Cambridge Assessment International Education

Skills Pack

Lenses and Ray Diagrams

Cambridge IGCSE®

Physics

0625/0972

This *Skills Pack* can also be used with the following syllabuses:
- Cambridge IGCSE® (9–1) Chemistry **0971**
- Cambridge IGCSE® Combined Science **0653**
- Cambridge O Level Chemistry **5070**

Contents

Icons used in this pack:

Briefing lesson

Lab lesson: Option 1 – run the experiment

Lab lesson: Option 2 – virtual experiment

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Skills Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Skills Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Lenses and Ray Diagrams

This *Skills Pack* focuses on a using lenses to obtain accurate measurements and the accurate drawing of ray diagrams.

In this experiment, you will take measurements and use these to calculate a value for the focal length of a converging lens.

This experiment has links to the following syllabus content (see syllabus for detail):

- 3.2.3 Thin lenses

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- take readings with appropriate precision, reading to the nearest half-scale division where required
- make observations, measurements or estimates that are in agreement with expected results or values
- process data, including for use in further calculations or for graph plotting, using a calculator as appropriate
- present data graphically, including the use of best-fit lines where appropriate
- comment on and explain whether results are equal within the limits of experimental accuracy (assumed to be ± 10% at this level of study)

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 3.1 General properties of waves
- 3.2.1 Reflection of light
- 3.2.2 Refraction of light

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about correcting vision defects.

Briefing lesson: An introduction to converging lenses

Resources	• selection of converging and diverging lenses • squared paper • Worksheet A • Worksheet B • 30cm rulers • sharp pencils
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe an image compared to the object using the words enlarged, same size, diminished, upright, inverted, real and virtual. • ***most*** learners should be able to draw an accurate ray diagram for the formation of a real image by a converging lens and describe the image compared to the object • ***some*** learners will be able to draw an accurate ray diagram for the formation of a virtual image by a converging lens and describe the image compared to the object

Timings	Activity
10 minutes	**Starter/Introduction** Give all learners a small converging lens and ask them to describe the lens and to use the lens to look at some nearby text and objects further away. Demonstrate the use of page in their notebook as a screen. Allow them some time to experiment with the lens and ask them to make notes of what they notice. Discuss their observations and introduce the terminology. E.g. Objects look blurred most of the time. They had to move the lens back and forth to see a clear image (focus). The image was upside down (inverted) /right way up (upright). Draw a diagram on the board showing a converging lens focusing parallel rays of light to a point and point out the focal length and the principal focus. **Safety** Ensure learners do not look through windows at the sun
5 minutes	**Main lesson** Explain to learners it is possible to work out where an image will be formed. This is important because you would not want to use the same lens if you were using the lens for spectacles or for a projector. Use the whiteboard and a marker or graph paper and a camera to show learners how to accurately draw a ray diagram for a converging lens. Use the following as a suggestion for your diagram: *A 2 cm tall object is placed 3.5 cm from a converging lens with a focal length of 5 cm. Describe the image formed by this lens.*

35 minutes	Construct this from scratch on blank squared paper and define and show how we draw the principal axis, the lens and how we use the focal length to place the principal focus. Demonstrate how we draw the two main rays: one from the top of the object parallel to the principal axis and then refracting through the principal focus on the right of the lens and a second diagonally from the top of the object through the centre of the lens. Give **worksheet A** to the learners and give them time to accurately practise drawing ray diagrams and describing the images produced on the diagrams provided. Review these with the class.
10 minutes	**Plenary** Use **worksheet B** which contains a matching exercise for the main terminology used in the lesson.

Lab lesson: Option 1 – run the experiment

Resources	• Converging lens (f = 15cm) and holder • Illuminated object with a triangular hole covered by translucent paper – see teacher notes • Metre rule capable of reading to the nearest 1mm • Screen – Stiff white card 15 cm x 15 cm and capable of being supported vertically by a wooden block or blu tack. • 24W filament lamp and power supply • Calculators • Worksheet C1 • Worksheet D
Learning objectives	By the end of the lesson: • ***all*** learners should be able to follow the procedure and obtain accurate measurements of distance • ***most*** learners should be able to risk assess the procedure • ***some*** learners will be able to troubleshoot the procedure before starting the experiment

Timings	Activity
20 minutes	**Starter/Introduction** Explain to the learners they are going to use a ruler to take accurate measurements of object distance u and image distance v for a converging lens. This will then be used to calculate the focal length. Hand out **worksheet C1** and ask learners to read it through carefully. Ask them to work in pairs to discuss what the procedural difficulties are likely to be and to propose solutions to these problems. Also ask them to complete the risk assessment on **worksheet C1** and to plan their results table. Usual issues are • Accurate positioning of the object, screen and lens • Ensuring object, screen and lens are perpendicular to the bench top • Accurate measurement to the centre of the lens and edge of the screen and object • Ensuring the room is dark enough • Patience when slowly manipulating the equipment to find the most in focus image • Perpendicular reading of the ruler
25 minutes	**Main lesson** Review the task from the starter section before learners do the practical work. Emphasise the time allowed so they can take sufficient time to gather data that is as accurate as it can be. Allow learners time to follow the instructions and to obtain the data.

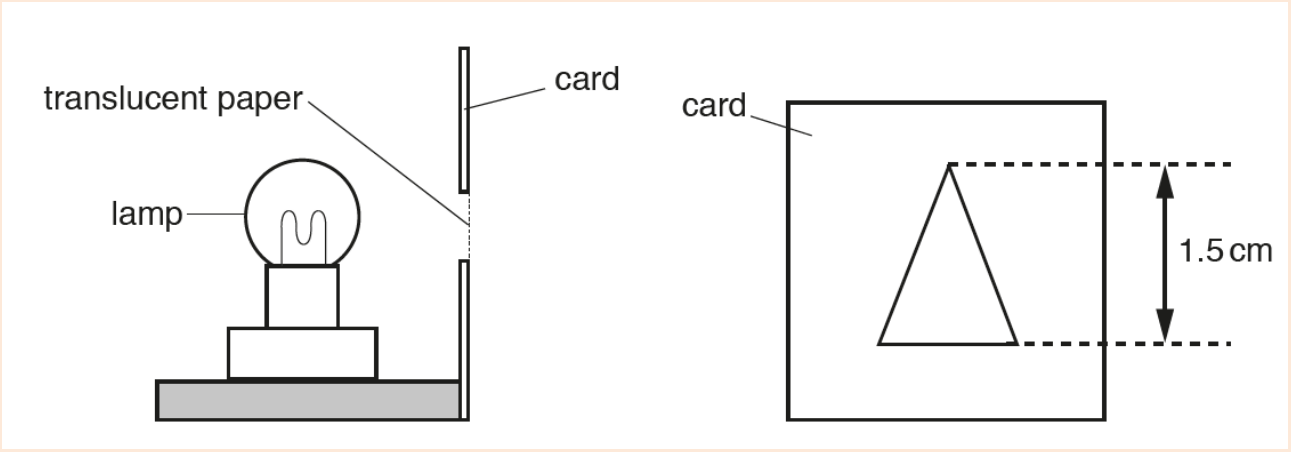
	Safety Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate. Filament lamps may get hot. Ensure learners do not look through lenses at the sun. Beware of broken glass from bulbs and lenses.
15 minutes	**Plenary** Learners analyse the graphs on **Worksheet D** to find common mistakes This will be reviewed at the start of the next lesson.

Teacher notes

Watch the video (teacher version) and read these notes.

This experiment has been chosen because it is one that involves very precise manipulation of the equipment in order to get satisfactory results. Learners often do not have enough patience in adjusting the position of the lens and “fine tuning” these movements to get the most focussed image possible.
It also involves accurately plotting a graph and calculating a gradient. This is an area in the practical papers where candidates often have difficulty.

Each group will require:
An illuminated object



Illuminated object with a triangular hole of height 1.5 cm (see diagrams above). The hole is to be covered with thin translucent paper (e.g. tracing paper).
The centre of the triangular hole, the lamp filament and the centre of the lens in its holder are all to be at the same height above the bench.

A screen
A vertical sheet of white stiff card. This could be held upright by being attached to a wooden block or held upright using Blu tack

Safety

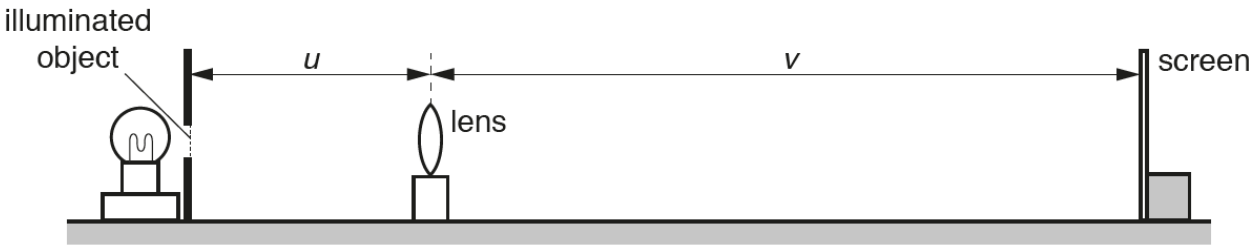
The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
	Eye damage or fire risk from improper use of lens	Ensure experiment is conducted away from direct sunlight. Caution learners to not look at bright lights through lenses.

Substance	Hazard	First aid
	Risk of cuts due to broken glass, e.g. bulbs and lenses. Wounds can lead to infection, especially if the blade or point is contaminated.	**Minor cuts:** Rinse the wound with water. Get the casualty to apply a small, sterile dressing. **Severe cuts**: Lower the casualty to the floor. Raise the wound as high as possible. If feasible, ask the casualty to apply pressure on or as close to the cut as possible, using fingers, a pad of cloth or, better, a sterile dressing (adding further layers as necessary). If the casualty is unable to do so, apply pressure yourself, protecting your skin and clothes from contamination by blood if possible. Leave any embedded large bodies and press around them. Send for a first aider.
	Burns	Bulb can be hot. Treat with caution and assume it is hot unless certain to the contrary.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. They use **worksheet C1 or C2**

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 1-2 learners)
- the amount of equipment required

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Step	Notes

Clean-up

After the experiment learners should:

- tidy up their work space
- return all equipment to you.

Lab lesson: Option 2 – virtual experiment

Resources	• video • rulers • Worksheet C2 • Worksheet D
Learning objectives	By the end of the lesson: • ***all*** learners should be able to obtain accurate measurements of distance • ***most*** learners should be able to risk assess the procedure • ***some*** learners will be able to troubleshoot the procedure before starting the experiment

Timings	Activity
20 minutes	**Starter/Introduction** Explain to the learners they are going to use a ruler to take accurate measurements of object distance u and image distance v for a converging lens. This will then be used to calculate the focal length. Hand out **worksheet C2** and ask learners to read it through carefully. Ask them to work in pairs to discuss what the procedural difficulties are likely to be and to propose solutions to these problems. Also ask them to complete the risk assessment on **worksheet C2** and to plan their results table. Usual issues are • Accurate positioning of the object, screen and lens • Ensuring object, screen and lens are perpendicular to the bench top • Accurate measurement to the centre of the lens and edge of the screen and object • Ensuring the room is dark enough • Patience when slowly manipulating the equipment to find the most in focus image • Perpendicular reading of the ruler
25 minutes	**Main lesson** Learners work through **Worksheet C2.** The teacher will need to show them the video and pause it to allow learners to write down the measurements in their table on **Worksheet C2.** Review their work at appropriate intervals.
15 minutes	**Plenary** Learners analyse the graphs on **Worksheet D** to find common mistakes. This will be reviewed at the start of the next lesson.

Debriefing lesson: Processing data

Resources	• Learners' work from worksheet D • Learners' work from worksheet C1 or C2 • Worksheet E1 (practical) or E2 (virtual) • Worksheet F
Learning objectives	By the end of the lesson: • ***all*** learners should be able to plot the graph of the results • ***most*** learners should be able to calculate the gradient of the graph to find the focal length of the lens • ***some*** learners will be able to compare values of focal length and state whether they are similar within the limits of experimental accuracy

Timings	Activity
10 minutes	**Starter/Introduction** Review the graphs from the plenary activity **Worksheet D** in the previous lesson. Explain that these are common mistakes made by exam candidates. Particularly explain that awkward graph scales can often lead to the loss of two marks as they will lose the mark for the scale and are highly likely to make a mistake in the plotting as a result. Scales are best drawn using numbers like 1 2 5 10 20 50 100 etc
35 minutes	**Main lesson** Learners use their **Worksheet C1 or C2** from the previous lesson and work through **worksheets E1 or E2** to process their data in this lesson. Once completed, the learners should swap their work with someone else in the class who will then formatively assess it. The teacher can supervise this using the answer sheet if necessary.
15 minutes	**Plenary** **Worksheet F** is an exam question from Paper 6. It shows an alternative way of finding focal length. The student has made several mistakes in their answers. Learners should find these mistakes and correct them.

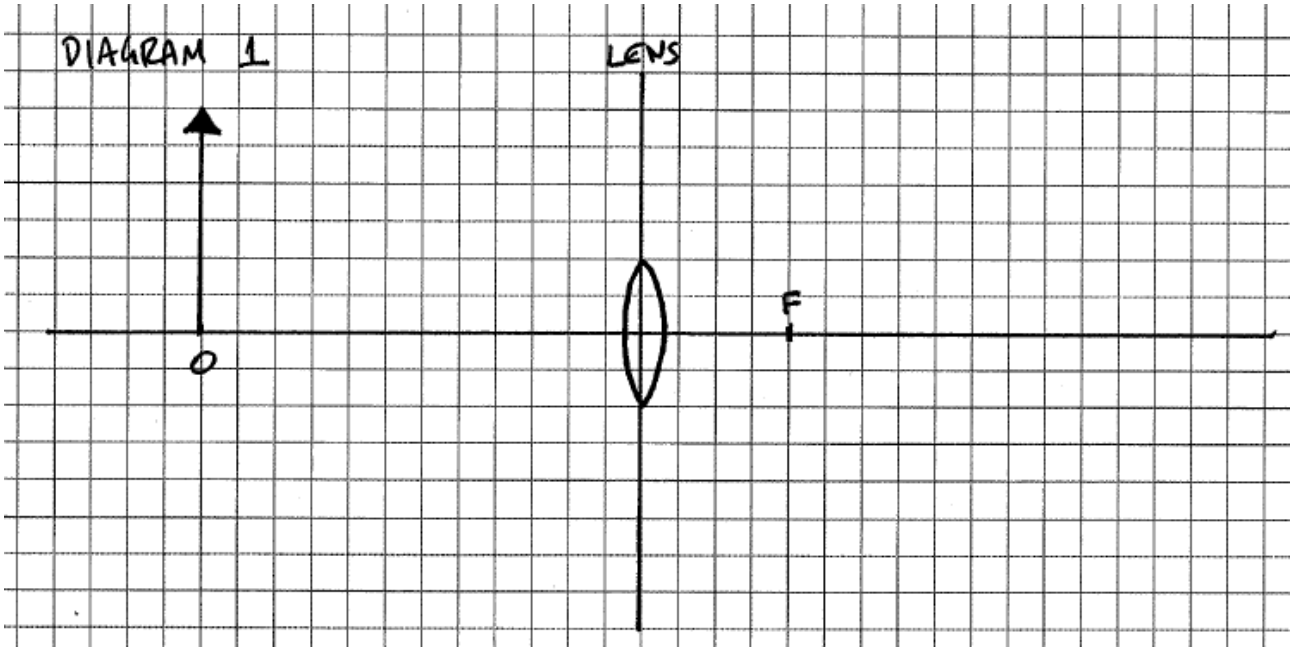
Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson:*		
A: Ray diagrams	**x**	**x**
B: Matching key terms	**x**	**x**
For use in *Lab lesson: Option 1:*		
C1: Method: Practical lesson	**x**	**x**
D: Incorrect graphs	**x**	**x**
For use in *Lab lesson: Option 2:*		
C2: Method Video lesson	**x**	**x**
D: Incorrect graphs	**x**	**x**
For use in the *Debriefing lesson:*		
D: Incorrect graphs	**x**	**X**
C1/C2: Method: Practical/Video Lesson	**x**	**x**
E1/E2: Processing data	**x**	**x**
F: Another way?	**x**	**x**

Worksheet A: Ray diagrams

Use this worksheet with Briefing lesson: An introduction to converging lenses

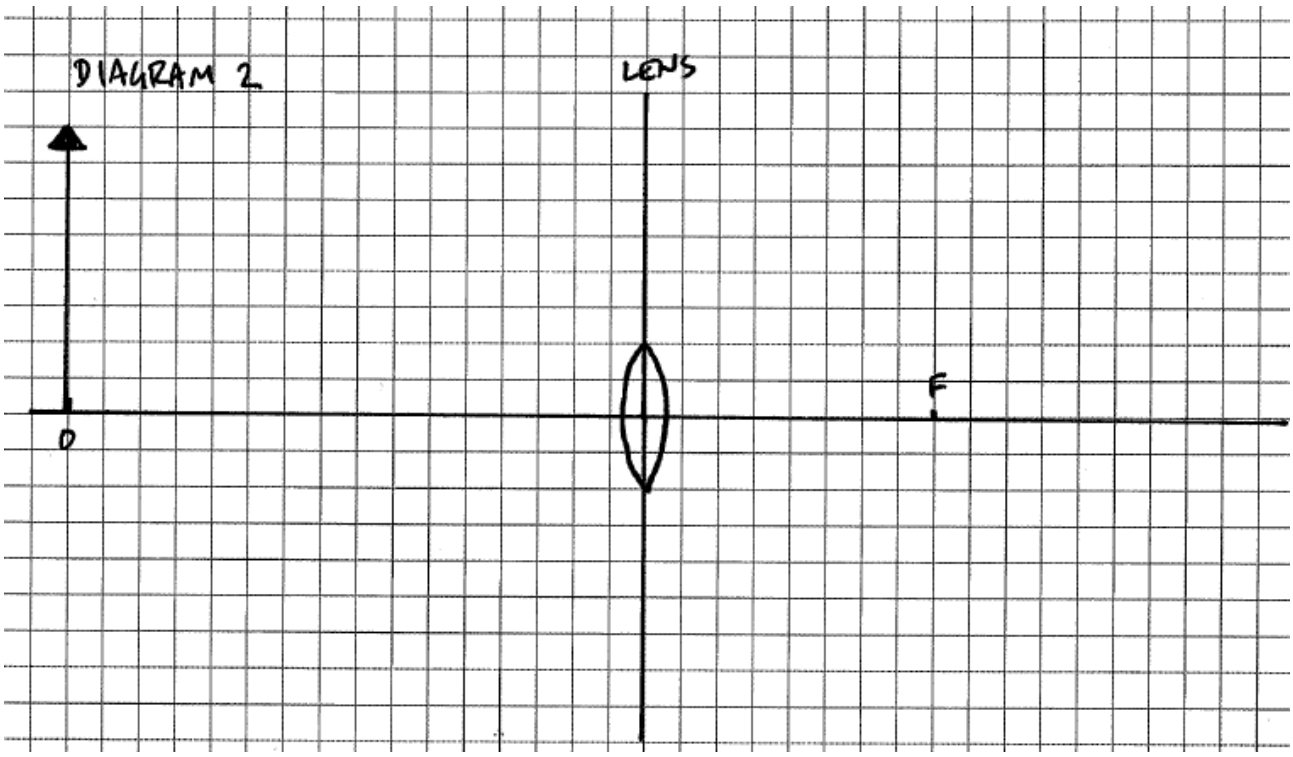
Accurately complete the ray diagrams. Use a sharp pencil and a ruler.



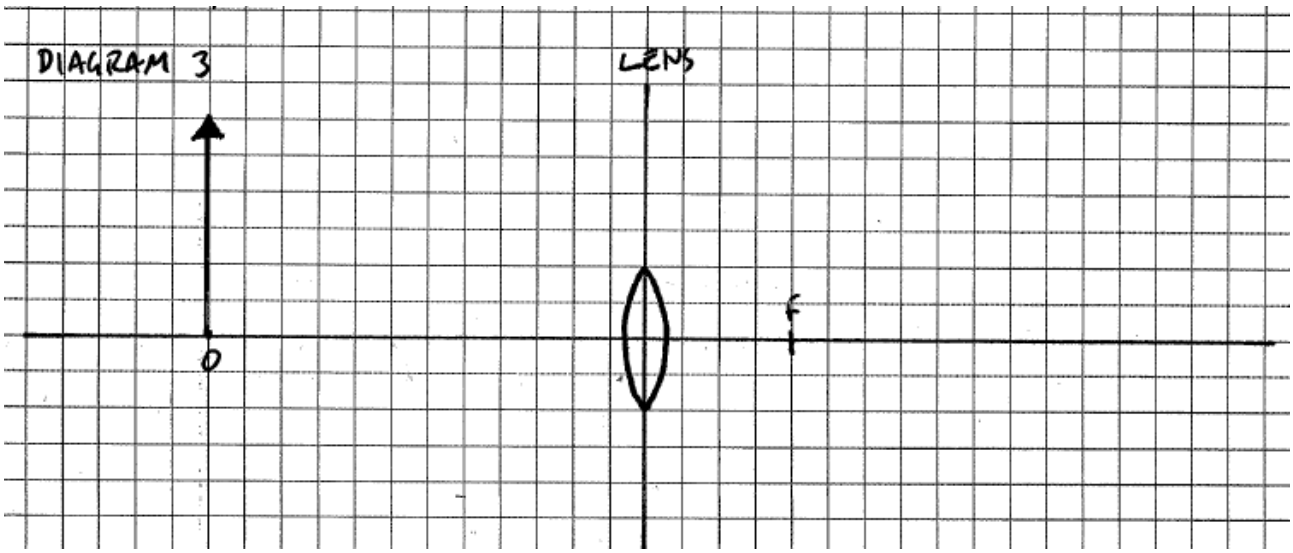
Describe the image by filling in the gap or by circling one word from each choice in **bold**.

The image is _____ cm tall. The image is _____ cm from the centre of the lens.

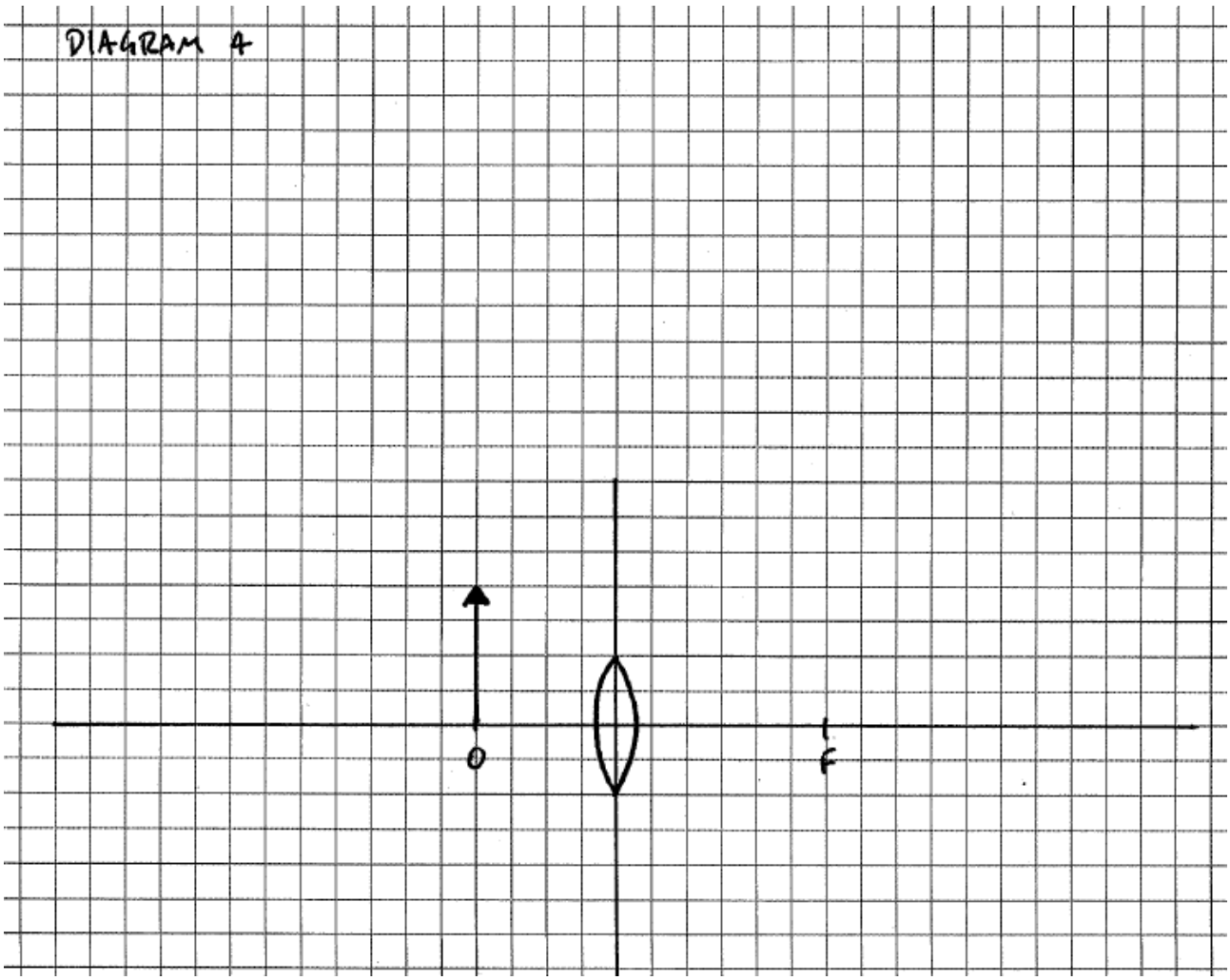
The image is **real / virtual , upright / diminished** and **enlarged / reduced / the same size** when compared to the object.



Describe the image by comparing it to the object.



Describe the image by comparing it to the object.



When you have completed your diagram, think carefully where the rays **could** cross.
These are virtual rays. Draw them using dotted lines.

Describe the image by comparing it to the object.

Diagram 5
A converging lens has a focal length of 5 cm. An 2 cm tall object is placed 3 cm from the lens.
Draw a ray diagram and describe the object.

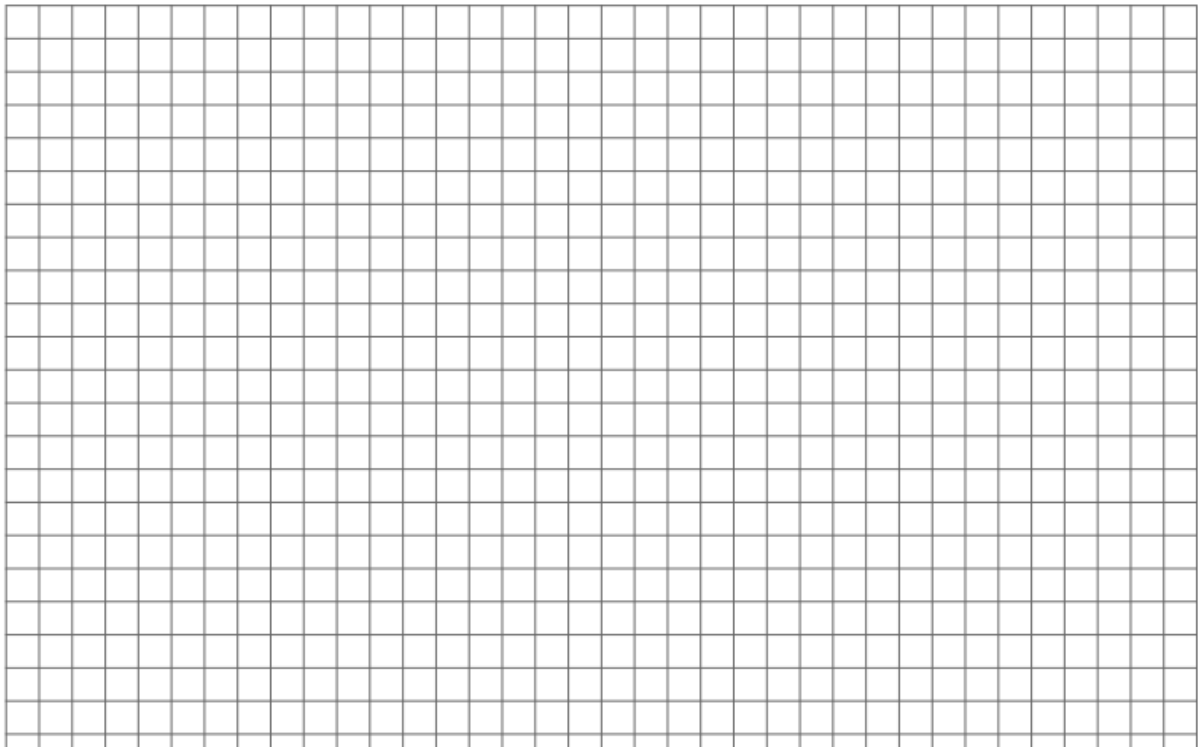
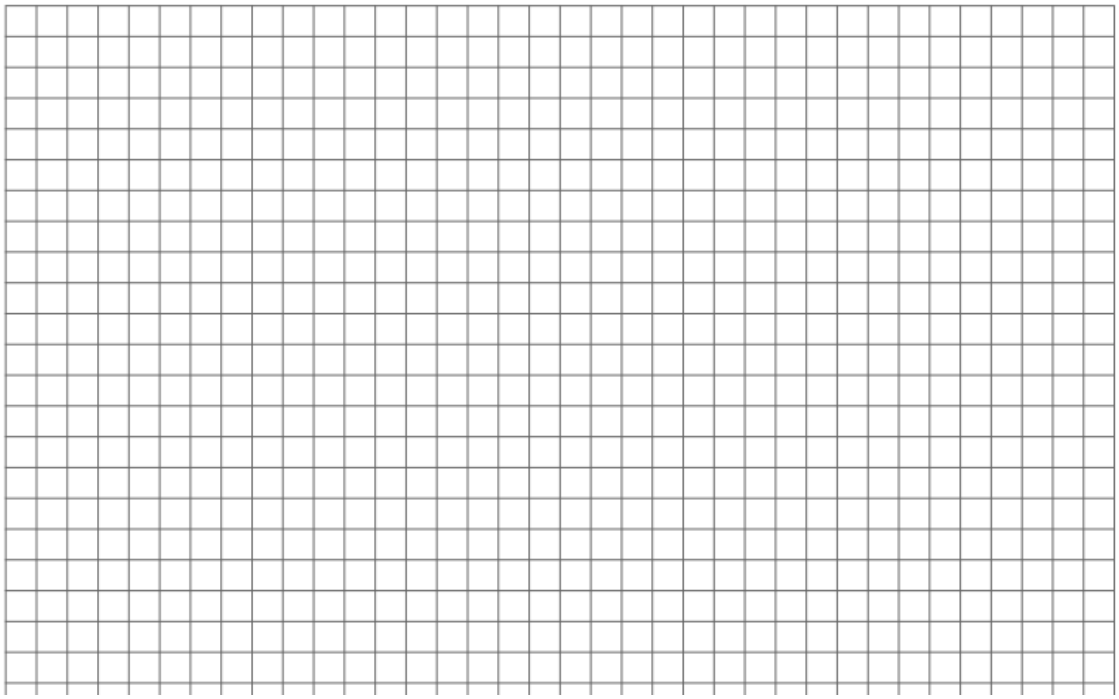


Diagram 6
A converging lens of focal length 20cm is used to produce an image of an object that is placed 25cm away from the lens.
Draw a ray diagram using a scale of 2cm in real life to 1 cm on the page.
Describe the image formed.



Worksheet B: Matching key terms

Match the key terms on the left with the correct description on the right.

Some key terms may join to more than one description

Inverted	Focuses rays to the same point
Diminished	Point where all the rays cross after passing through the lens
Real image	Horizontal line joining all the features of a ray diagram
Principal axis	Smaller than the object
Focal length	Can be projected onto a screen
Diverging lens	Bigger than the object
Converging lens	Formed where real rays cross
Principal focus	Distance between the centre of the lens and the principal focus
Virtual image	Formed where virtual rays cross
	Causes light rays to spread out
	Cannot be projected onto a screen
	Upside down

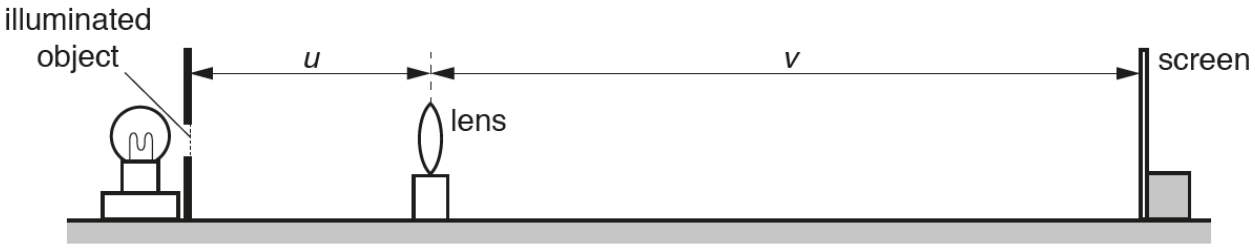
Worksheet C1: Method: practical lesson

In this experiment, you will determine the focal length f of a lens.

Read through the instructions in (a) and then answer the questions in (b) and (c).

Your teacher will review (b) and (c) with the class before you start the experiment.

Follow these instructions referring to the diagram.



(a) • Place the screen a distance ***D*** = 70.0 cm from the illuminated object.

• Place the lens between the object and the screen so that the lens is very close to the screen.

• Move the lens slowly away from the screen until a clearly focused image is formed on the screen.

(i) • Measure, and record in your table, the distance ***u*** between the centre of the lens and the illuminated object.

• Measure, and record in the table, the distance ***v*** between the centre of the lens and the screen.

(ii) Calculate the product ***uv***. Record your answer in the table.

(iii) Repeat the procedure using values for ***D*** of 75.0 cm, 80.0 cm, 85.0 cm and 90.0 cm.

Work with your partner.

(b) What problems might you encounter in obtaining accurate data for this experiment? How might you solve these before starting?

(c) Identify any safety hazards in the procedure and fill in the table to say how you would minimise these.

Hazard	Why it is dangerous	What could you do to make it safe?

(d) Plan a results table by filling in the column headings and units.

/	/	/	/
70.0			
75.0			
80.0			
85.0			
90.0			

Once your teacher has reviewed your work, follow the instructions and do the experiment.

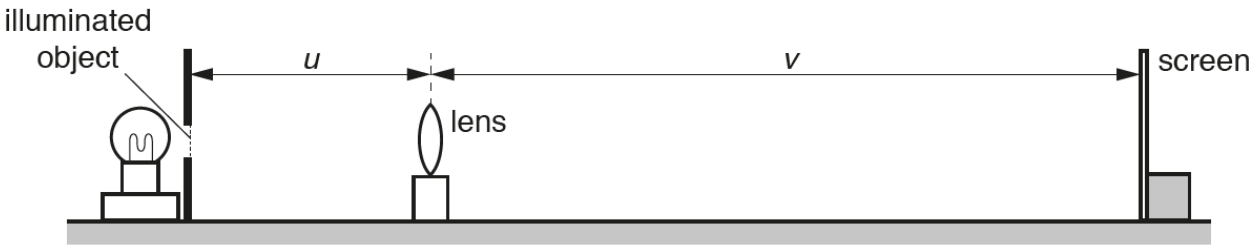
Worksheet C2: Method: video lesson

In this experiment, some students determined the focal length f of a lens.

Read through the instructions in (a) and then answer the questions in (b) and (c).

Your teacher will review (b) and (c) with the class before you start the next part.

The students followed these instructions.



(a) • Place the screen a distance ***D*** = 70.0 cm from the illuminated object.

• Place the lens between the object and the screen so that the lens is very close to the screen.

• Move the lens slowly away from the screen until a clearly focused image is formed on the screen.

(i) • Measure, and record in your table, the distance ***u*** between the centre of the lens and the illuminated object.

• Measure, and record in the table, the distance ***v*** between the centre of the lens and the screen.

(ii) Calculate the product ***uv***. Record your answer in the table.

(iii) Repeat the procedure using values for ***D*** of 75.0 cm, 80.0 cm, 85.0 cm and 90.0 cm.

Work with your partner.

(b) What problems might the students have encountered in obtaining accurate data for this experiment?
How might they have solved these problems before they started?

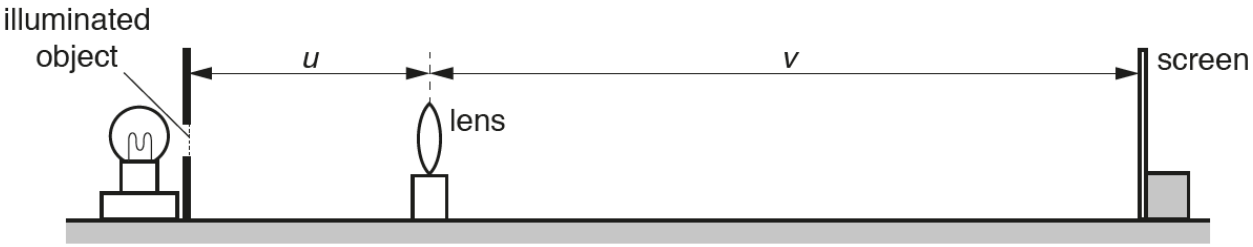
(c) Identify any safety hazards in the procedure and fill in the table to say how you would minimise these.

Hazard	Why it is dangerous	What could you do to make it safe?

(d) Plan a results table by filling in the column headings and units.

/	/	/	/
70.0			
75.0			
80.0			
85.0			
90.0			

e) This was the set up they used.



Use your ruler to accurately measure the distances u and v in the diagram above.

u = _____

v = _____

The diagram was drawn to 1/9th actual size.
Calculate the actual sizes of u and v that the students measured.

u = _____

v = _____

f) Calculate the focal length, f, by using the following formula for the actual values of u and v.

$$f = \frac{uv}{u + v}$$

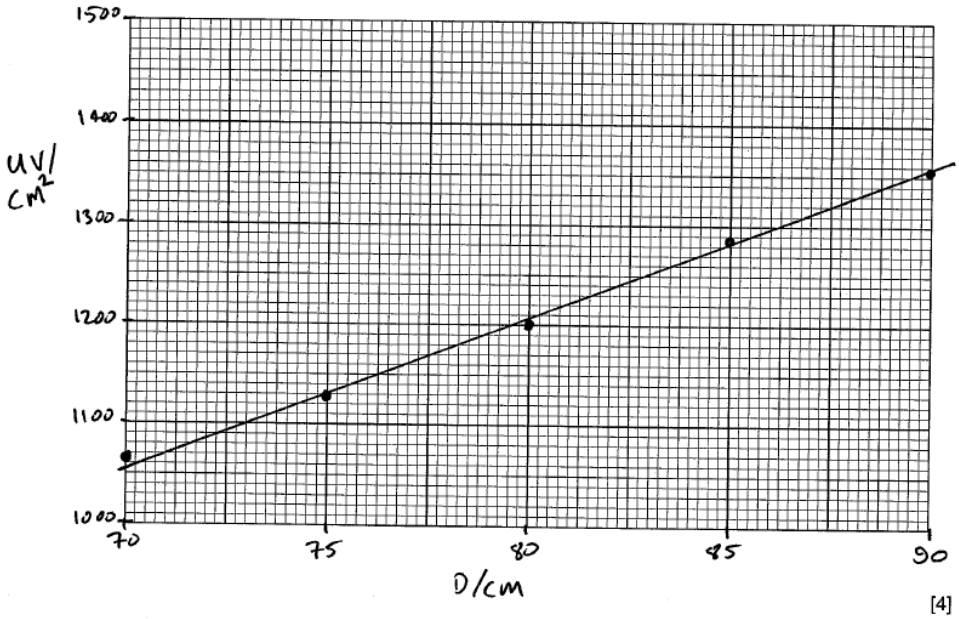
f = _____

g) Your teacher will show you the video of the experiment and they will pause it to allow you to take the measurements that will be shown on the screen.
Write your measurements in your table in section (d).

Worksheet D: Incorrect graphs

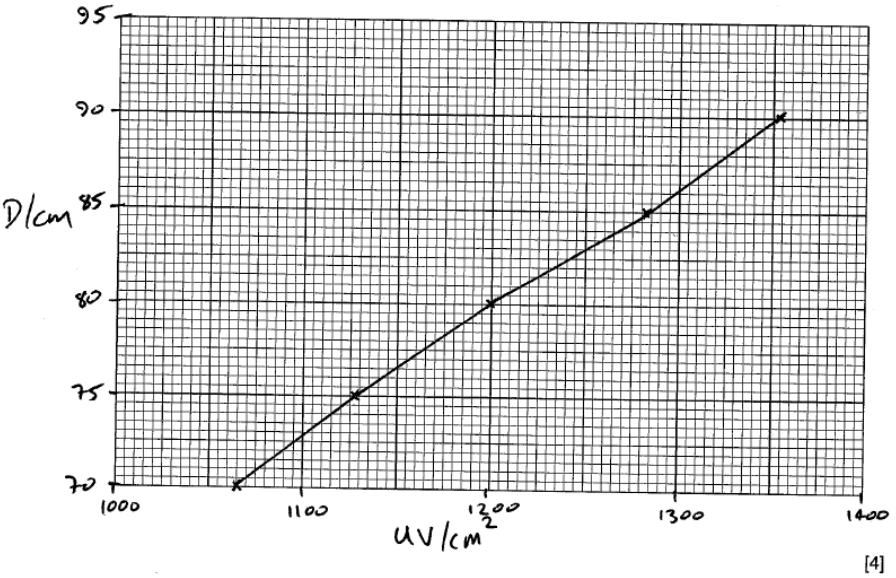
What is wrong with each of the following graphs?

(b) Plot a graph of uv/cm^2 (y-axis) against D/cm (x-axis). You do **not** need to start your axes at the origin (0,0).



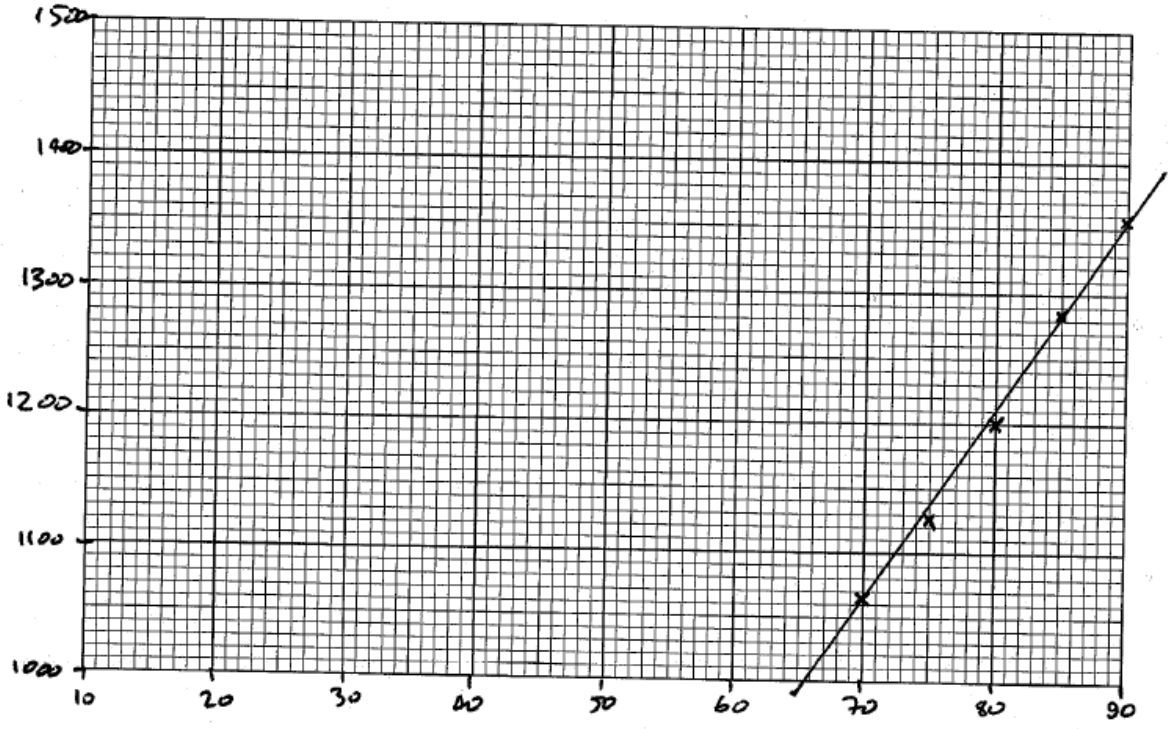
[4]

(b) Plot a graph of uv/cm^2 (y-axis) against D/cm (x-axis). You do **not** need to start your axes at the origin (0,0).



[4]

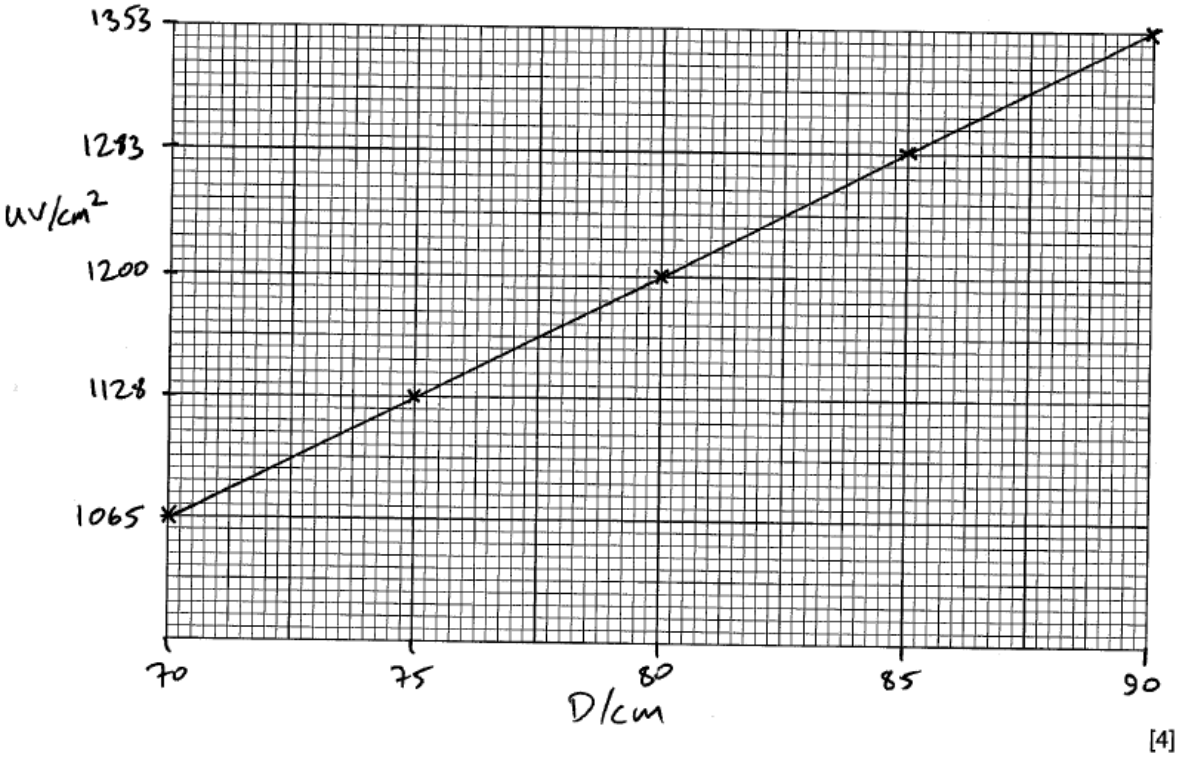
(b) Plot a graph of uv/cm^2 (y-axis) against D/cm (x-axis). You do **not** need to start your axes at the origin (0,0).



[4]

9

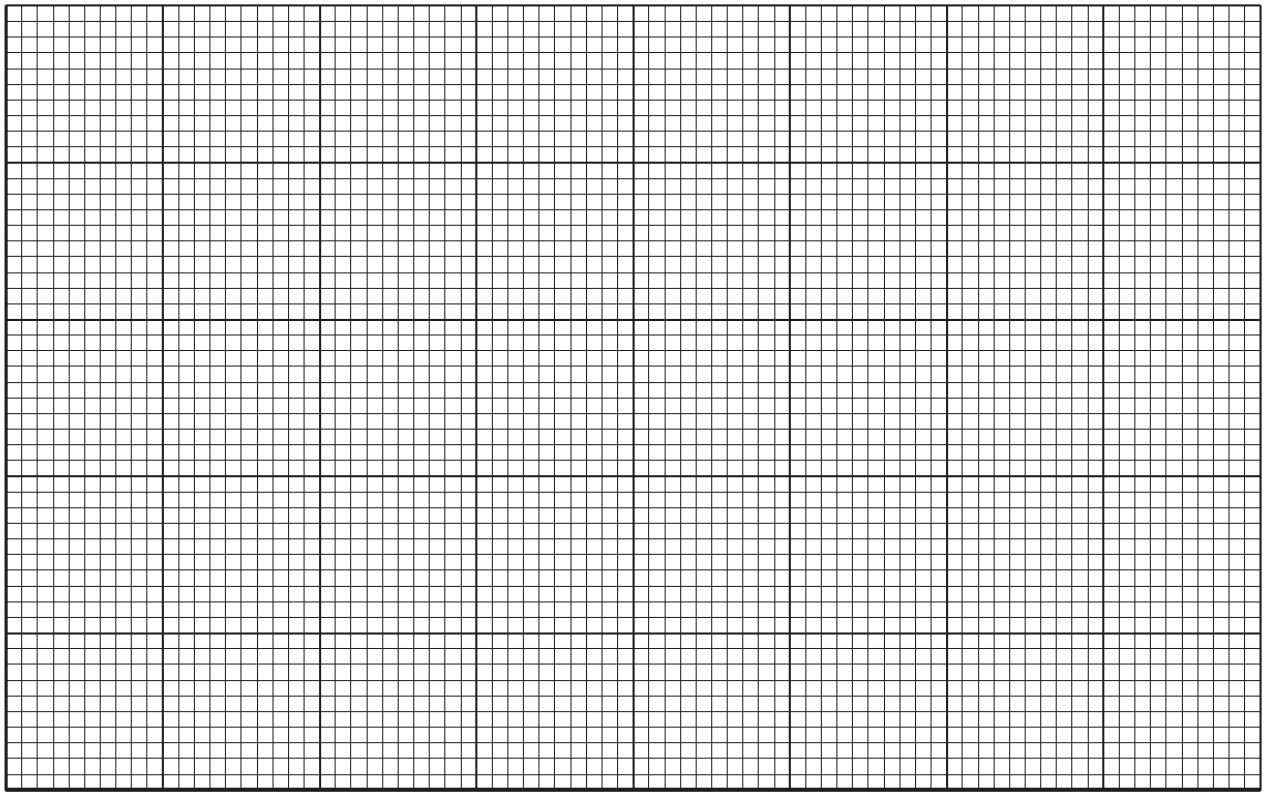
(b) Plot a graph of uv/cm^2 (y-axis) against D/cm (x-axis). You do **not** need to start your axes at the origin (0,0).



[4]

Worksheet E1: Processing data

Use your experimental data from the previous lesson to plot a graph of uv/cm^2 (on the Y axis) against D/cm (on the X axis).
You do not need to start your axes at the origin (0,0)



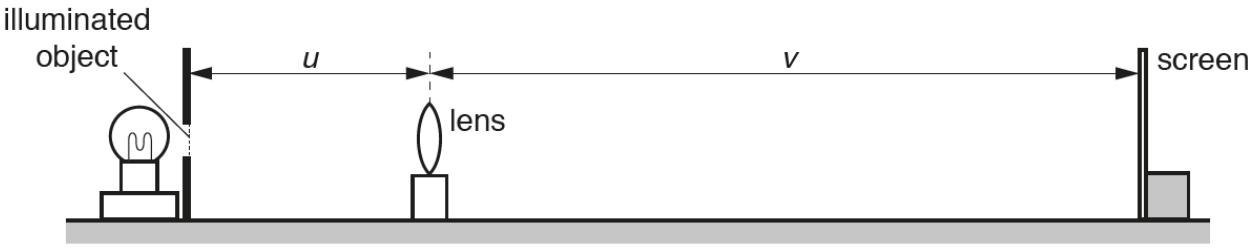
The focal length f of your lens is equal to the gradient of the line.

Use your graph to calculate the gradient of the line.

Show clearly on the graph how you obtain the necessary information.

Gradient = _____

Some students did the same experiment as you did in the previous lesson.
This was the set up they used.



Use your ruler to accurately measure the distances u and v in the diagram above.

u = _____

v = _____

The diagram was drawn to 1/9th actual size.
Calculate the actual sizes of u and v that the students measured.

u = _____

v = _____

f) Calculate the focal length for the students' lens, f, by using the following formula for the actual values of u and v.

$$f = \frac{uv}{u + v}$$

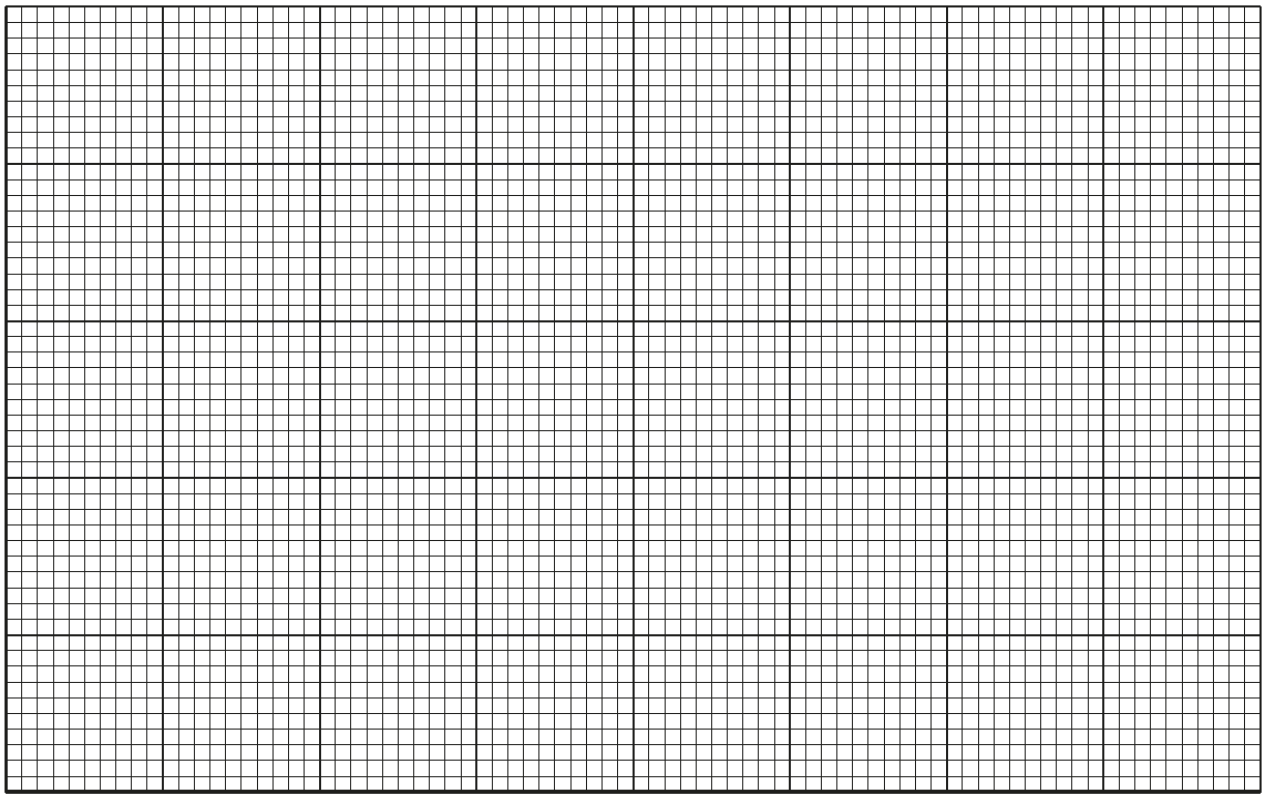
f = _____

One of the students says that the lens you used and the lens that they used have the same focal length.

State and explain whether the two lenses used have the same focal length within the limits of experimental accuracy.

Worksheet E2: Processing data

Use your experimental data from the previous lesson to plot a graph of uv/cm^2 (on the Y axis) against D/cm (on the X axis).
You do not need to start your axes at the origin (0,0)



The focal length f of the lens is equal to the gradient of the line.

Use your graph to calculate the gradient of the line.

Show clearly on the graph how you obtain the necessary information.

Gradient = _____

In part f of worksheet C2, you calculated a value for the focal length for the lens that the students used.

One of the students says that the lens used in the video and the lens that they used have the same focal length.

State and explain whether the two lenses used have the same focal length within the limits of experimental accuracy.

Worksheet F: Another way?

Here is another way of finding focal length by experimental means.

This student has made several mistakes in their answers. Find the mistakes and correct them.

h_0 = 2.0cm

3 A student investigates the image produced by a converging lens.

He uses the apparatus shown in Fig. 3.1.

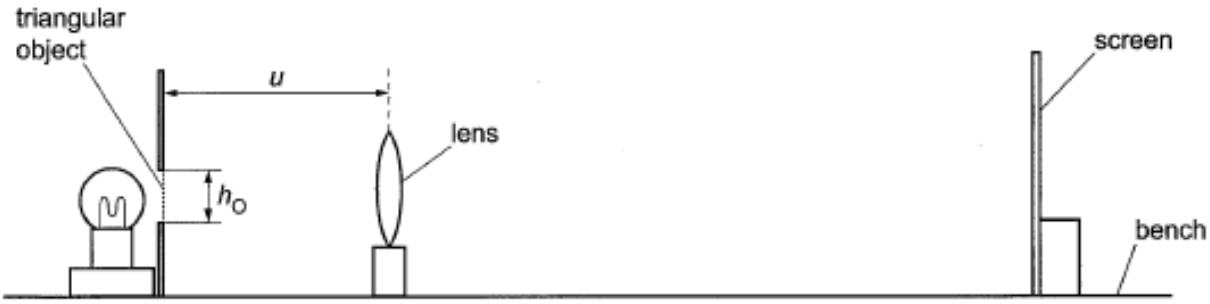


Fig. 3.1

(a) The triangular object is shown full size in Fig. 3.2.

Measure and record the height h_O of the triangular object in Fig. 3.2.

h_O = 19 cm [1]

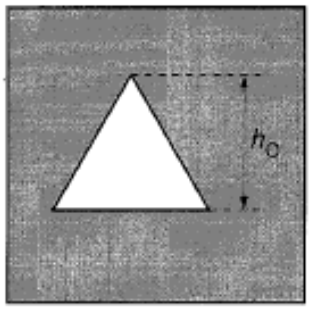


Fig. 3.2

(b) The student sets the distance u between the triangular object and the lens to 20.0 cm. He moves the screen until a sharp image of the triangular object is seen on the screen. The student measures, and records in Table 3.1, the height h_I of the image on the screen.

Briefly describe a technique to obtain an image on the screen that is as sharp as possible in this experiment.

Move the lens backwards and forwards slowly [1]

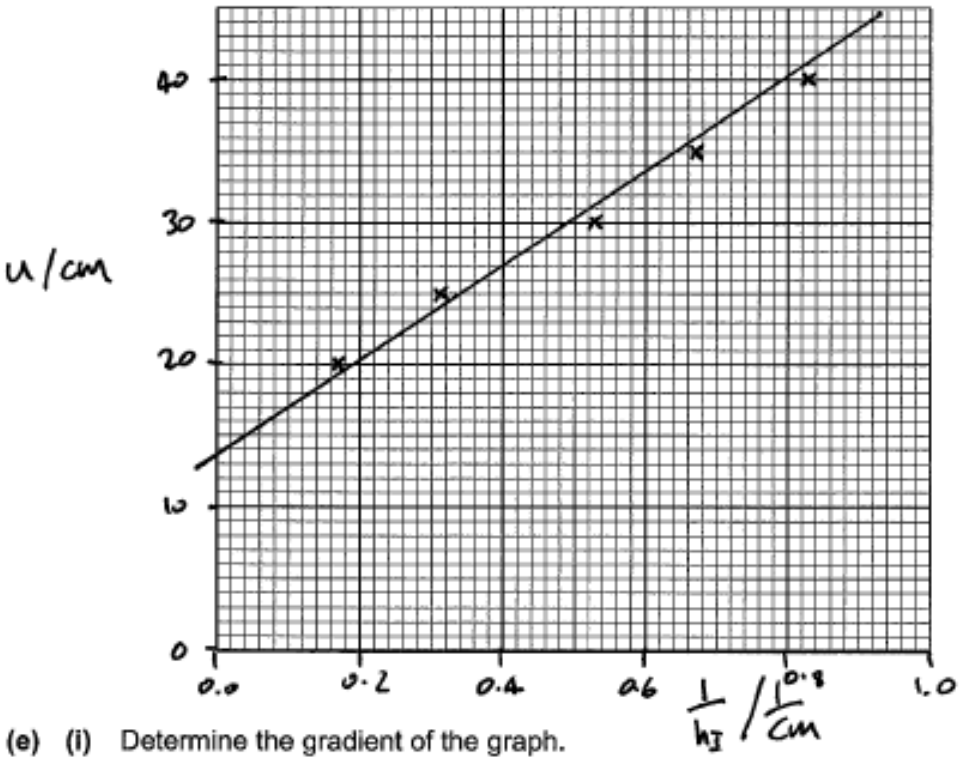
(c) The student repeats the process for u = 25.0 cm, u = 30.0 cm, u = 35.0 cm and u = 40.0 cm. His readings are shown in Table 3.1.

For distance u = 20.0 cm, calculate, and record in Table 3.1, the value of $\frac{1}{h_I}$. [1]

Table 3.1

u/cm	h_I/cm	$\frac{1}{h_I} / \frac{1}{\text{cm}}$
20.0	5.6	0.1786
25.0	3.2	0.31
30.0	1.9	0.53
35.0	1.5	0.67
40.0	1.2	0.83

(d) Plot a graph of u/cm (y-axis) against $\frac{1}{h_I} / \frac{1}{\text{cm}}$ (x-axis).



[4]

(e) (i) Determine the gradient of the graph.

Show clearly on the graph how you obtained the necessary information.

$\frac{40-20}{0.93-0.1786} = \frac{20}{0.6514} = 30.703$

gradient = 30.7 [1]

(ii) Calculate the focal length f of the lens. Use your value of h_O from **(a)** and the equation

$$f = \frac{G}{h_O},$$

where G is numerically equal to the gradient from **(e)(i)**.

$\frac{G}{h_o} = \frac{30.7}{1.9} = 16.16$

$f =$ 16.2 cm [1]

(f) Describe **one** difficulty that can be experienced when measuring the height of the image.

Suggest an improvement to overcome this difficulty.

difficulty Hand wobbling when holding the ruler.

improvement Clamp the ruler so it stays still

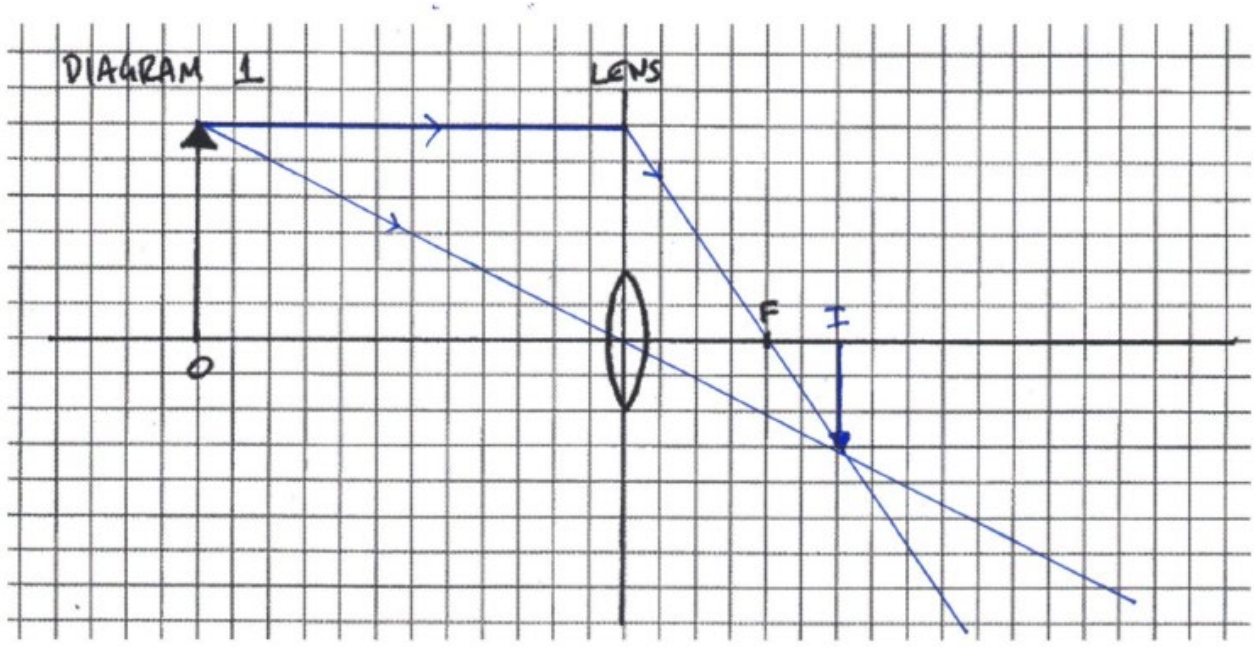
[2]

[Total: 11]

Worksheet A: Ray diagrams Answers

Use this worksheet with Briefing lesson: An introduction to converging lenses

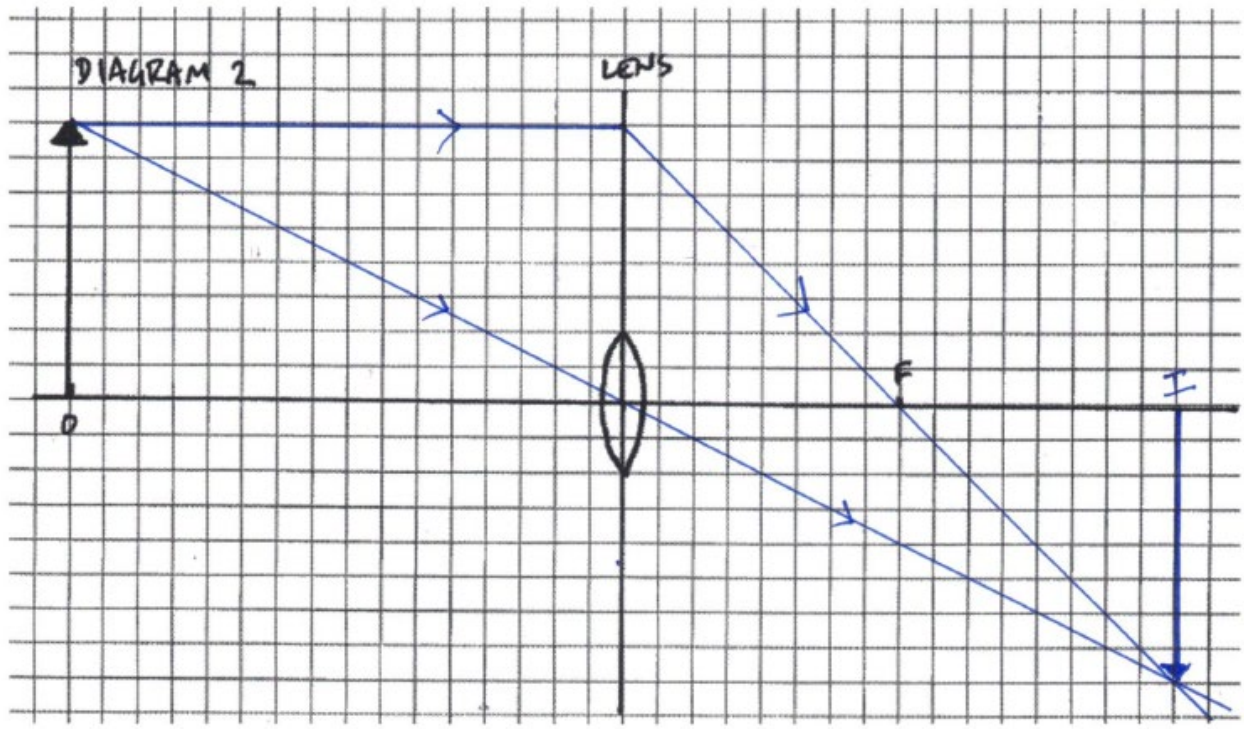
Accurately complete the ray diagrams. Use a sharp pencil and a ruler.
Assume one square = 1 cm.



Describe the image by filling in the gap or by circling one word from each choice in **bold**.

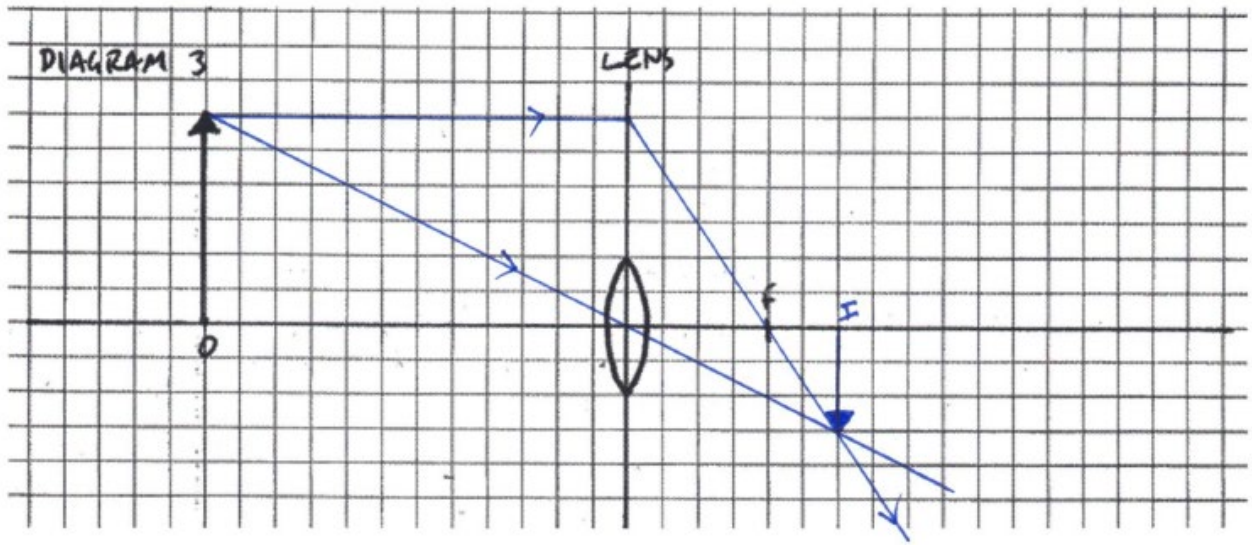
The image is _____3___ cm tall. The image is ____6_____ cm from the centre of the lens.

The image is **real** / ~~**virtual**~~ , ~~**upright**~~ / **diminished** and ~~**enlarged**~~ / **reduced** / ~~**the same size**~~ when compared to the object.

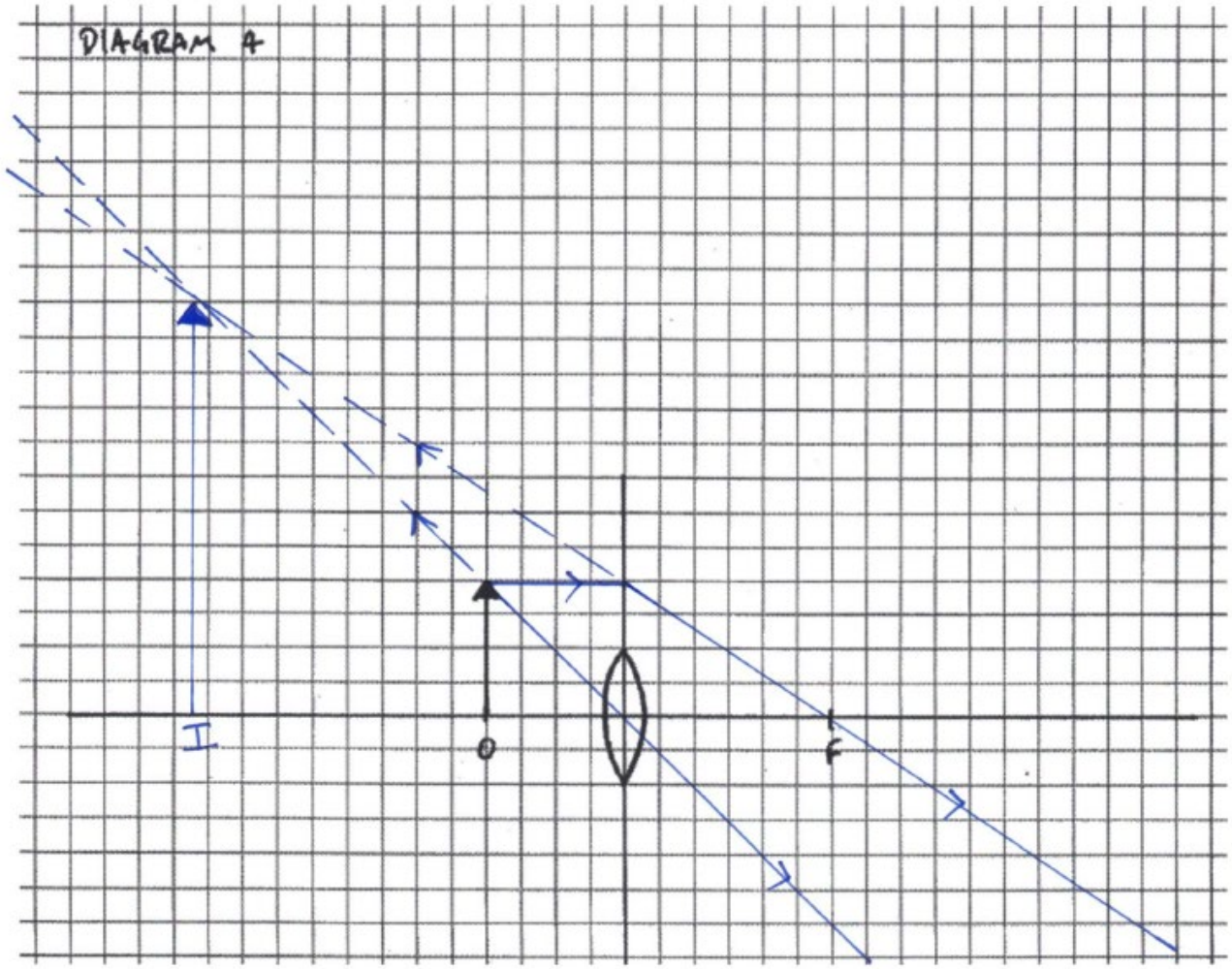


Describe the image by comparing it to the object.

Real. Inverted. Same size.



Describe the image by comparing it to the object.
Real. Inverted. Diminished/smaller.



When you have completed your diagram, think carefully where the rays **could** cross.
These are virtual rays. Draw them using dotted lines.

Describe the image by comparing it to the object.

Virtual. Magnified/larger. Upright.

Diagram 5
A converging lens has a focal length of 5 cm. A 2 cm tall object is placed 3 cm from the lens.
Draw a ray diagram and describe the image.

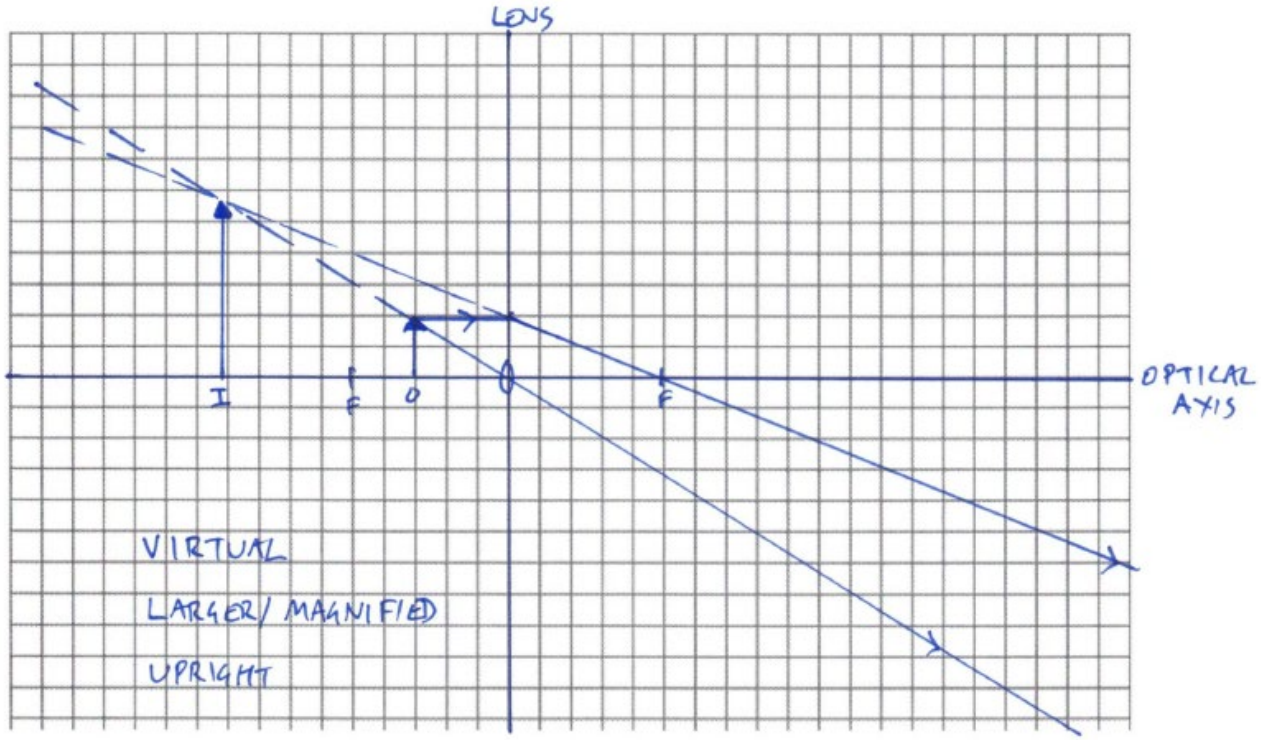
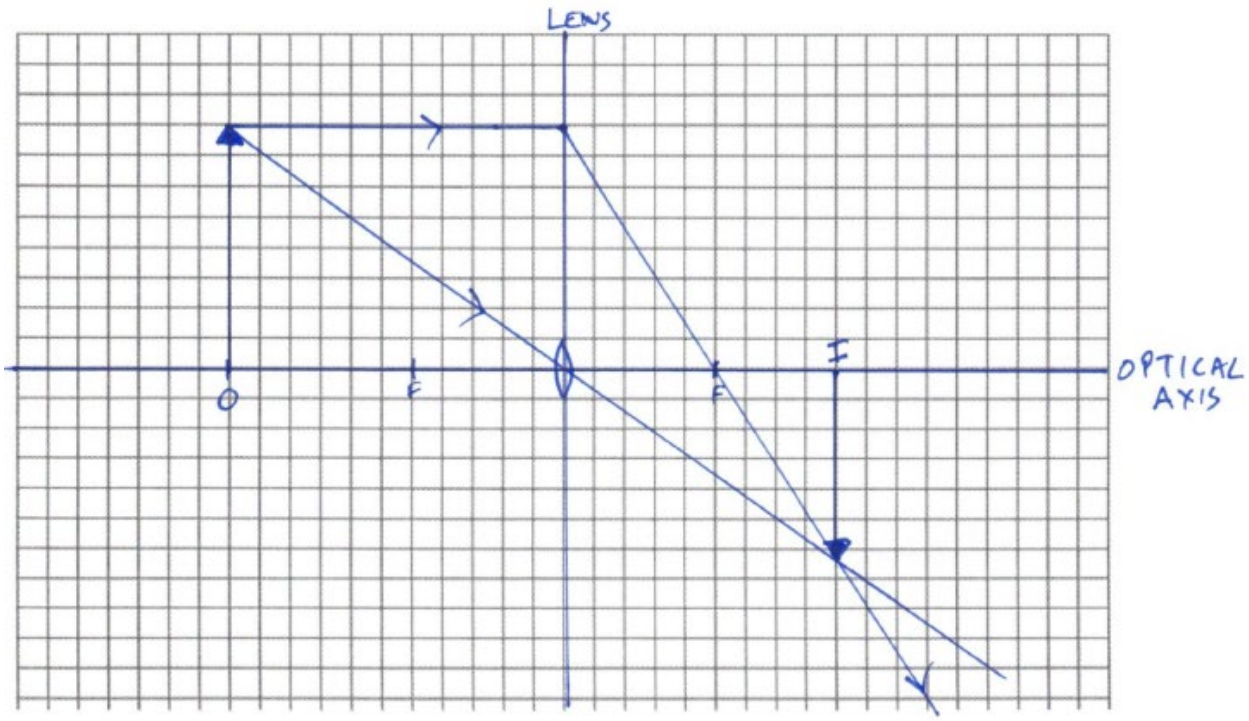


Diagram 6
A converging lens of focal length 10 cm is used to produce an image of a 16cm tall object that is placed 22 cm away from the lens.
Draw a ray diagram using a scale of 2 cm in real life to 1 cm on the page.
Describe the image formed.



REAL, INVERTED, REDUCED

Worksheet B: Matching key terms Answers

Match the key terms on the left with the correct description on the right.

Some key terms may join to more than one description

Bigger than the object	
Inverted	Upside down
Diminished	Smaller than the object
Real image	Can be projected onto a screen
	Formed where real rays cross
Principal axis	Horizontal line joining all the features of a ray diagram
Focal length	Distance between the centre of the lens and the principal focus
Diverging lens	Causes light rays to spread out
Converging lens	Focuses rays to the same point
Principal focus	Point where all the rays cross after passing through the lens
Virtual image	Formed where virtual rays cross
	Cannot be projected onto a screen

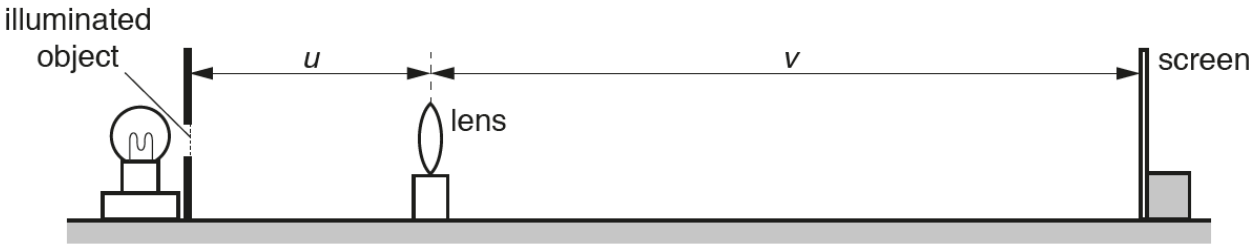
Worksheet C1: Method: practical lesson Answers

In this experiment, you will determine the focal length f of a lens.

Read through the instructions in (a) and then answer the questions in (b) and (c).

Your teacher will review (b) and (c) with the class before you start the experiment.

Follow these instructions referring to the diagram.



(d) • Place the screen a distance ***D*** = 70.0 cm from the illuminated object.

• Place the lens between the object and the screen so that the lens is very close to the screen.

• Move the lens slowly away from the screen until a clearly focused image is formed on the screen.

(i) • Measure, and record in your table, the distance ***u*** between the centre of the lens and the illuminated object.

• Measure, and record in the table, the distance ***v*** between the centre of the lens and the screen.

(ii) Calculate the product ***uv***. Record your answer in the table.

(iii) Repeat the procedure using values for ***D*** of 75.0 cm, 80.0 cm, 85.0 cm and 90.0 cm.

Work with your partner.

(e) What problems might you encounter in obtaining accurate data for this experiment? How might you solve these before starting?

Parallax error.
Read the ruler from directly above.

Problems aligning the apparatus.
Ensure the lens, object and screen are all at the same height.

Problems finding a sharp image.
Ensure the room is darkened/bulb is bright. Move the lens slowly.

Apparatus covering readings on ruler.
Measure position of each end of the apparatus and find the midpoint.

(f) Identify any safety hazards in the procedure and fill in the table to say how you would minimise these.

Hazard	**Why it is dangerous**	**What could you do to make it safe?**
Bulb can be hot.	Can burn fingers.	Assume bulb is hot so switch off and allow to cool before touching.
Sunlight being focussed by lens.	Can start fires.	Keep lens out of direct sunlight.
Bulb is fragile and glass can easily break.	Can cut skin.	Handle carefully and keep away from edge of table.

(d) Plan a results table by filling in the column headings and units.

D / cm	u / cm	v / cm	uv / cm^2
70.0	22.0	48.0	1056
75.0	20.9	54.1	1131
80.0	20.0	60.0	1200
85.0	19.5	65.5	1277
90.0	19.0	71.0	1349

Once your teacher has reviewed your work, follow the instructions and do the experiment.

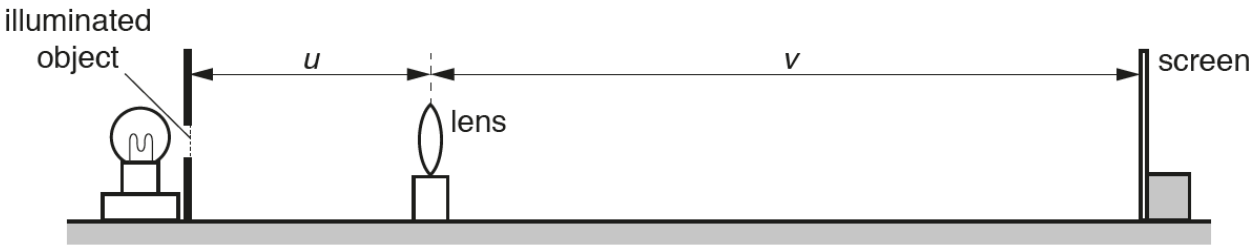
Worksheet C2: Method: video lesson Answers

In this experiment, some students determined the focal length f of a lens.

Read through the instructions in (a) and then answer the questions in (b) and (c).

Your teacher will review (b) and (c) with the class before you start the next part.

The students followed these instructions.



(d) • Place the screen a distance ***D*** = 60.0 cm from the illuminated object.

• Place the lens between the object and the screen so that the lens is very close to the screen.

• Move the lens slowly away from the screen until a clearly focused image is formed on the screen.

(i) • Measure, and record in your table, the distance ***u*** between the centre of the lens and the illuminated object.

• Measure, and record in the table, the distance ***v*** between the centre of the lens and the screen.

(ii) Calculate the product ***uv***. Record your answer in the table.

(iii) Repeat the procedure using values for ***D*** of 70.0 cm, 80.0 cm, 90.0 cm and 100.0 cm.

Work with your partner.

(e) What problems might the students have encountered in obtaining accurate data for this experiment?
How might they have solved these problems before they started?

Parallax error.
Read the ruler from directly above.

Problems aligning the apparatus.
Ensure the lens, object and screen are all at the same height.

Problems finding a sharp image.
Ensure the room is darkened/bulb is bright. Move the lens slowly.

Apparatus covering readings on ruler.
Measure position of each end of the apparatus and find the midpoint.

(f) Identify any safety hazards in the procedure and fill in the table to say how you would minimise these.

Hazard	Why it is dangerous	What could you do to make it safe?
Bulb can be hot.	Can burn fingers.	Assume bulb is hot so switch off and allow to cool before touching.
Sunlight being focussed by lens.	Can start fires.	Keep lens out of direct sunlight.
Bulb is fragile and glass can easily break.	Can cut skin.	Handle carefully and keep away from edge of table.

(d) Plan a results table by filling in the column headings and units.

D / cm	u / cm	v / cm	uv / cm^2
60.0	21.0	39.2	823.2
70.0	19.5	50.6	986.7
80.0	18.8	61.1	1148.7
90.0	17.4	72.5	1251.5
100.0	16.5	83.6	1387.8

e) This was the set up they used.

Use your ruler to accurately measure the distances u and v in the diagram above.

u = _____3.2 cm_____

v = ____9.3 cm_____

The diagram was drawn to 1/9th actual size.
Calculate the actual sizes of u and v that the students measured.

u = ___28.8 cm_____

v = _____83.7 cm_____

f) Calculate the focal length, f, by using the following formula for the actual values of u and v.

$$f = \frac{uv}{u+v}$$

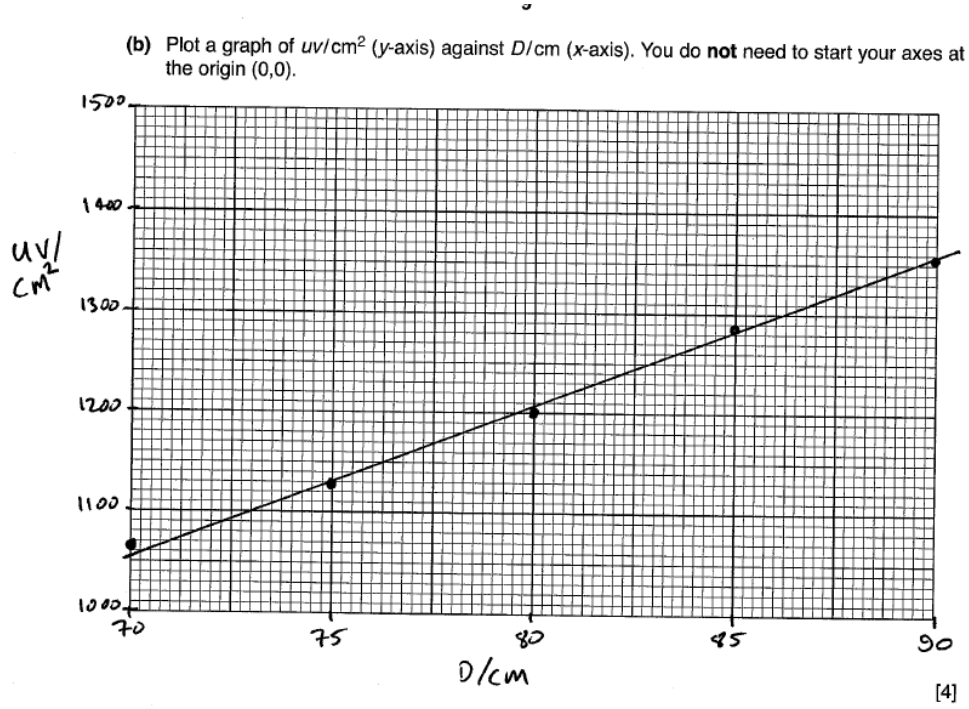
$\frac{28.8 \times 83.7}{28.8 + 83.7} = \frac{2410.56}{112.5} = 21.43$

f = _____21.43 cm_____

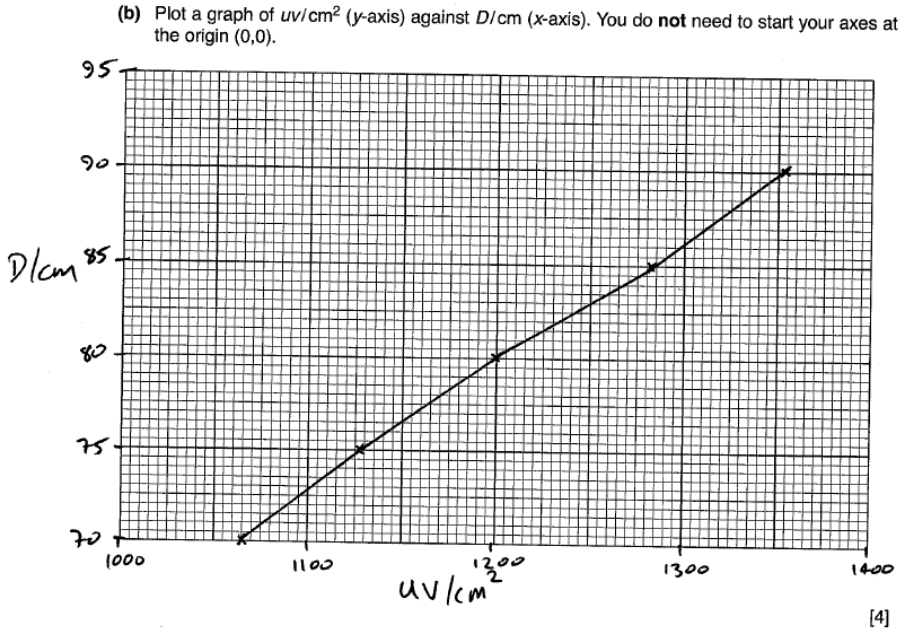
g) Your teacher will show you the video of the experiment and they will pause it to allow you to take the measurements that will be shown on the screen.
Write your measurements in your table in section (d).

Worksheet D: Incorrect graphs Answers

What is wrong with each of the following graphs?

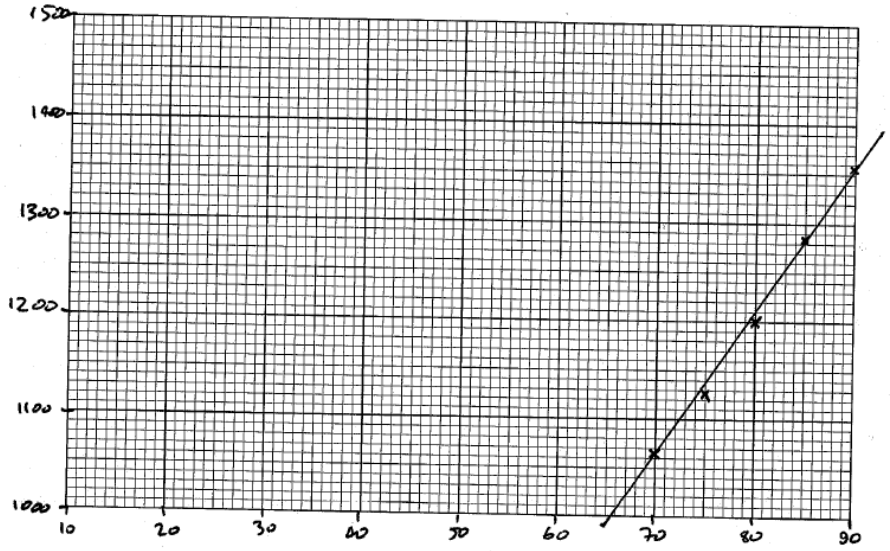


Points drawn with large blobs instead of small, neat crosses.



Axes are wrong way around and the line is drawn dot to dot.

(b) Plot a graph of uv/cm^2 (y-axis) against D/cm (x-axis). You do **not** need to start your axes at the origin (0,0).

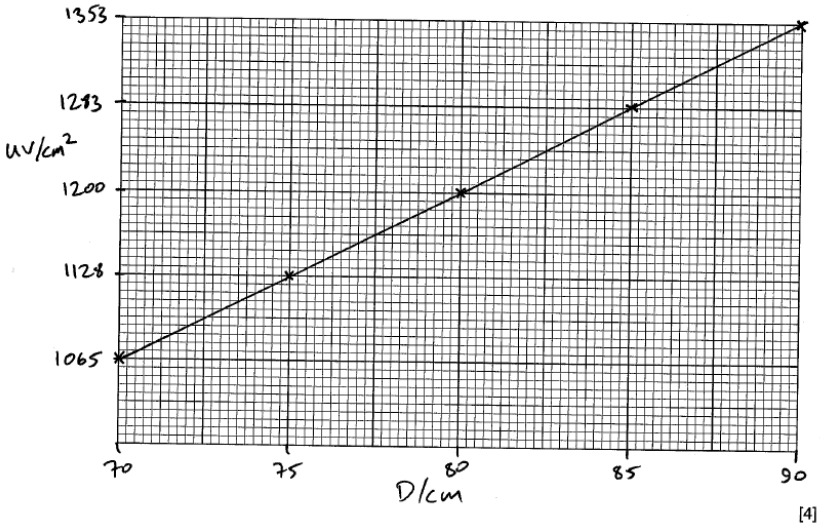


[4]

Axes are not labelled with the quantity and unit.
Horizontal scale only uses the right hand side of the grid.

9

(b) Plot a graph of uv/cm^2 (y-axis) against D/cm (x-axis). You do **not** need to start your axes at the origin (0,0).

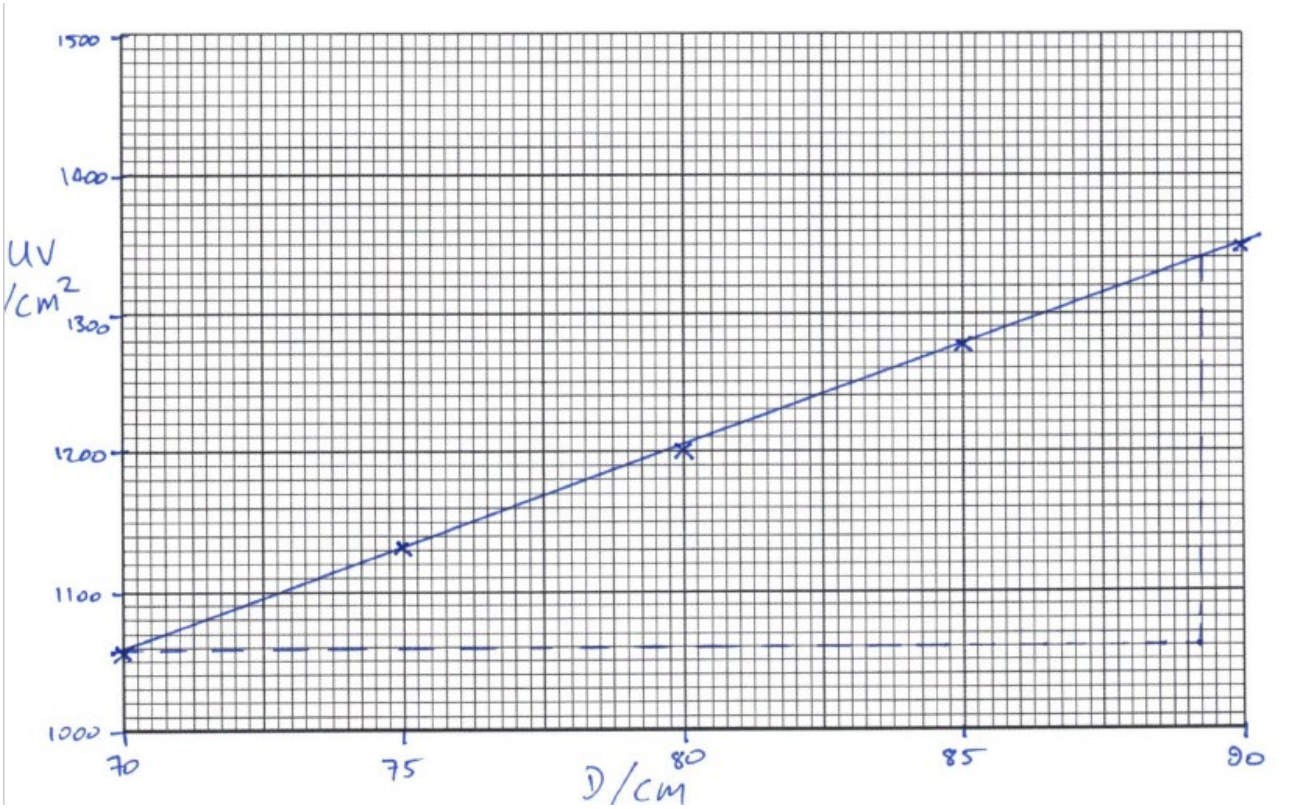


[4]

uv axis uses the data values from the table and is not linear.

Worksheet E1: Processing data Answers

Use your experimental data from the previous lesson to plot a graph of uv/cm^2 (on the Y axis) against D/cm (on the X axis).
You do not need to start your axes at the origin (0,0)



The focal length f of your lens is equal to the gradient of the line.

Use your graph to calculate the gradient of the line.

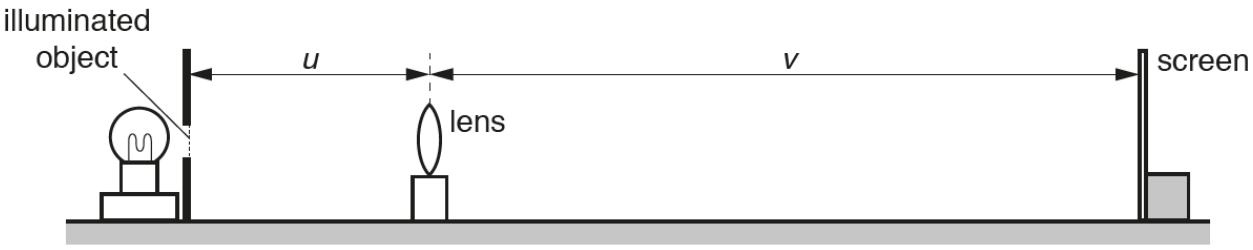
Show clearly on the graph how you obtain the necessary information.

Coordinates (70,1060) and (89.25, 1340)

$$f = \frac{1340 - 1060}{89.25 - 70} = \frac{280}{19.25} = 14.54545$$

Gradient = _____14.5 cm_____

Some students did the same experiment as you did in the previous lesson.
This was the set up they used.



Use your ruler to accurately measure the distances u and v in the diagram above.

u = _____3.1 cm_____

v = _____9.3 cm_____

The diagram was drawn to 1/9th actual size.
Calculate the actual sizes of u and v that the students measured.

u = _____27.9 cm_____

v = _____83.7 cm_____

f) Calculate the focal length for the students' lens, f, by using the following formula for the actual values of u and v.

$$f = \frac{uv}{u+v}$$

$= \frac{27.9 \times 83.7}{27.9 + 83.7}$

$= \frac{2335.23}{111.6}$

= 20.925

f = _____20.9 cm_____

One of the students says that the lens you used and the lens that they used have the same focal length.

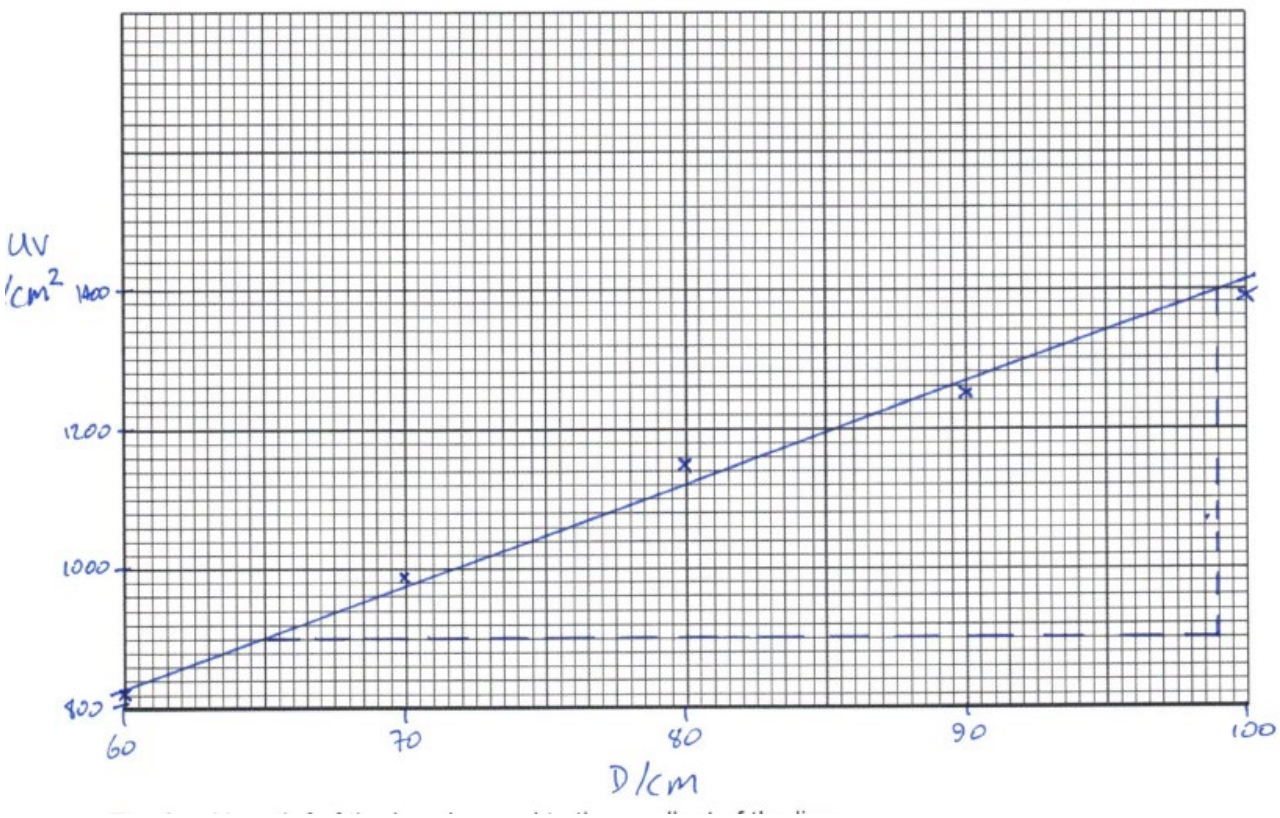
State and explain whether the two lenses used have the same focal length within the limits of experimental accuracy.

14.5 + 10% = 14.5 + 1.45 = 15.95 cm (maximum limit)

20.9 is much higher than 15.95 so he lenses do not have the same focal length within the limits of experimental accuracy.

Worksheet E2: Processing data Answers

Use your experimental data from the previous lesson to plot a graph of uv/cm^2 (on the Y axis) against D/cm (on the X axis).
You do not need to start your axes at the origin (0,0)



The focal length f of the lens is equal to the gradient of the line.

Use your graph to calculate the gradient of the line.

Show clearly on the graph how you obtain the necessary information.

Coordinates (65,900) and (99, 1400)

$$f = \frac{1400 - 900}{99 - 65} = \frac{500}{34} = 14.706$$

Gradient = ___14.7 cm_____

In part f of worksheet C2, you calculated a value for the focal length for the lens that the students used.

One of the students says that the lens used in the video and the lens that they used have the same focal length.

State and explain whether the two lenses used have the same focal length within the limits of experimental accuracy.

Value of f from worksheet C2 = 21.43 cm

F = 14.7 cm
14.7 + 10% = 14.7 + 1.47 = 16.17 cm (maximum limit)

21.43 is much higher than this maximum value so the two lenses used do not have the same focal length within the limits of experimental accuracy.

Worksheet F: Another way? Answers

Here is another way of finding focal length by experimental means.

This student has made several mistakes in their answers. Find the mistakes and correct them.

h_0 = 2.0cm

3 A student investigates the image produced by a converging lens.

He uses the apparatus shown in Fig. 3.1.

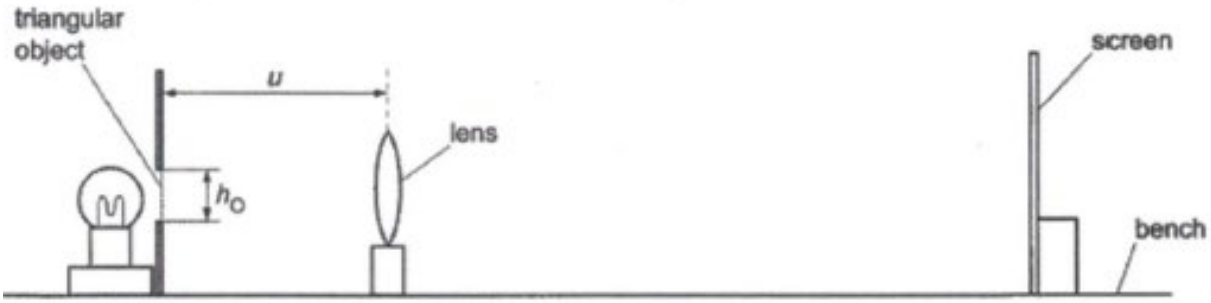


Fig. 3.1

(a) The triangular object is shown full size in Fig. 3.2.

Measure and record the height h_O of the triangular object in Fig. 3.2.

h_O = 19 X 1.9 cm [1]

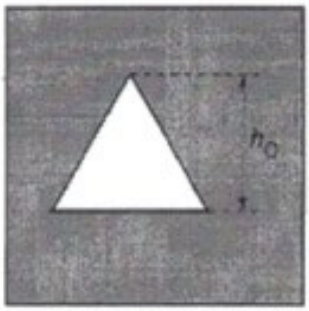


Fig. 3.2

(b) The student sets the distance u between the triangular object and the lens to 20.0 cm. He moves the screen until a sharp image of the triangular object is seen on the screen. The student measures, and records in Table 3.1, the height h_I of the image on the screen.

Briefly describe a technique to obtain an image on the screen that is as sharp as possible in this experiment.

Move the lens (X) backwards and forwards, slowly (V) screen [1]

The screen is moved, not the lens.

(c) The student repeats the process for $u = 25.0\,\text{cm}$, $u = 30.0\,\text{cm}$, $u = 35.0\,\text{cm}$ and $u = 40.0\,\text{cm}$. His readings are shown in Table 3.1.

For distance $u = 20.0\,\text{cm}$, calculate, and record in Table 3.1, the value of $\frac{1}{h_I}$. [1]

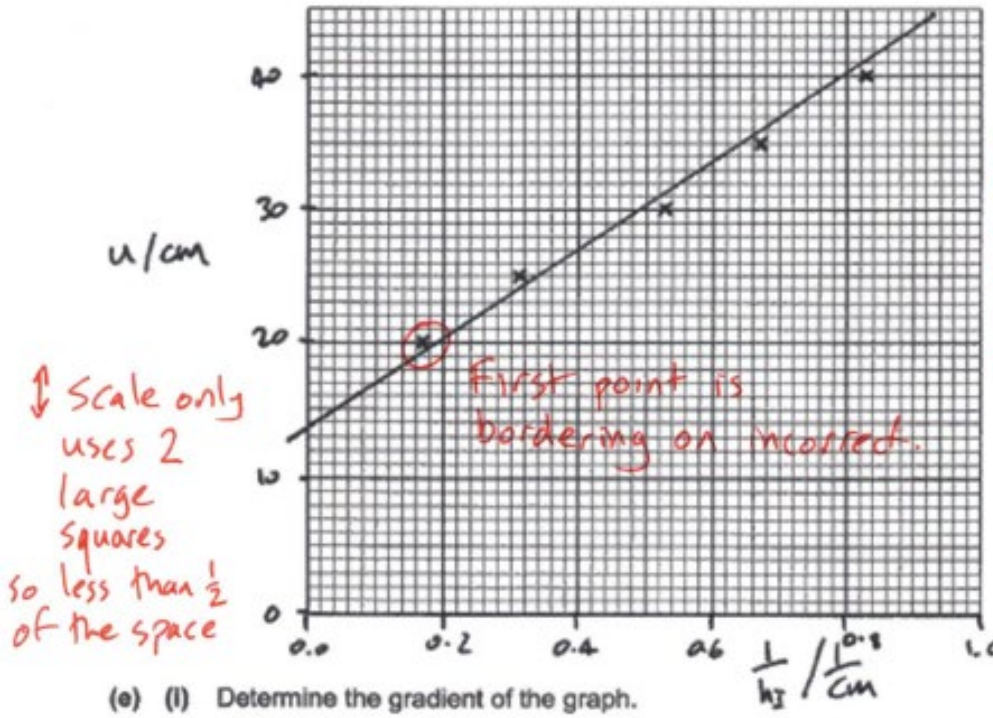
Table 3.1

u/cm	h_I/cm	$\frac{1}{h_I} / \frac{1}{\text{cm}}$
20.0	5.6	0.1786
25.0	3.2	0.31
30.0	1.9	0.53
35.0	1.5	0.67
40.0	1.2	0.83

× 0.18

Other results to 2 d.p.

(d) Plot a graph of u/cm (y-axis) against $\frac{1}{h_I} / \frac{1}{\text{cm}}$ (x-axis).



↕ Scale only uses 2 large squares so less than ½ of the space

Axis labels ✓
Vertical scale ✗
Points ✗
LoBF ✓

[4]

(e) (i) Determine the gradient of the graph.

Show clearly on the graph how you obtained the necessary information.

$\frac{40-20}{0.93-0.1786} = \frac{20}{0.6514} = 30.703$

gradient = 30.7 [1]

Candidate has used values from the table and has not indicated values on the graph

Cambridge Assessment International Education
The Triangle Building, Shaftesbury Road, Cambridge, CB2 8EA, United Kingdom
t: +44 1223 553554
e: info@cambridgeinternational.org www.cambridgeinternational.org