Physics 535 – Lecture 8
Physics of Lightning

Kasemir's treatment of a lightning leader as an equipotential

2/5/16

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(Photo courtesy of Harald Edens)

We noticed in the last lecture that a model of a leader with a uniform charge on it fit well with the measured electric fields on the ground.

Kasemir gives a simple picture that explains why this is a good choice for charge model.

Kasemir claimed that you simply needed to

Look at how an equipotential

Line adjusted to an ambient potential to understand

The charge on a lightning channel.

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A Contribution to the Electrostatic Theory of a Lightning Discharge

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Abstract. The electrostatic treatment of the field and charge distribution of a lightning discharge leads to the result that the charge distribution of a lightning stroke is composed of (1) the influence charges induced by the electric field of the thundercloud with the net charge zero, and (2) the net charge, which results from the potential difference of the lightning stroke and the ground before the lightning hits the ground. The first kind of charge distribution is that of a cloud discharge and that of the first leader of a ground discharge. The second kind of charge distribution is a feature of the main or return stroke of a ground discharge only. It is the charge distribution of a charged body and independent of the field distribution in the thundercloud. We can therefore apply to the return stroke the well-known electrodynamic theory of transients on a transmission line.

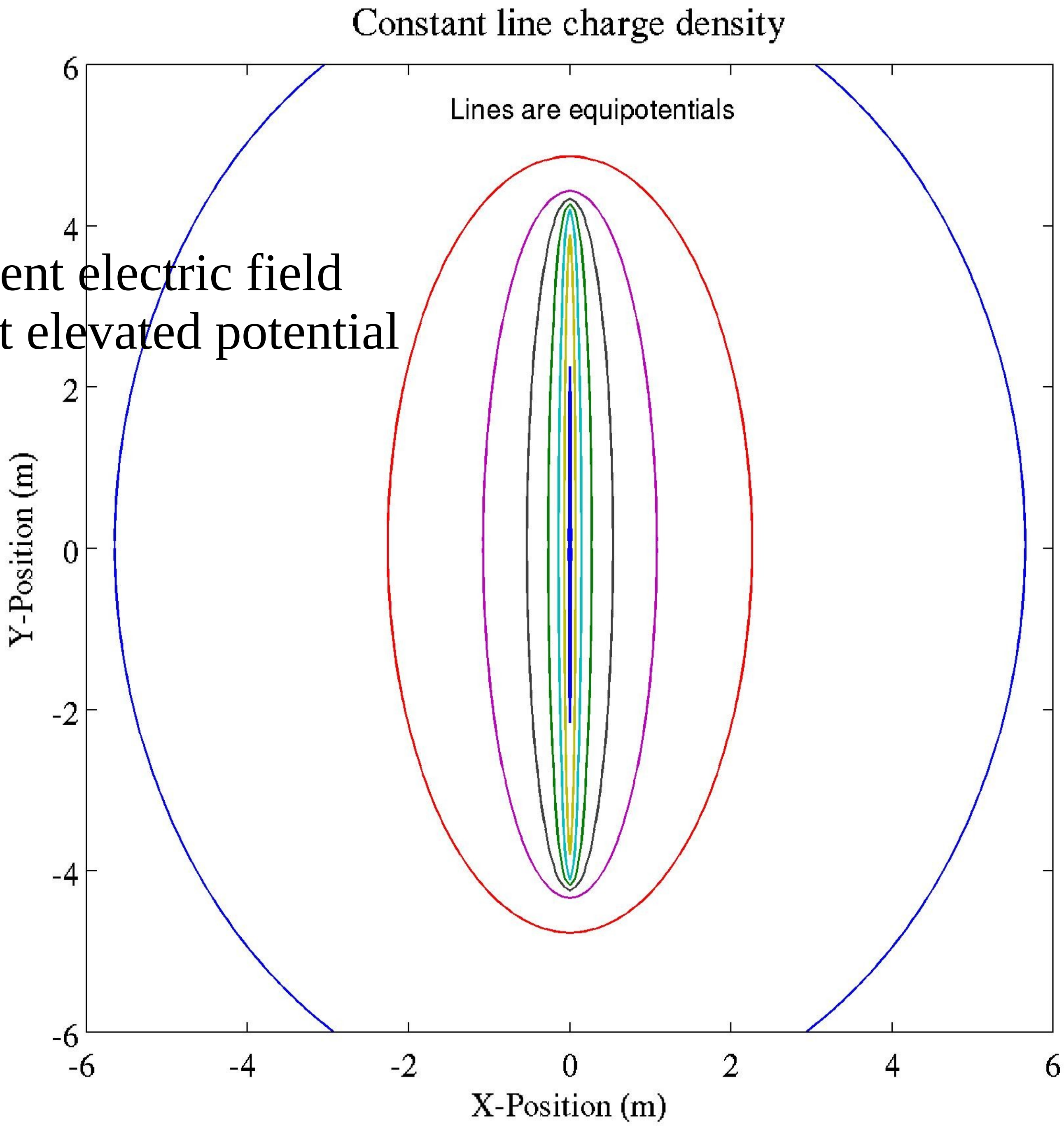
Kasemir said he "Used a spheroid"

He means an very prolate ellipsoid of revolution.

Note that in my simulation of charges on a line, the equipotentials rapidly approach prolate ellipsoids. I used a line … that is not an exact equipotential (as you can tell from my plots).

However, it is much easier than an ellipsoid, and it is "close enough"

No ambient electric field
Line is at elevated potential

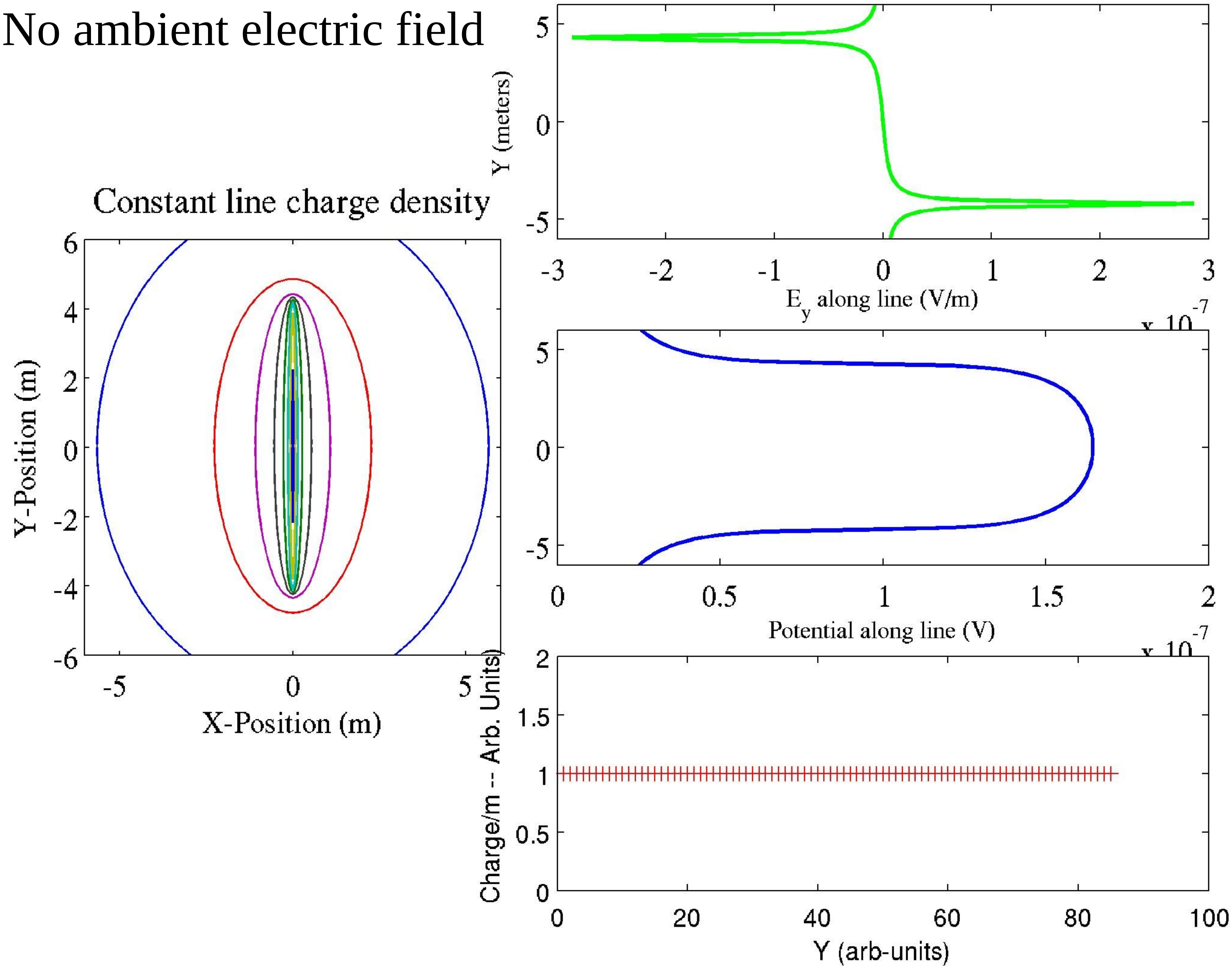


If you want an ellipsoid to be an equipotential … you can simply not put any charge on it.

However … if you put a uniform charge per unit length, it will still be an equipotential, but it will no longer be at ground potential.... so to move a conducting line from ground to any other potential … charge it.

The strong E-fields at the ends (green curves) bring the potential up.

No ambient electric field



If you have a uniform vertical field, and you put a vertical conductor in it, there will be what Kasimir calls an “influence charge”.

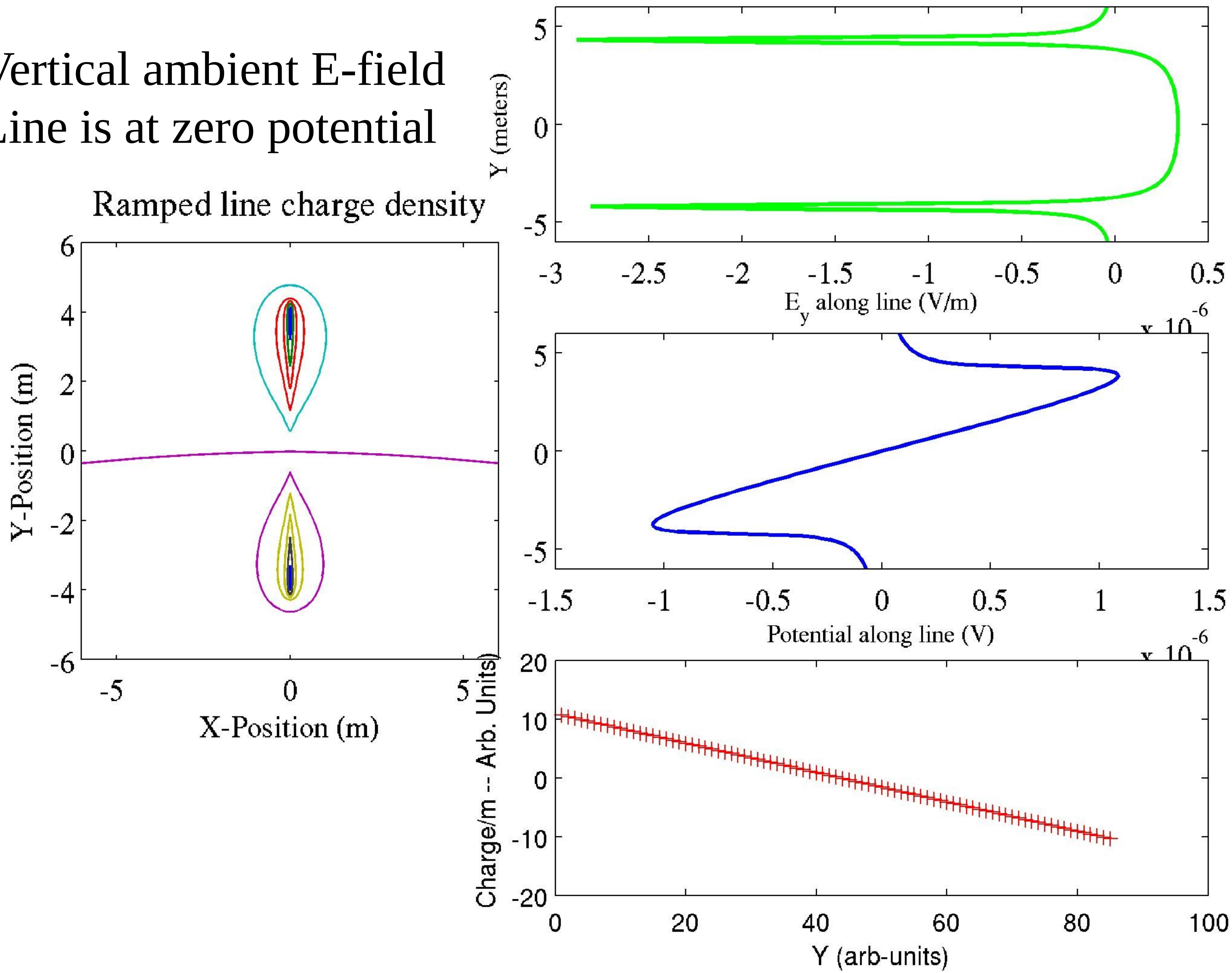
You can't have any field inside the conductor … but you have a field outside it, so there must be some charge re-arrangement to cancel the outside field.

One way to think about this is … “what charge would be need to create a vertical field = and opposite to the pre-existing field. It turns out that you can put a linearly varying surface charge on the conductor. The charge isn't IN the conductor … it's ON the conductor.

The field IN the conductor is zero, but the surface charge creates an opposite field at its surface that allows this to be so.... you can almost pretend the field IS inside the conductor (but it's not)

Hope I cleared that up!!!

Vertical ambient E-field
Line is at zero potential



Kasemir's very
Insightful cartoons

Dark vertical line=
Conductor

Light solid line=
Ambient potential
vs. altitude.

Shaded region=
Charge density vs.
Altitude.
(arbitrary scale
Makes charge look
Like mirror image
Of potential.

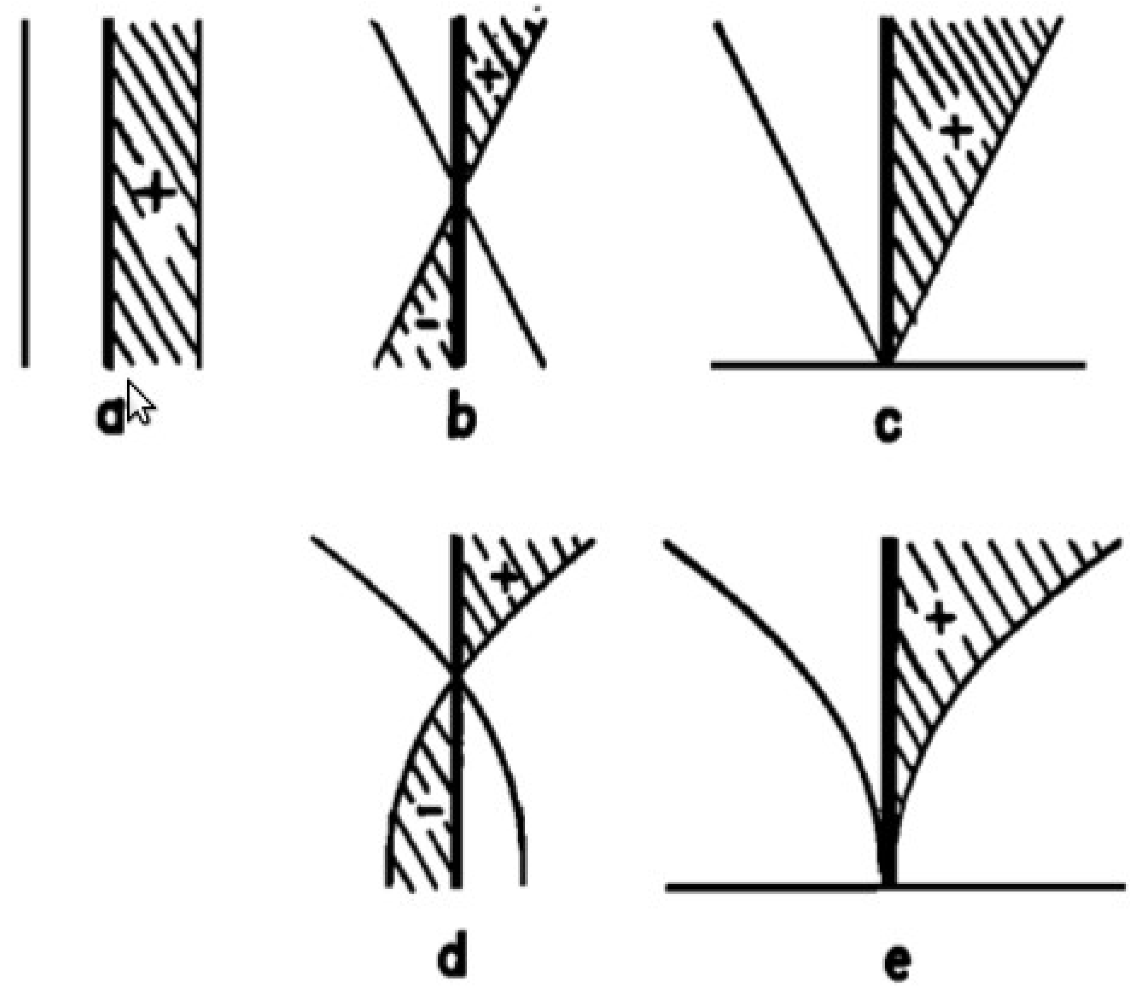


Fig. 1. Charge distribution: (*a*) on a charged spheroid; (*b*) on an uncharged spheroid in a homogeneous electric field; (*c*) on a charged spheroid in a homogeneous electric field; (*d*) on an uncharged spheroid in an inhomogeneous electric field; (*e*) on a charged spheroid in an inhomogeneous electric field.

Appox. Potential
For tripole charge
Structure.

Lightning leader is at
Potential of green dot.

When channel touches
Ground, the reference
Potential changes to
Zero volts at ground.

That is only possible
By adding a uniform
Charge to the channel

Add a constant to previous
Charge curve.