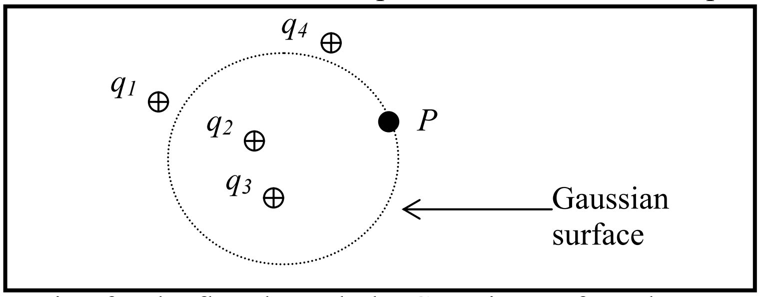
Workshop Tutorials for Physics

ER3: **Flux and Gauss' Law**

A. Qualitative Questions:

1. Consider a Gaussian surface that encloses part of the distribution of positive charges shown below.



a. Write an expression for the flux through the Gaussian surface shown.
b. Which of the charges contribute to the electric field at point *P*?
Suppose you have a Gaussian surface which contains no net charge.
c. Does Gauss' law require that there is no electric field at all points on the surface? Draw a diagram to help explain your answer.
d. Is the converse necessarily true, i.e. that if the electric field is zero everywhere then the charge contained must be zero?

2. A "Faraday cage" is a metal cage used to shield devices from electromagnetic fields. These are often used in precision experiments when a very small voltage needs to be measured. For example, a Faraday cage is usually used when measuring potential changes across nerve membranes, otherwise these changes cannot be detected due to "noise" from nearby electrical wiring.
a. Using gauss' law, explain how a conducting wire cage can shield its contents from external electric fields.
It is regularly proposed that Faraday cages be placed around sources of electric fields, such as mobile phones and large transformers, to protect people from possible effects of exposure to electric fields.
b. Would this shield nearby people? Explain why or why not.

B. Activity Questions:

1. Faraday's Icepail
Explain how the initially neutral pail became charged.
Why is the charge transferred totally to the pail and not shared between the pail and the ball?
How does this experiment confirm Gauss' law?

2. Gauss' law
Fill the metal can with polystyrene balls and place it on the generator.
Now turn the generator on. Explain what happens.
Remove the metal can and replace it with the plastic one.
Explain what happens this time when you turn the generator on.

3. Flux
Hold the solar panel in front of the light.
What is the direction of the vector representing the area upper surface of the panel?
Give an expression for the flux of light onto the panel.
How can you orient the panel to maximise the flux?
If the orientation were kept constant, how would the flux change if you doubled the area of the panel?

C. Quantitative Questions:

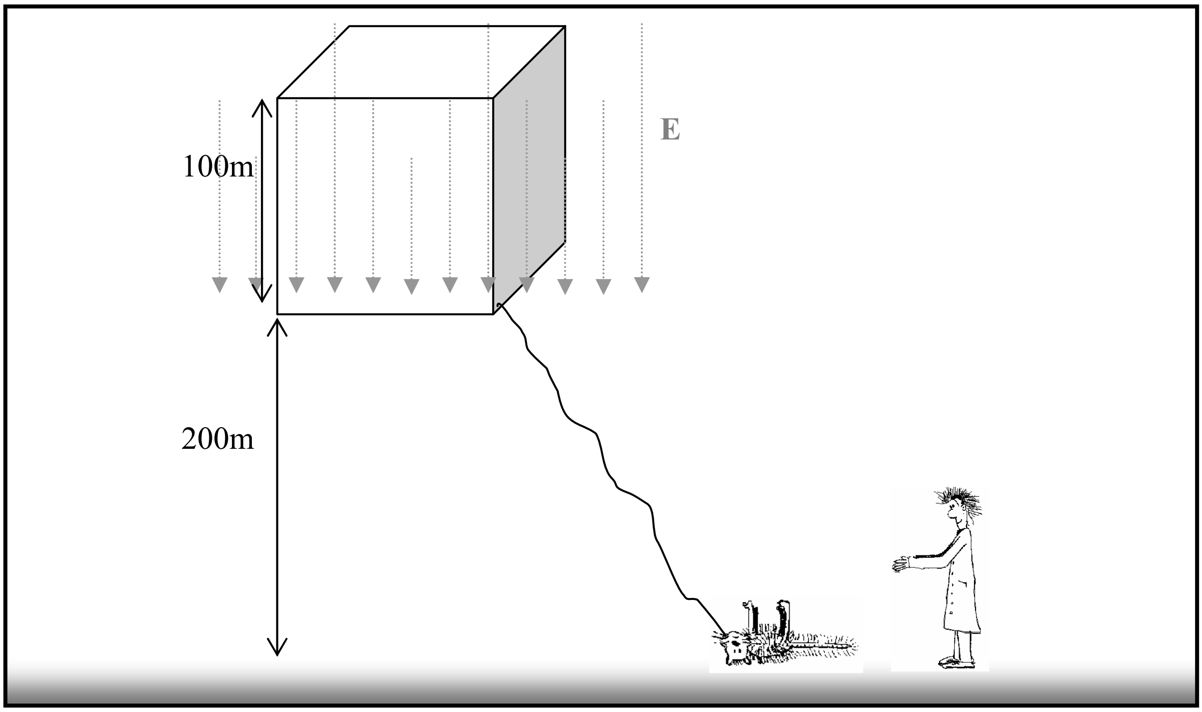
1. Doctor Frankenstein's great grandson, Wayne Frankenstein, has discovered the original notebooks explaining the process of reanimation. Being a scientist himself, he sets out to continue his great grandfather's experiment. Wayne finds a vacant block where he measures the electric field at a height of 300m to have a magnitude of 60 $N.C^{-1}$, and at 200m the field has a magnitude of 100 $N.C^{-1}$. The field is directed vertically down.

Wayne builds a machine which will capture all the charge in a cube of size 100 m×100 m×100 m.

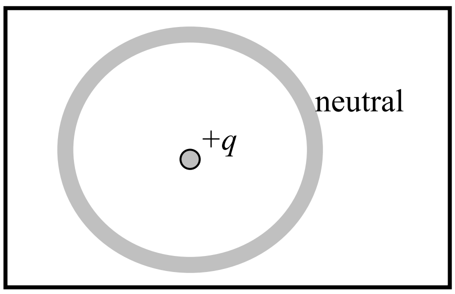
a. If the cube has horizontal faces at altitudes 200 m and 300 m, what will be the flux through the surface of this cube?

b. How much charge will Wayne's machine collect?

c. Wayne directs the charge through a dead cat to reanimate it. If all the charge flows through the cat in 1.0 ms, what current will flow through the cat?



2. A neutral, spherical, thin metal shell has a point charge $+q$ at its centre.



a. Draw a diagram showing the field lines and distribution of charges.

b. Use Gauss' law to derive expressions for the electric field between the charge and the shell, and the field outside the shell.

c. Has the shell any effect on the field due to q?

d. Has the presence of q any effect on the charge distribution of the shell?

e. If a second point charge is held outside the shell, does this outside charge experience a force?

f. Does the inside charge experience a force?

g. Is there a contradiction with Newton's third law here? Why or why not?