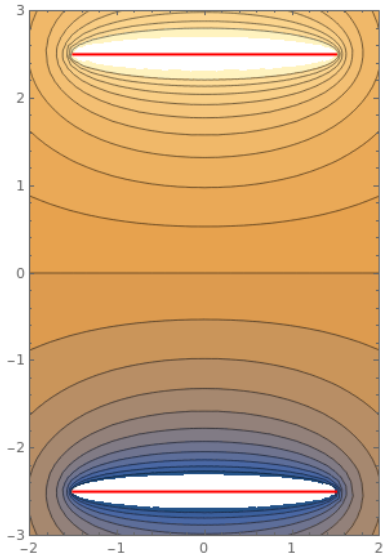


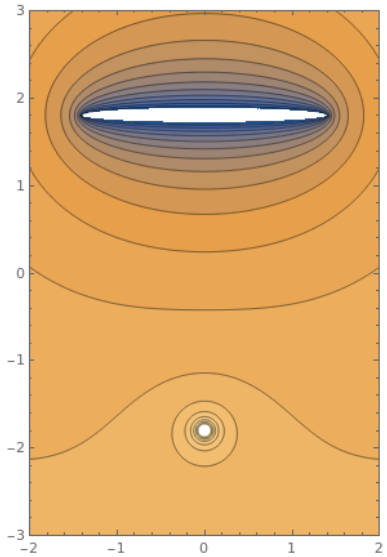
two line charges



line and point charge



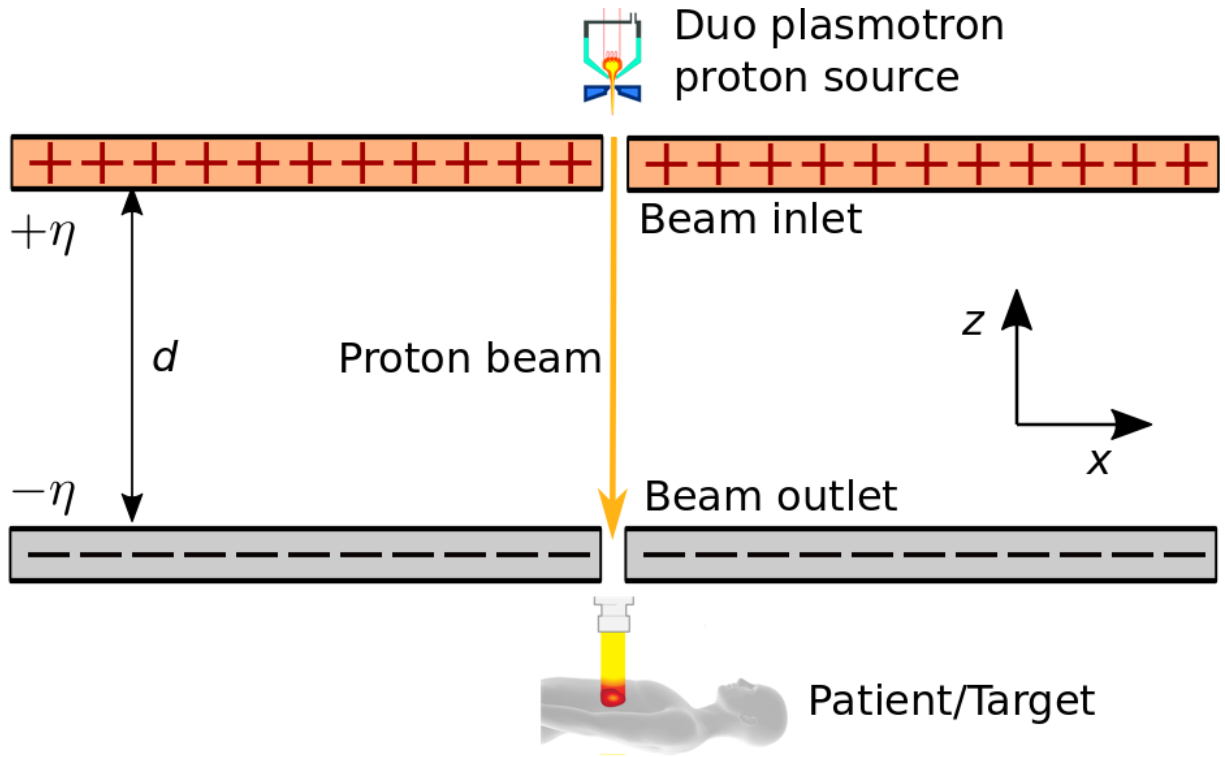




Accelerating Protons 47

To create a particle beam for cancer therapy protons are injected at low velocity between two large, metal plates with surface charge densities $\pm\eta$ and separated by a distance d. The particles speed up as they cross between the plates. What is the field between the plates? What is the electric potential across the plates in terms of the η and d? What is the kinetic energy of the protons after they leave the accelerator? What is the proton velocity?

$d = 0.1\ m$
$\eta = 8.85 \times 10^{-8}\ C/m^2$



Accelerating Protons 48

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electric potential across
kinetic energy of the pro
proton velocity?

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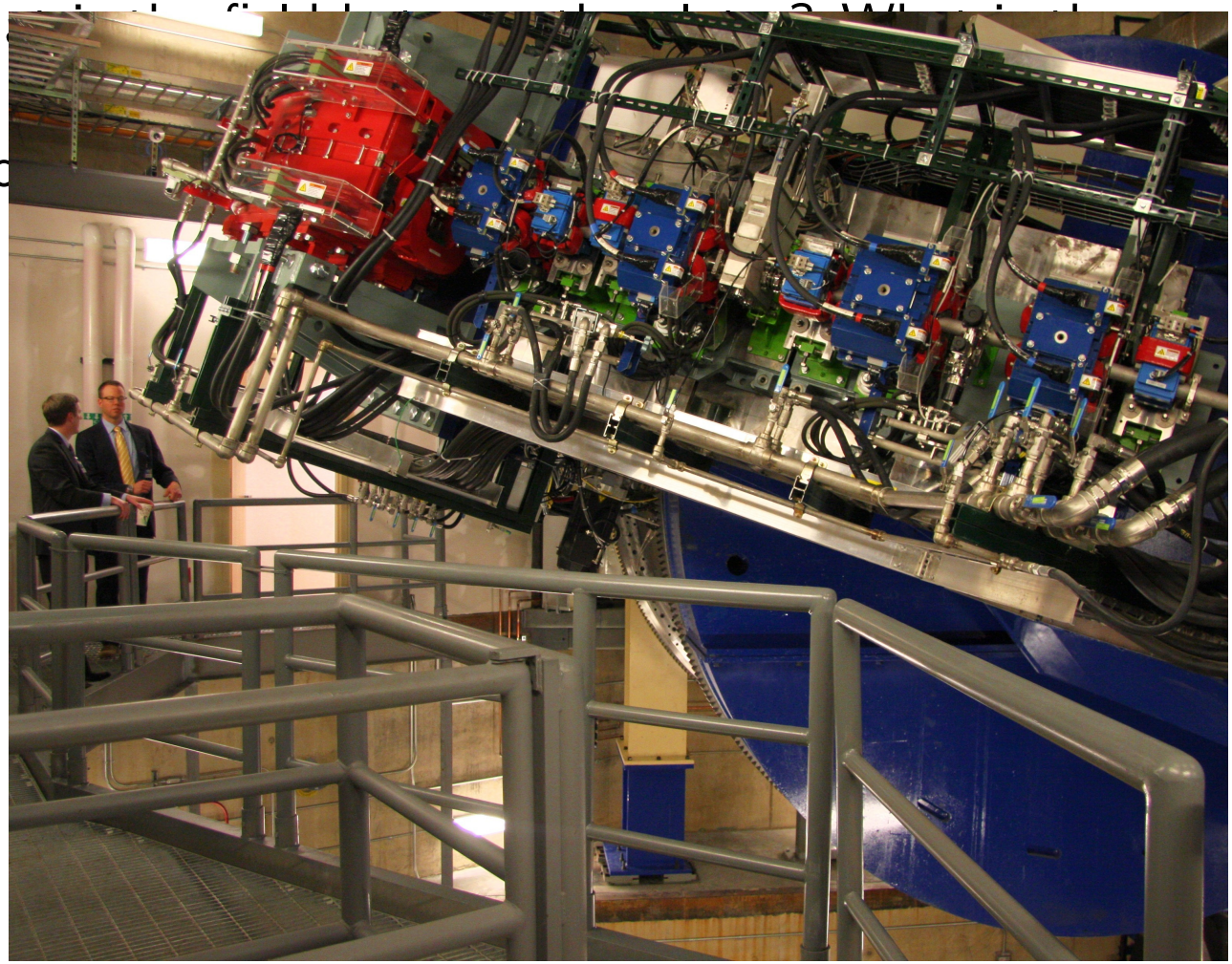

Proton therapy machine at the Mayo Clinic in Rochester, NY.

New Treatments for Cancer 49

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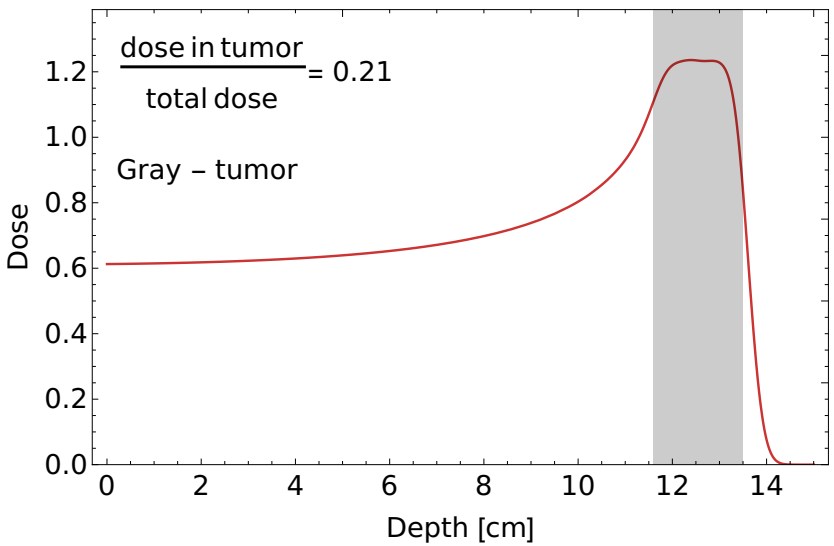
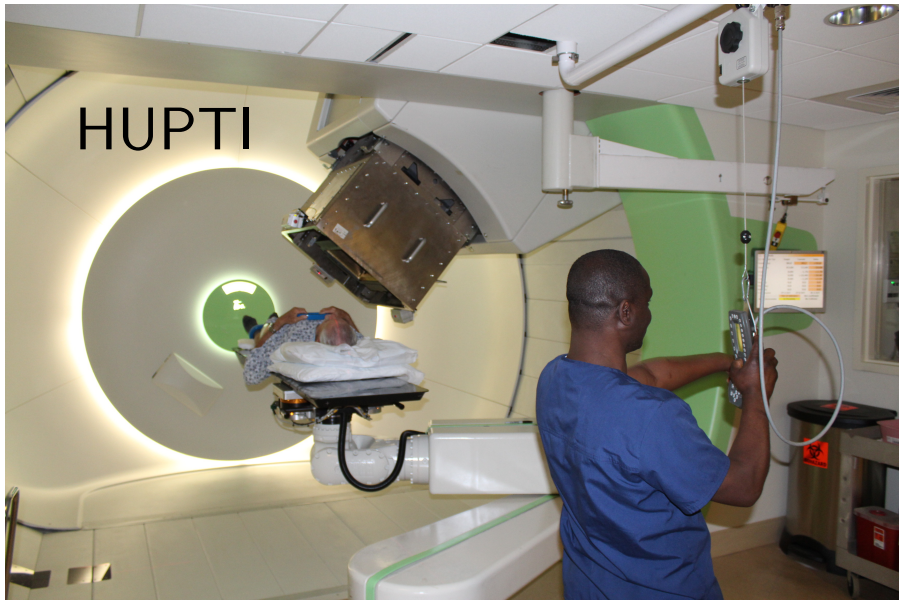
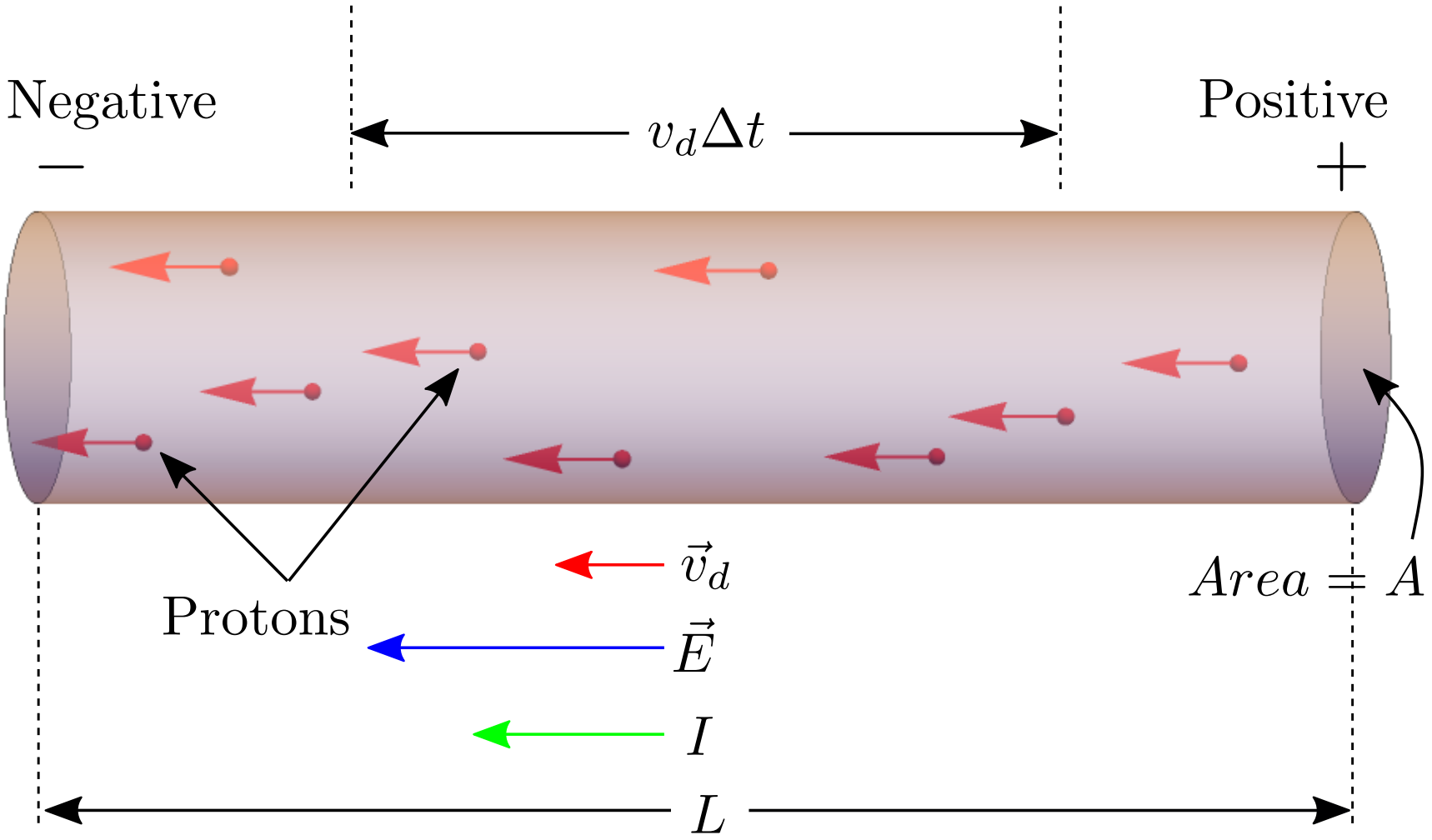




The Current of Protons in the Beam 50



New Treatments for Cancer 51

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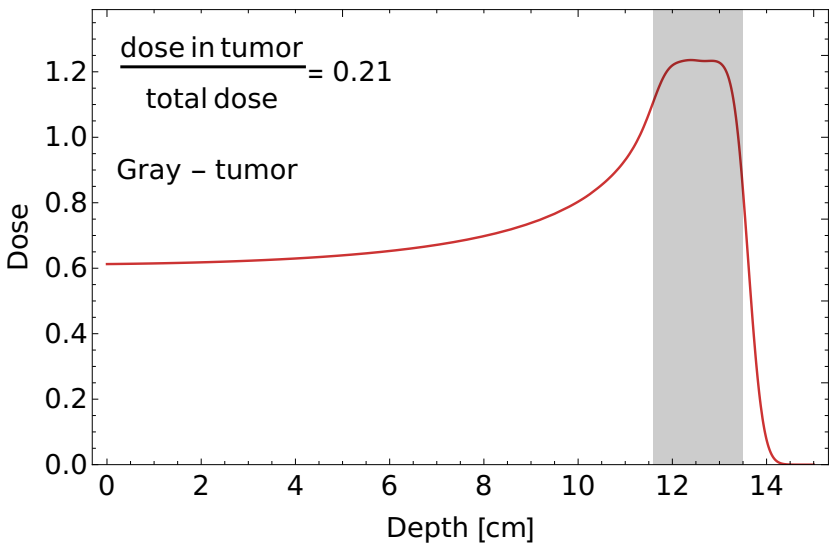
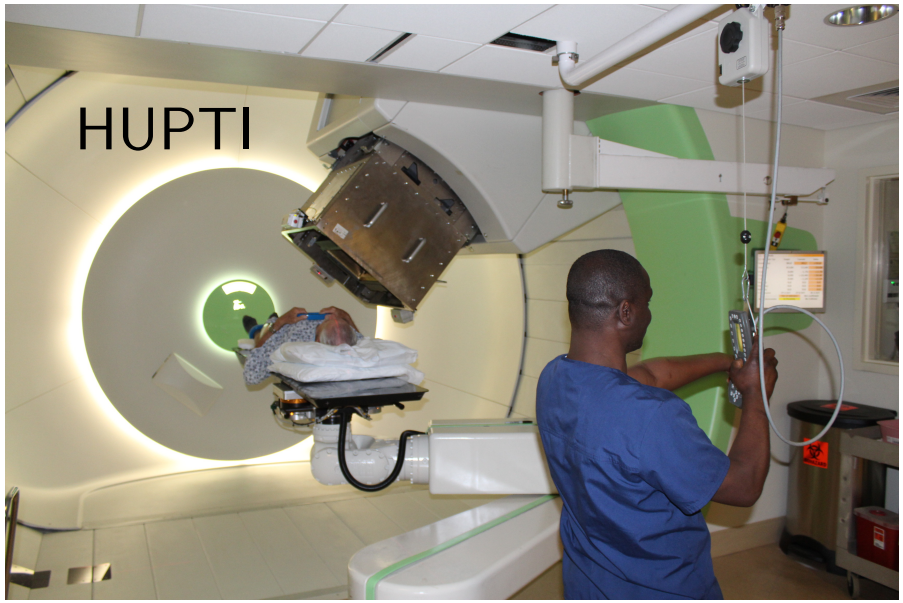
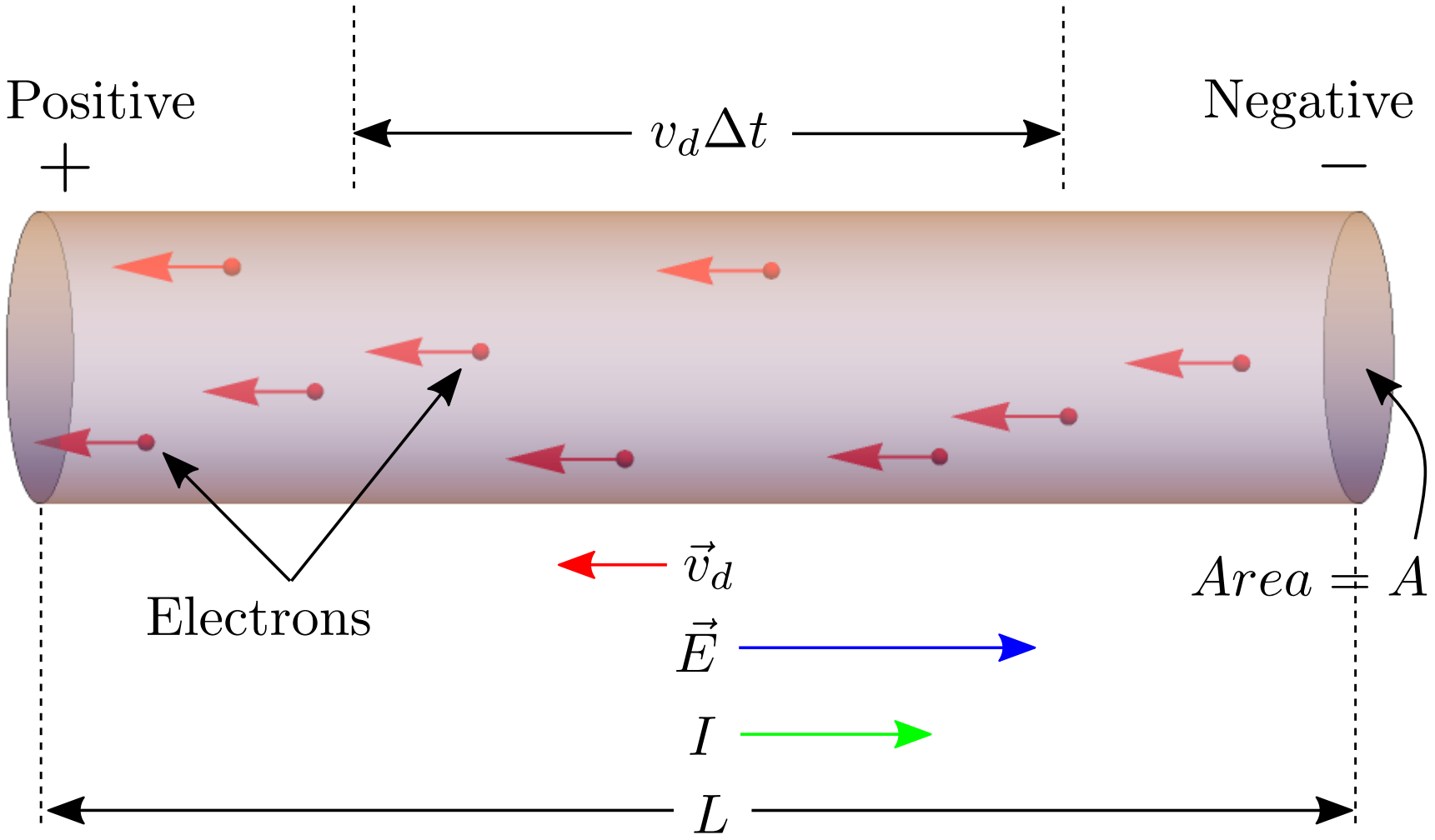





Positive
+
$v_d\Delta t$
Negative
−
Electrons
$\vec{v}_d$
$\vec{E}$
I
L
$Area = A$

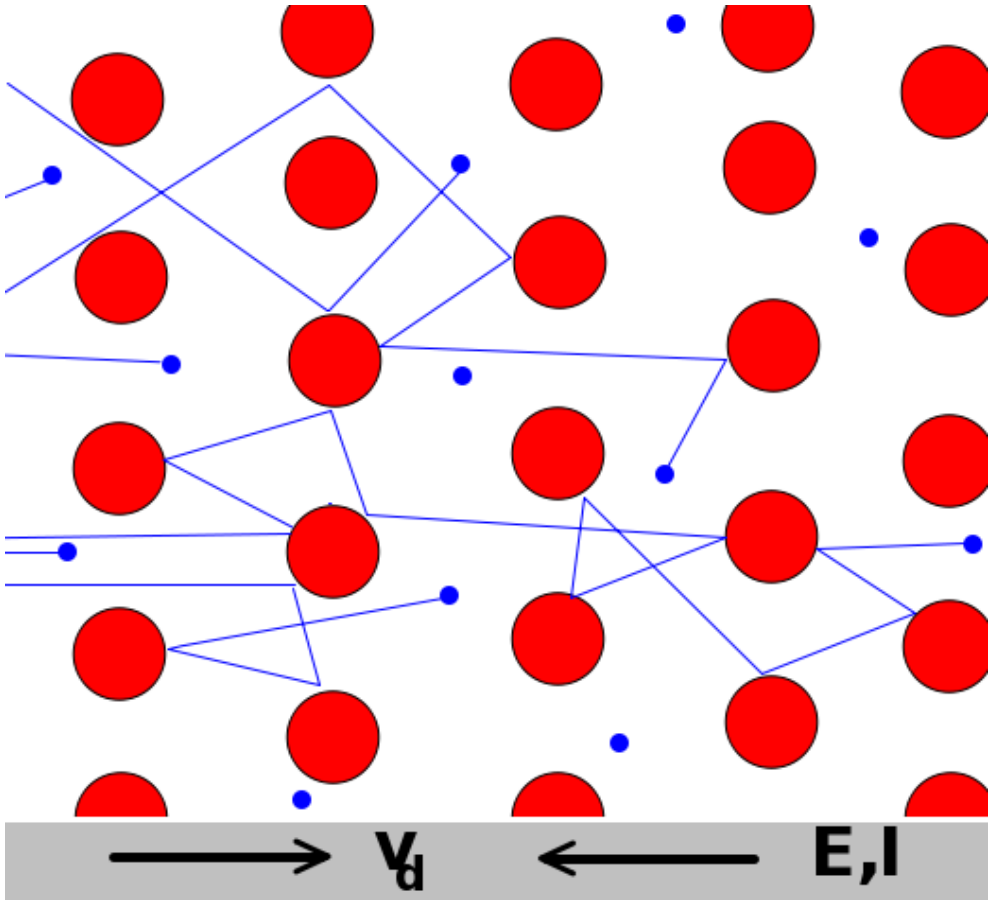
Why Are Electrons Negative? 53

Cueball tells Franklin that the charge left on a glass rod by rubbing it with silk should be the negative charge, not the positive charge, because the friction removes electrons from the rod. This would not have been intuitive to Franklin, because the electron had not as of yet been discovered. Yet by telling Franklin to reverse the positive and negative conventions, this would ultimately result in an alternate universe where electrons are assigned a positive charge. One can only speculate what other changes this reversal of convention would lead to, as small changes tend to cascade into huge ones. Would the positron have been instead named the negatron? And would this affect the success of the Transformers franchise?

567: Urgent Mission by xkcd

The Drift Velocity of Conduction Electrons - 2 54

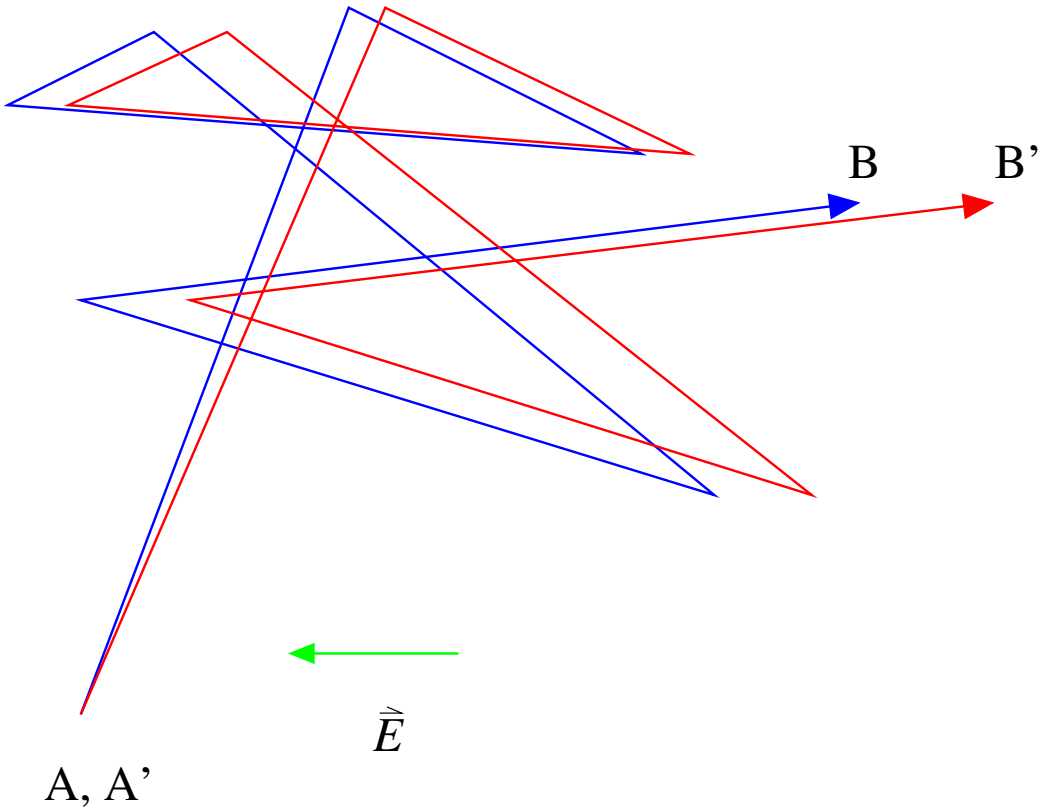
We are using the *free-electron model* to describe the conduction electrons in a metal. In this model these electrons are free to move about the entire volume of the metal and behave like the molecules or atoms of a gas in a closed container.



The Drift Velocity of Conduction Electrons - 3 55

A copper wire carrying a current $i = 20\ C/s$ has a cross sectional area of $A = 7.1 \times 10^{-6}\ m^2$. The number density of conduction electrons in copper is $n = 8.46 \times 10^{28}\ particles/m^3$. What is the drift velocity $\vec{v}_d$ of the conduction electrons? What is the average speed of electrons in the metal at a temperature $T = 25^\circ C$?

Electron Paths in a Metal



Blue: No applied voltage or field
Red: Voltage applied.