UBC Physics 102

Lecture 7

Rik Blok

Outline

- ▷ Electric potential
- ▷ Relation to electric field
- ▷ Point charges
- ▷ Potential energy
- ▷ Cathode ray tube
- ▷ End

Electric potential [Text: Sect. 23-1]

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  - Analogy: potential, $V \leftrightarrow$ height.

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  - Unit of electric potential.
  - Electric potential also called *voltage*.

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- **Discussion: Uniform field**
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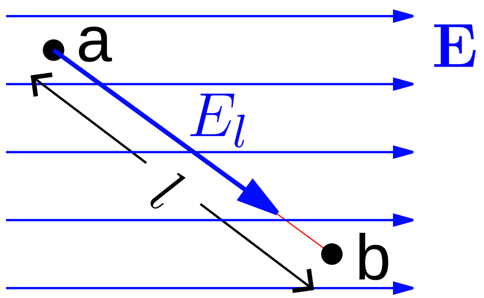

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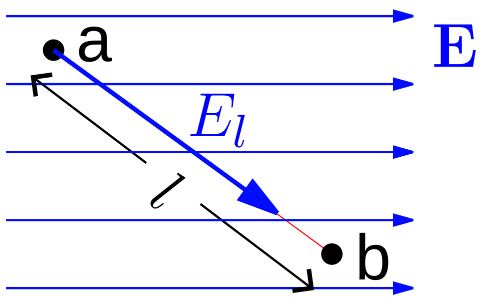

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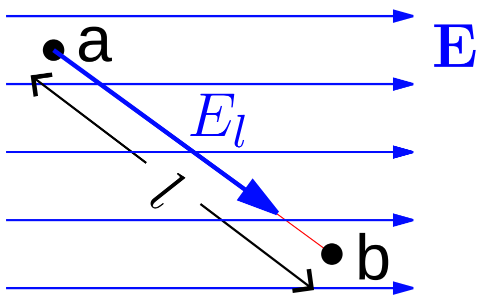

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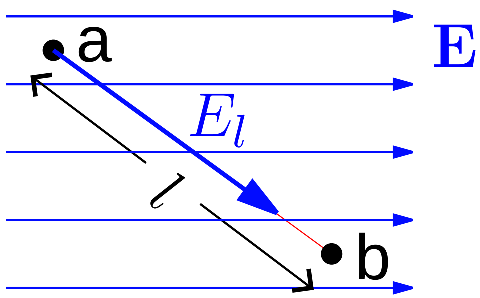

  - If $\mathbf{E}$ uniform and path straight then

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  - E_l is component of $\mathbf{E}$ parallel to path (a to b).
  - V decreases when travelling along direction of $\mathbf{E}$.

Relation to electric field, contd

- **Interactive Quiz: PRS 07a**

Relation to electric field, contd

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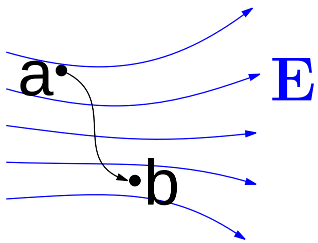
- **Discussion: Non-uniform field**



Relation to electric field, contd

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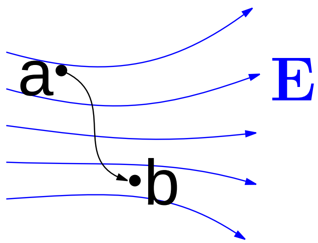

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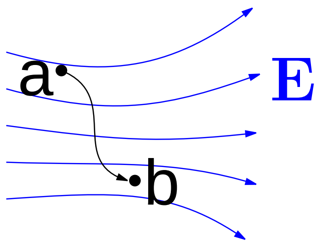

  - If $\mathbf{E}$ or path not uniform then $V = -E_l l$ meaningless.
  - But $dV = -E_l dl$ must still hold over small enough segment dl so

$$\boxed{E_l = -\frac{dV}{dl}.}$$

Relation to electric field, contd

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  - Can use to find electric field vector from potential, eg.

$$\begin{aligned}\mathbf{E} &= E_x\hat{\mathbf{i}} + E_y\hat{\mathbf{j}} + E_z\hat{\mathbf{k}} \\ &= -\frac{dV}{dx}\hat{\mathbf{i}} - \frac{dV}{dy}\hat{\mathbf{j}} - \frac{dV}{dz}\hat{\mathbf{k}}.\end{aligned}$$

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- **Interactive Quiz: PRS 07b**

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Point charges [Text: Sect. 23-3]

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- If $V = \frac{kQ}{r} + \mathrm{constant}$ then $E = -\frac{dV}{dr} = \frac{kQ}{r^2}$, Coulomb's law.
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  - So potential is defined as zero far away from Q.

Point charges, contd

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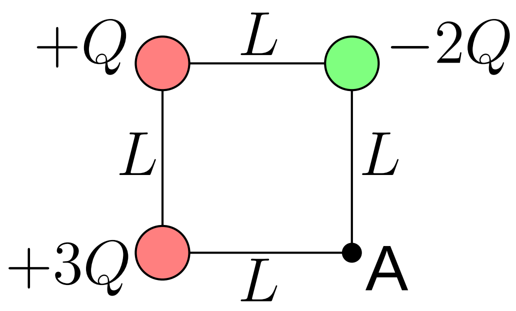
$$V = V_1 + V_2 + \cdots .$$

  - Superposition similar to rule for $\mathbf{E}$ but easier because V a scalar, so don't need to do vector addition.
  - Some cases easier to work with V, others $\mathbf{E}$.

Point charges, contd

- **Example: Pr. 30**



Point charges, contd

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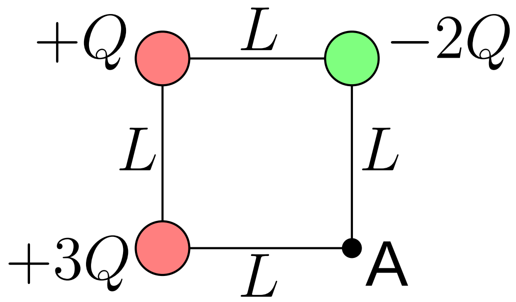

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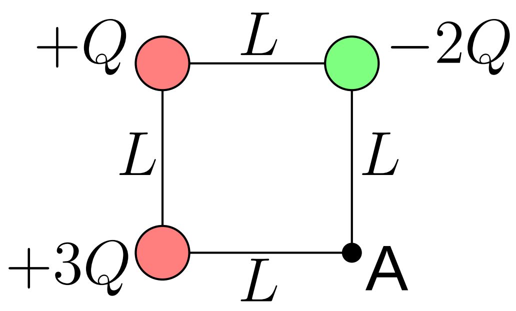

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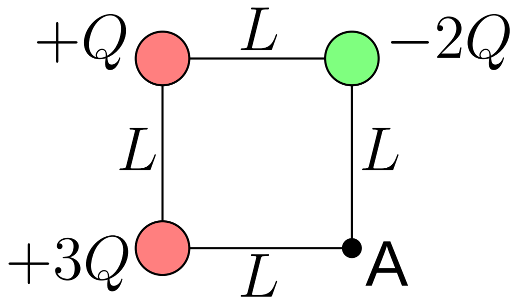

  - Three point charges are arranged at the corners of a square of side L as shown above. What is the potential at the fourth corner (point A)?

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  - First we need to calculate the potential from each charge, individually.

Point charges, contd

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  - Starting with the $+3Q$ charge, $V_3 = \frac{3kQ}{L}$.
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  - Superposing these gives the total potential at A,

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  - Much easier than calculating $\mathbf{E}$ at A!

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  - So plate B must be at a higher potential.

Potential energy, contd

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  - The change in potential energy is $\Delta U = -\Delta K = -16.4 \times 10^{-16}$ J.

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  - Voltage change from A to B is

$$
\begin{aligned}
V_{BA} &= \frac{\Delta U}{q} = \frac{-16.4 \times 10^{-16}\ \mathrm{J}}{-1.60 \times 10^{-19}\ \mathrm{C}} \\
&= 10,300\ \mathrm{V}.
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  - So B is at a potential $10,300$ V higher than A.

Potential energy, contd

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  - Use $U = qV$ and $V = \frac{kQ}{r}$ to get energy held between each pair q and Q.

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- **Discussion: Multiple charges**
  - Potential energy of a system of multiple point charges is sum of potential energies between each pair.
  - Use $U = qV$ and $V = \frac{kQ}{r}$ to get energy held between each pair q and Q.
  - Be careful not to double-count.

Potential energy, contd

- **Example: Pr. 70**

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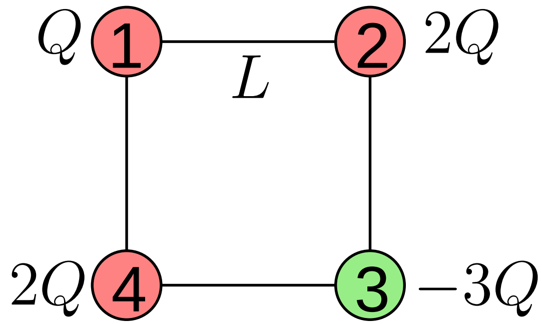
  - Four point charges are located at the corners of a square with side L, as shown. What is the total electric potential energy stored in the system?



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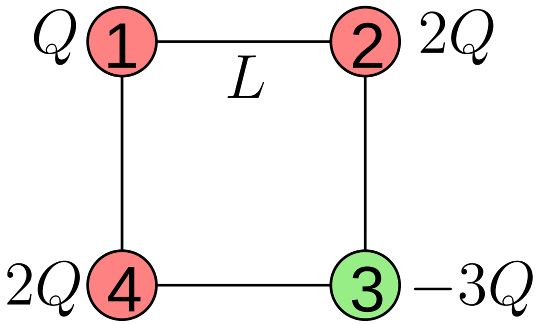

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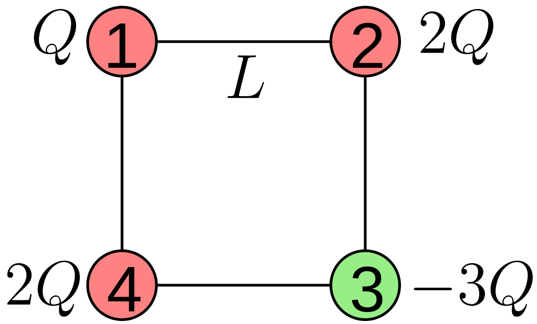

- **Solution: Pr. 70**
  - There are 6 pairs of charges. For each pair we need to calculate the potential energy stored between them.

Potential energy, contd

- **Solution: Pr. 70, contd**

Potential energy, contd

- **Solution: Pr. 70, contd**
  - Pairs:

Pair, ij	U_{ij}	Pair, ij	U_{ij}
12	$2\frac{kQ^2}{L}$	23	$-6\frac{kQ^2}{L}$
13	$-\frac{3}{\sqrt{2}}\frac{kQ^2}{L}$	24	$\frac{4}{\sqrt{2}}\frac{kQ^2}{L}$
14	$2\frac{kQ^2}{L}$	34	$-6\frac{kQ^2}{L}$

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Solution: Pr. 70, contd

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- So the total potential energy is

$$
\begin{aligned}
U &= \sum_{\text{Pairs},ij} U_{ij} = \left(2 - \frac{3}{\sqrt{2}} + 2 - 6 + \frac{4}{\sqrt{2}} - 6\right)\frac{kQ^2}{L} \\
&= \left(\frac{1}{\sqrt{2}} - 8\right)\frac{kQ^2}{L}. \quad \square
\end{aligned}
$$

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  - Energy acquired by an electron when it moves through a potential difference of $1\ \mathrm{V}$.

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  - More convenient unit than J when dealing with individual particles.

Cathode ray tube [Text: Sect. 23-9]

- **Discussion: Cathode ray tube**

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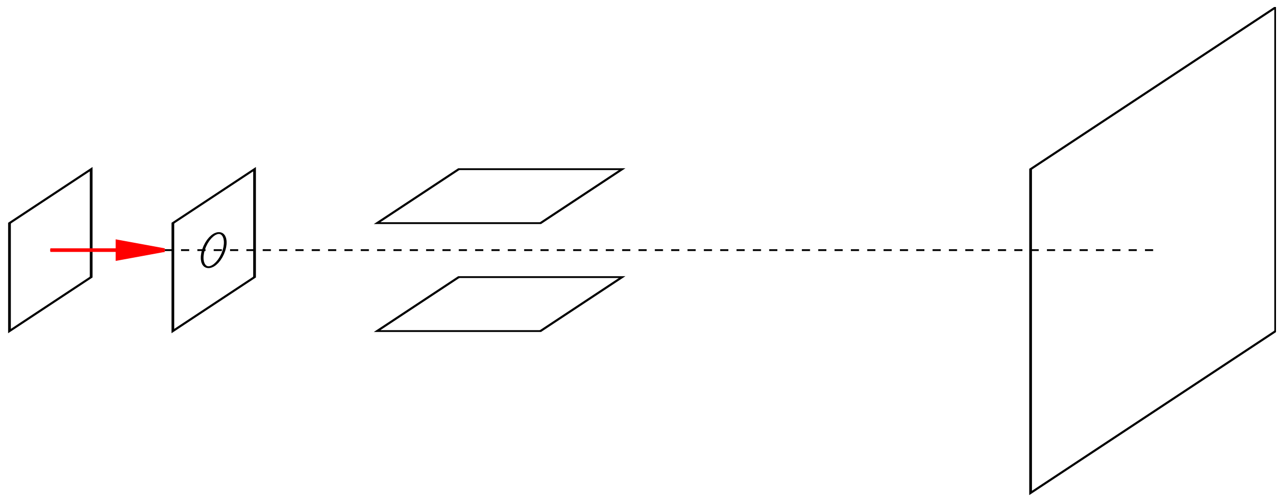
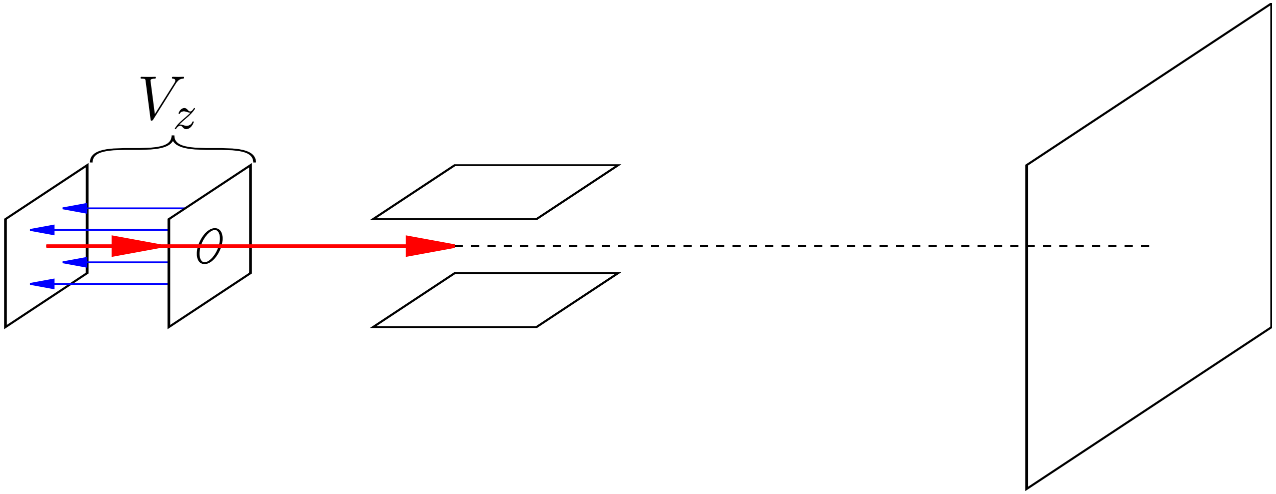
Discussion: Cathode ray tube



- When cathode heated up it "boils" off electrons.

Cathode ray tube [Text: Sect. 23-9]

- **Discussion: Cathode ray tube**



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  - CRTs use anode, V_z, to accelerate electrons.

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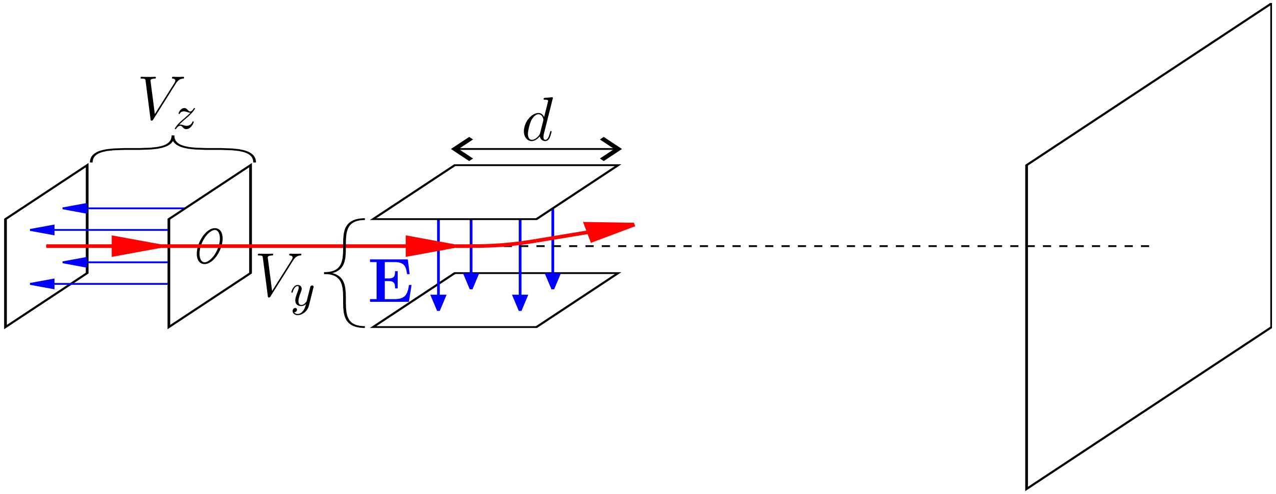

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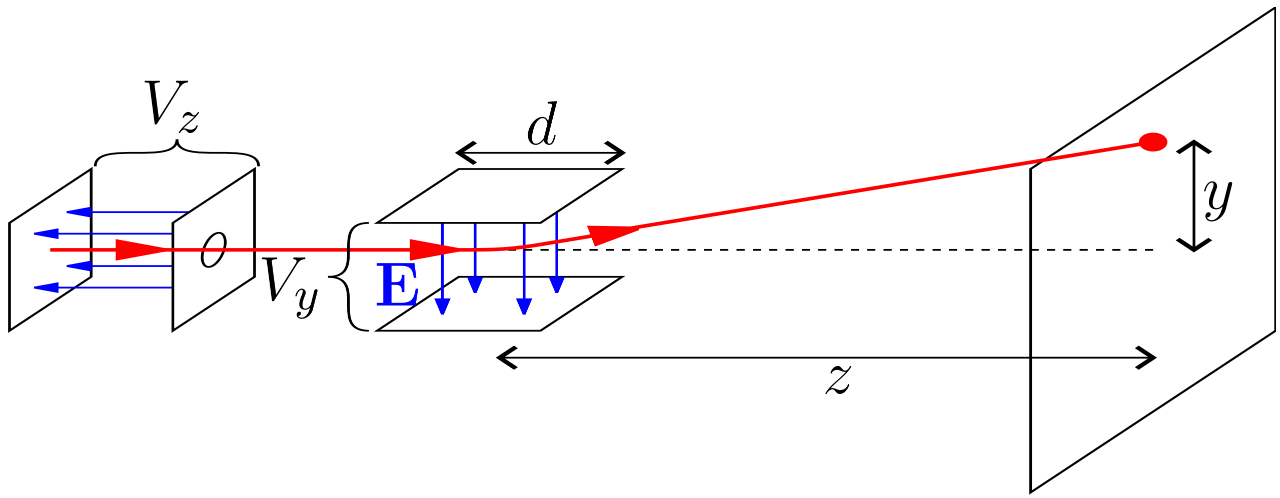

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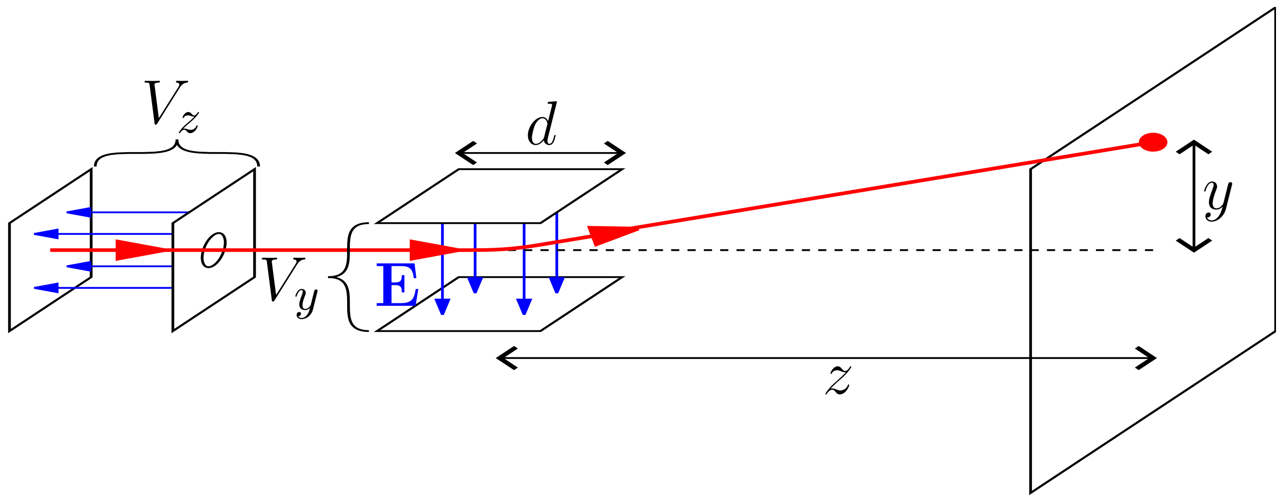

- When cathode heated up it “boils” off electrons.
- CRTs use anode, V_z, to accelerate electrons.
- Voltage V_y applied to plates to deflect electron.
- Can position precisely where electron will hit screen.
- Screen glows at point where hit.

End

- **Practice Problems:**
  - Ch. 23: Q. 1, 3, 5, 7, 11, 15, 17, 19.
  - Ch. 23: Pr. 1, 3, 5, 7, 11, 15, 21, 23, 25, 27, 29, 45, 47, 49, 51, 55, 61, 65, 57, 71, 73, 75, 77.

End

- **Practice Problems:**
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- **Interactive Quiz: Feedback**

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- **Interactive Quiz: Feedback**
- **Tutorial Question: tut07**