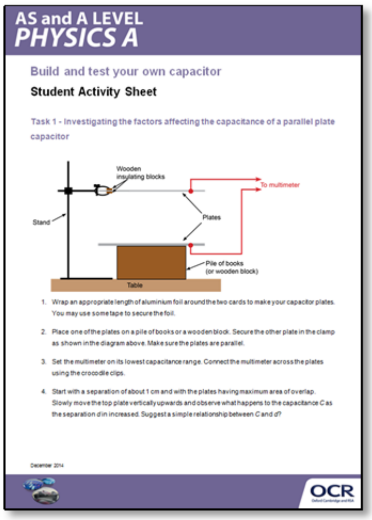
AS and A LEVEL
PHYSICS A

Lesson Element

Build and test your own capacitor

Instructions and answers for teachers

***These instructions should accompany the OCR resource* ‘Build and test your own capacitor’ *activity** *which supports OCR AS and A Level Physics A.*


AS and A LEVEL
PHYSICS A

Build and test your own capacitor

Student Activity Sheet

Task 1 - Investigating the factors affecting the capacitance of a parallel plate capacitor

1. Wrap an appropriate length of aluminium foil around the two cards to make your capacitor plates. You may use some tape to secure the foil.
2. Place one of the plates on a pile of books or a wooden block. Secure the other plate in the clamp as shown in the diagram above. Make sure the plates are parallel.
3. Set the multimeter on its lowest capacitance range. Connect the multimeter across the plates using the crocodile clips.
4. Start with a separation of about 1 cm and with the plates having maximum area of overlap. Slowly move the top plate vertically upwards and observe what happens to the capacitance C as the separation d in increased. Suggest a simple relationship between C and d?

December 2014

The Activity:

This resource comprises of 1 task.

This activity offers an opportunity for English skills development.

This activity offers an opportunity for maths skills development.

Associated materials:

‘Build and test your own capacitor’ Lesson Element learner activity sheet.

Suggested timings:

Task 1: 10 minutes **Task 2:** 30 minutes

Introduction

There are many different types of commercial capacitors. They differ in size and construction, but they all have one common feature – they all store charge. Students will no doubt use such commercial capacitors to build and test circuits as part of their Physics A course, but surely, the real fun must be to build and test your very own capacitor.

The learning outcome **6.2.3 (b)** requires students to understand the parallel plate capacitor and the equation $C = \frac{\varepsilon_0 A}{d}$. This lesson element provides a teacher with the necessary resources and strategies to cover the important aspects of this learning outcome.

Background information

The following two resources are very useful in providing background information on capacitors.

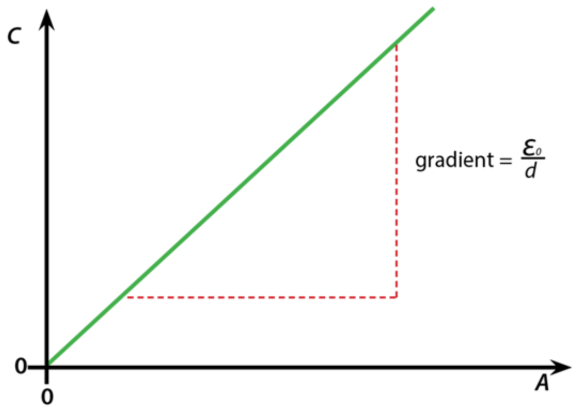
1. http://www.nationalstemcentre.org.uk/elibrary/resource/4097/bin-bag-capacitor
2. http://www.youtube.com/watch?v=jOBoDixh7lY

You can either show the class the short video clip from the first web-link or you could build your own capacitor as described by the presenter. Building your own capacitor and describing its function in your own style has many advantages. The choice is yours.

The second web-link shows how a simple multimeter, set to measure capacitance, can be used to investigate the factors affecting the capacitance of a parallel plate capacitor. This task is best carried out by the students. They can quickly investigate how capacitance *C* is affected by the separation *d* between the plates and the area *A* of overlap between the plates. If the experiments are conducted well, then the students can determine an approximate value for the permittivity of free space ε_0.

The capacitance of a parallel plate capacitor is given by the equation $C = \frac{\varepsilon_0 A}{d}$.

The activity outlined in Worksheet 1 should take about 50 minutes. In the main experiment, students are instructed to keep the separation *d* constant and vary the area *A* of overlap between the plates. The capacitance *C* is measured directly using a multimeter set on the smallest capacitance range. A graph of *C* against *A* should be a straight line through the origin. The gradient of the line is ε_0/d, hence ε_0 can be determined.



However, in this experiment, the graph is unlikely to pass through the origin. The reasons for this can be the zero error of the multimeter and stray capacitance due to the metal stand etc. In spite of this, the linear graph can still be used to give a reasonable estimate of the permittivity of free space.

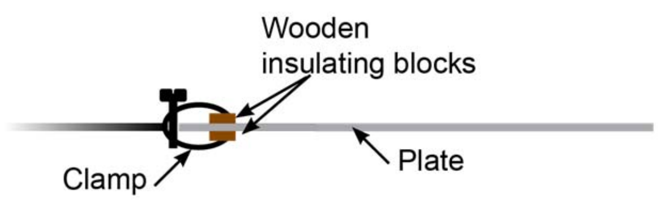
Equipment required for the task

Depending on your class size, students can either work individually, in pairs or in small groups. The following set of equipment is required to investigate the capacitor.

- Multimeter – set on the smallest range, e.g. 2 nF
- Metre rule or 30 cm plastic ruler
- Two A4 size thick cards (See Note 1)
- Aluminium foil (See Note 1)
- Crocodile clips
- Connecting leads
- Stand with boss and clamp (See Note 2)
- Small blocks of wood (See Note 2)

Notes

1. Each capacitor plate is made by carefully wrapping the thick card with aluminium foil. This is a cheap way of making the capacitor plates. Large aluminium plates may be used as an alternative.
2. One of the capacitor plates will be held in the clamp. In order to electrically insulate this plate from the clamp and stand, it is a good idea to use the small wooden blocks as shown below.



The activity

All the instructions and details of how to conduct the experiments are outlined for the students in Worksheet 1.

The students can either report their findings to each other, to the class or the teacher can summarise the key ideas through discussion.

The important conclusions are:

1. The capacitance *C* decreases with increasing separation *d*
2. The capacitance *C* increases with increasing area *A* of overlap between the plates
3. The permittivity of free space $\varepsilon_0 \sim 10^{-11}$ F m^{-1}

Some typical results for the teacher

Experiment: Relationship between *C* and *A* for a constant separation.

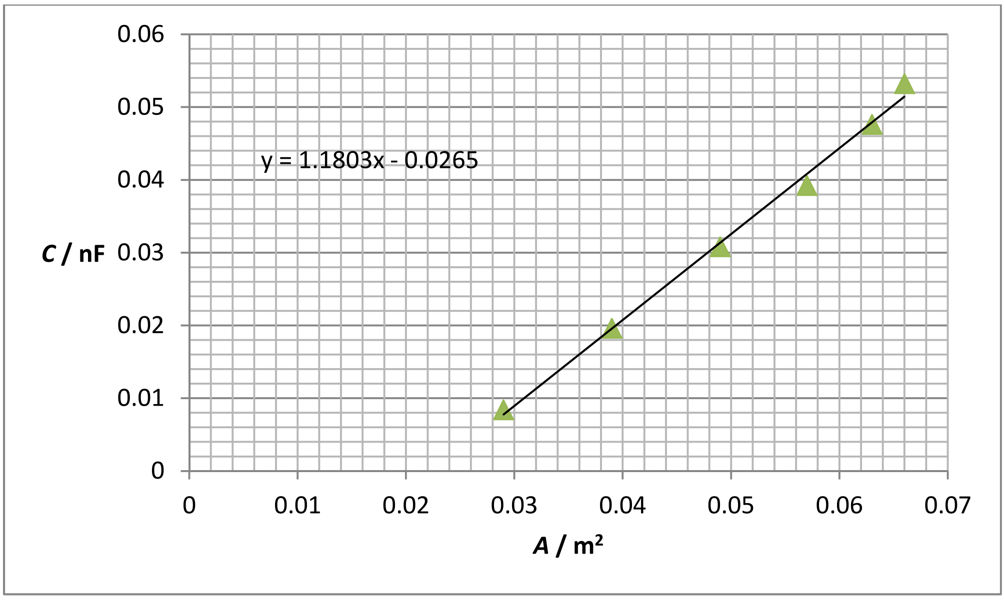
separation *d* = 1.0 cm

x = width of overlap and *y* = length of overlap

The results shown in the table below were obtained by placing one of the capacitor plates on a plastic dustbin and moving the other plate over it with the help of the retort stand.

C / nF	*x* / m	*y* / m	*A* / m^2
0.066	0.190	0.280	0.0532
0.063	0.170	0.280	0.0476
0.057	0.140	0.280	0.0392
0.049	0.110	0.280	0.0308
0.039	0.070	0.280	0.0196
0.029	0.030	0.280	0.0084

The graph of *C* against *A* shows that capacitance increases with the area of overlap. As expected, the results show that the graph (see below) does not pass through the origin for the reasons already mentioned.



Note: Students may determine the gradient using calculations from their line of best fit, alternatively this may be an opportunity to use graph plotting software.

The gradient of the graph is equal to ε_0/d .

Therefore

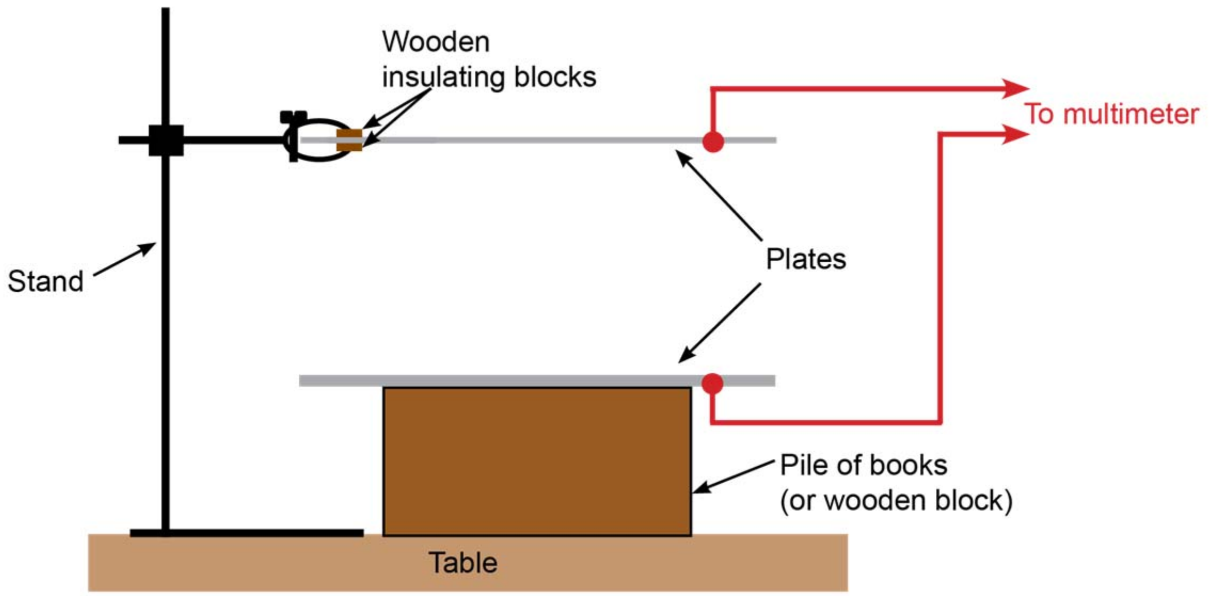
$\varepsilon_0/d = 1.18 \times 10^{-9}$

$\varepsilon_0 = 1.18 \times 10^{-9} \times 1.0 \times 10^{-2}$

$\varepsilon_0 \sim 10^{-11}\ \mathrm{F\,m^{-1}}$

The graph of *C* against *A* shows that capacitance increases with the area of overlap. As expected, the results show that the graph does not pass through the origin for the reasons already mentioned.
The accepted value for ε_0 is $8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$. So for our crude experiment, the results are not too bad. It gives you the chance to discuss the limitations of this experiment.

Task 1 - Investigating the factors affecting the capacitance of a parallel plate capacitor



Procedure

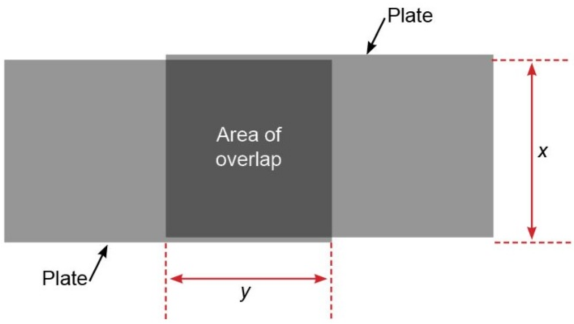
1. Wrap an appropriate length of aluminium foil around the two cards to make your capacitor plates. You may use some tape to secure the foil.

2. Place one of the plates on a pile of books or a wooden block. Secure the other plate in the clamp as shown in the diagram above. Make sure the plates are parallel.

3. Set the multimeter on its lowest capacitance range. Connect the multimeter across the plates using the crocodile clips.

4. Start with a separation of about 1 cm and with the plates having maximum area of overlap. Slowly move the top plate vertically upwards and observe what happens to the capacitance C as the separation d is increased. Suggest a simple relationship between C and d?

5. You will now carry out an experiment to determine an approximate value for the permittivity of free space ε_0.
   a. Start with the plates having maximum area of overlap and a separation of about 1.0 cm.
   b. Move the top plate horizontally to reduce the area of overlap. Keep the separation between the plates constant. Measure and record the width *x* of the overlap and the length *y* of the overlap in the table below.



In the table, also record the capacitance *C* of the capacitor and calculate the area *A* of overlap.

C / nF	**x / m**	**y / m**	**A / m²**

a) Repeat the step above for a range of *A* values.

b) Suggest a simple relationship between *C* and *A.*

c) Plot a graph of *C* against *A*. Draw a line of best fit through the points

d) Explain why the gradient of the graph is equal to ε_0/d. Note: The graph may not pass through the origin because of possible zero error with the multimeter and 'stray' capacitance.

e) Use the gradient to determine an approximate value for ε_0 .

f) Write a short paragraph to summarise your conclusions.

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