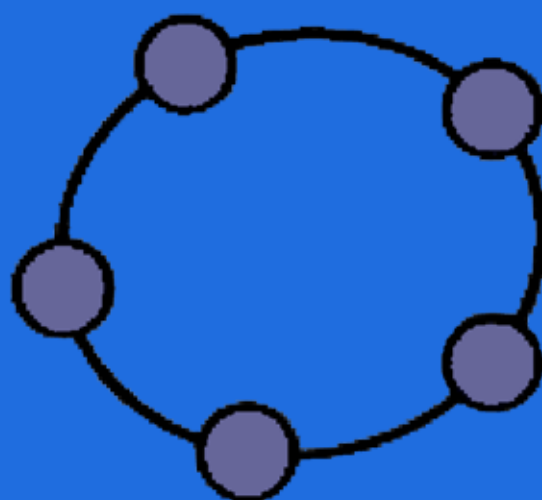


Samples of Applet Construction Using GeoGebra



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Foreword

The Regional Centre for Excellence in Mathematics Teaching and Learning (CEMTL) is one of six projects that form the Regional Approach to Outstanding Teaching, Learning and Learner Support for the Shannon Consortium. CEMTL aims to develop and implement a comprehensive regional mathematics and numeracy enhancement strategy. To that end the following material has been created not only to assist the mathematics education of all mathematics learners in second and third level institutions but also to enhance the instruction of mathematics by teachers and lecturers in Ireland.

Please be advised that the material contained in this document is for information purposes only. The information has been peer-reviewed and is correct and accurate at the time of publishing. CEMTL will endeavour to update the information contained in this document on a regular basis. This document has been created as a companion booklet to accompany the java applets available on the CEMTL website. These applets were created using GeoGebra, a free multi-platform dynamic mathematics software package designed for teachers and learners of mathematics.

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Examples of GeoGebra Applet Construction

A Straight Line Graph

In this example we will use GeoGebra to construct a java applet similar to the one displayed in Figure 1. This applet consists of two sliders labelled m and c that allow

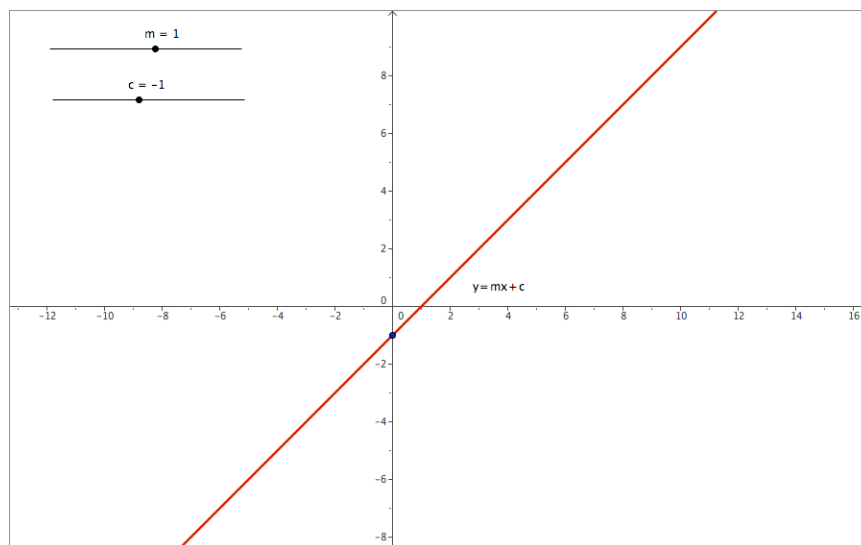


Figure 1: Applet to show slope and intercept of a line

the user to alter the slope of the line and its intercept on the y -axis. The line will be redrawn as the sliders change value allowing the user to see immediately the effect of any changes made. There is some text, $y = mx + c$, and a blue point also in the applet. The text is used to display the name of the line. The purpose of the blue point is to highlight the intercept on the y -axis and also to guide the user's eye. Without the blue point on the y -axis the perceived effect of changing the value of c is that the line moves from left to right. By putting the blue point on the line we simply changed this illusion to one where the line moves up and down which is in fact what is actually happening.

We will now see how to create the straight line applet. Open GeoGebra and you will be presented with the launch screen as shown in Figure 2. Move your mouse over the button at the top of the screen marked with the symbol of a slider and the equation

Examples of GeoGebra Applet Construction

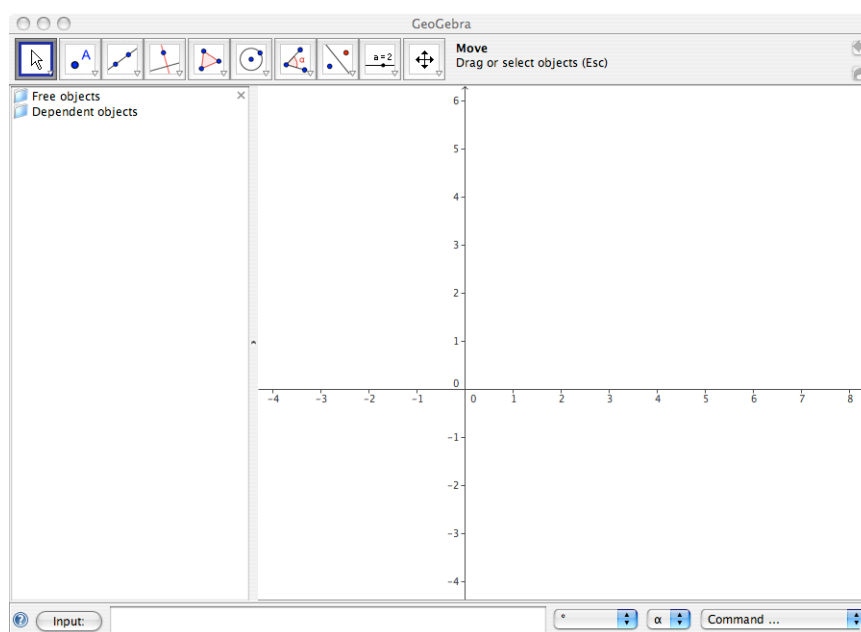


Figure 2: Opening screen of GeoGebra

$a = 2$. Click on this button to activate the tool. Click in the drawing screen where you want the slider to appear. The menu shown in Figure 3 will appear. You are going to

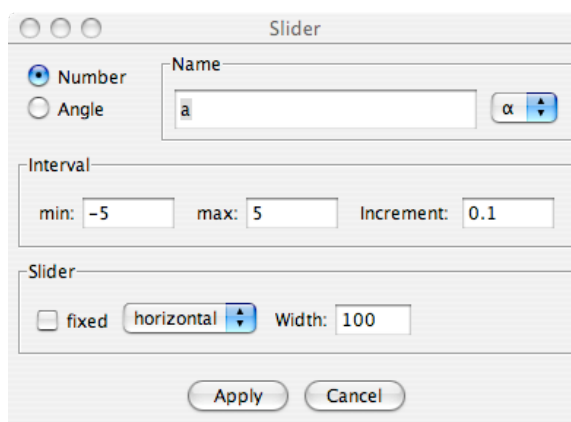


Figure 3: Construction of a slider

use this to construct a slider to give the slope of the line. The default value for a slider is **Number**. Since you want a number leave this box as is. GeoGebra names numbers using small letters in alphabetical order. Since this is the first number you have created the default name is a . Change this to m to represent the slope. The next thing you need to decide is what interval the slider should cover. The default value is $-5 \dots 5$ but for practise, if nothing else, change these values to -10 for the **min** and 10 for the **max**. You can leave the increment value as 0.1 . The slider can be horizontal or vertical. Choose whichever you like. The width of 100 units is also fine. If you change your mind

Examples of GeoGebra Applet Construction

about any of these values they can be edited later. There is a check-box marked **fixed** here also. This fixes the value, not the position, of the slider. Normally you will leave this unchecked otherwise it will not be possible to alter the value of the slider which will then behave as a constant instead of a parameter. In complicated constructions you may want this checked while you are carrying out the construction and uncheck it when you are happy with everything. Finally click the apply button and your slider is created.

Repeat this process to create a slider for the intercept of the line with the y -axis. Call this slider c . If you are unhappy with where the sliders are in the screen you can change their position. Use the mouse to click on the selection arrow in the toolbar. Catch either of the sliders on the straight line section of the slider and you will be able to move it. Notice that in the Algebra window, on the left of the screen, c and m have been created as Free objects. As you change the value of the slider, by clicking and dragging the dot on the slider, the values here will also change.

The next thing to do is create the straight line. Click the mouse in the **Input** window at the bottom of the screen. Enter the equation $y = m x + c$. Note the space between the letters m and x . This space is critically important as it is interpreted by GeoGebra as an instruction to multiply the quantities on either side of it, in this case m and x . Press the **Enter** key and the line is constructed. Notice that it appears as a *Dependent object* in the *Algebra window* on the left-hand side of the workspace. It has also been given a name, probably a , which you can change if you like. The name is very convenient in long constructions when you want to refer to a previously constructed object. You can also see that the name appears on the diagram. Often you will not want this to happen. Click on the selection arrow. Now double-click on the graph of the straight line. A dialog window as in Figure 4 appears on the screen. Uncheck the box marked **Show label** and the label will not be displayed on the screen. While the *Properties window* is open you can change the style of the line also. Click on **Color** and a colour palette

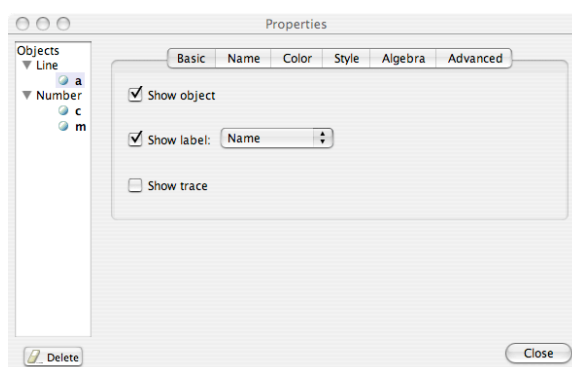


Figure 4: Properties window

appears. Click on the colour you want for your line. Now click on the **Style** menu. This allows you to choose the line thickness and the style of the line. Experiment until you get what you want.

A very convenient feature of the *Properties window* is that it reveals all the objects on the left. When you are finished adjusting the properties of one object you can click on

the name of a different one and then adjust that too. The sliders c and m can be moved by the user. You might like to fix that now. With the *Properties window* still open, click on c . Select the **Slider** tab in the *Properties window*. Check the **fixed** checkbox. Repeat for the slider m and close the *Properties window*. Choose the selection arrow and move the slope and intercept sliders to see if you get the effect you want. You may find that moving the slider for c gives the wrong optical effect. To help the eye see that the line is moving up and down I think you could create a point at $(0, c)$. This is very easy to do. Click in the Input field. Type **(0,c)** and press Enter. The point is created. It has been given a name, probably A . Use the *Properties window* to hide the name, change the colour etc. Now save your file.

All that remains to be done is to create the applet that will be displayed on the web page. First go to the **View** menu and uncheck the **Algebra window** and **Input field** if you would like these to be hidden in the applet. At this point you might find that the drawing has become off-centered. If you think this then use the move tool to re-center the whole drawing.

Next, go to the **File** menu and down to **Export**. This opens a sub-menu the first item of which is **Dynamic worksheet as web page (html)**. This is what you want. When you select this item the window shown in Figure 5 appears. You can fill in the

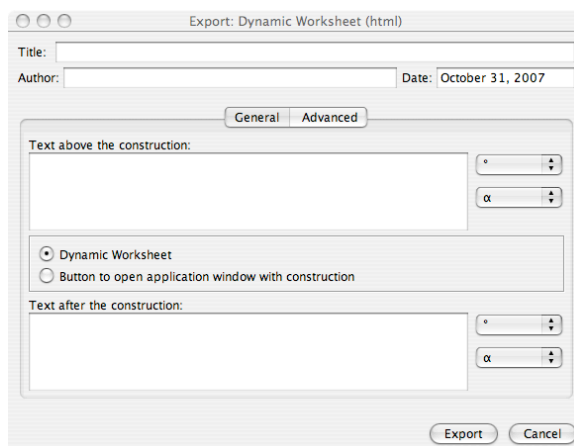


Figure 5: Export window

various options here as you choose. You can leave them all blank and edit your web page with any HTML editor instead if you prefer. You might prefer this choice as it gives you a lot more control over the design and layout of the page.

Now click on the **Advanced** tab. The options here, shown in Figure 6, allow you to decide how much control to pass onto the user. Again the **Title**, **Author** and **Date** are a matter of personal preference. In the **Functionality** panel the first check-box says **Right click enabled**. If you check this box then the user, by right clicking on a Windows machine or Ctrl-clicking on an Apple, will be able to bring up a menu that allows the GeoGebra applet to be edited. In the case of this particular applet you may not want this but there are cases where it would make sense for the user to be able to zoom, change functions, alter parameters or even constants.

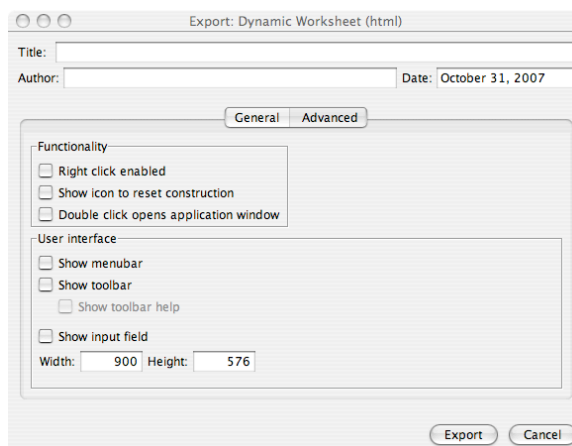


Figure 6: Advanced Export window

The next option, if checked, creates an icon on your web-page. This icon, when clicked, will reset the construction. If your applet is complex and permits user interactivity then you should consider including this icon. In complex situations it may be all too possible for the user to upset many of your constructs. If the user gets into trouble this icon will permit easy recovery. It may happen that you would like the user to perform their own constructions. The next icon, **Double click opens application window**, will allow the user to open GeoGebra on their own computer.

The **User interface** checkboxes allow you to show the menu, toolbar and input field if you choose. It depends what your applet is for whether you want this or not. Finally the **Width** and **Height** give the width and height of the applet in pixels.

When you are happy with everything click the **Export** button. It is a very good idea to export to a specific directory (folder). As well as creating an applet a number of other files are also created. There are five jar files, a html file and the exported ggb file. The jar files are about 2.4 MB in size. If these accompanied every applet it would take forever to view your web pages. It is suggested that you export all your GeoGebra applets to the same directory (folder). Then the five jar files are only created once. Finally you can alter the appearance of your page in any editor if you are familiar with html code.

A Quadratic Graph

In this example you will see how to create interactive text. The text tool in GeoGebra uses the language \LaTeX which is a dialect of \TeX created by Donald E. Knuth. It is widely accepted as the standard method of typesetting mathematics. There are many books and websites dedicated to \LaTeX so we will not go into the language in any detail here. Below, in Table 1, is a list of the commands to type for the most common mathematical expressions. Note the use of curly brackets when more than one item is needed as a power etc. There are many more \LaTeX commands but these few should be

You Type	GeoGebra shows
<code>x^2</code>	x^2
<code>e^{2 x}</code>	e^{2x}
<code>x_1</code>	x_1
<code>\frac{a}{b}</code>	$\frac{a}{b}$
<code>\int</code>	\int
<code>\int_0^1</code>	\int_0^1
<code>\int_{-\frac{\pi}{2}}^1</code>	$\int_{-\frac{\pi}{2}}^1$

Table 1: More common \LaTeX commands

sufficient for the moment.

To get the graph of the quadratic function is very easy and relies on methods you have already learned. Since a quadratic graph is a graph of the function

$$f(x) = ax^2 + bx + c$$

you can see that there are three parameters — a, b and c — that should be under the control of the user. The easiest way to introduce these is as sliders. Create three sliders calling them a, b and c . You can set their range to go between any values you like. For now let each of them go from $-5 \dots 5$. With these parameters created you can now easily create the graph. Click inside the **Input** window and type the following:

$$f(x) = a x \wedge 2 + b x + c$$

Note that there is a space between the letters **a** and **x** and also between the letters **b** and **x**. These spaces are crucial as they indicate the operation of multiplication to GeoGebra. Once this is done press the **Enter** key and the required graph is drawn on the screen. You can select the graph and edit it to change the thickness and colour until you are happy with it. Fix the positions of the sliders so that the user can change their values but not their positions.

The next step is to enter text on the screen. This will form the bulk of this example as there are a number of factors to consider. You are going to put two different messages on the screen. The first will be

A quadratic function is given by

$$y = ax^2 + bx + c$$

The second message will be, for example,

This is the graph of

$$y = 3x^2 + 2x + 1$$

Each of these apparently simple messages will require more input from you than it might appear now. The first message is the simplest. To put this on the screen we will break it into two parts. The default text size for the current version of GeoGebra is 12 pt. While this is fine in printed output it is not great on a computer screen. Go to the **Options** menu and scroll down until you come to **Font size**. Choose a more suitable size, say 14 pt. Remember that you can always edit the text afterwards and change any of its properties.

Select the text tool and click on the screen. In the window that appears type in

A quadratic function is given by

then click the **Apply** button. Your text appears on the screen. Change the tool to the selection arrow. Catch the text and position it where you like. Now double click on the text box. The edit menu appears. If the **Basic** tab is not highlighted then click on it. Check the box **Fix object** and close the window. Your text is now in a fixed position on the screen. Next you are going to type in the mathematical formula.

Select the text tool and click on the screen. Type into the box

$$y = ax^2 + bx + c$$

and **check the LaTeX formula box**. Click apply and you should see

$$y = ax^2 + bx + c$$

appear on the screen. Again use the selection arrow to place and fix this text. You now have two text objects that you can place so that the user thinks it is one message. Notice that these objects appear in the Algebra window as T1 and T2. This is the general pattern for text objects and is something you will make use of shortly. Follow a similar procedure to create, place and fix the message

This is the graph of

Now comes the more complicated part. You want to use dynamic text that will show the user the values of the three sliders in the name of the formula. First adjust the sliders so that the value of a is 2, b is 1 and c is 3. This is not necessary but will help in talking about the next step. The method used here is enclosing parts of a statement in quotations (""). The convention used by GeoGebra is that anything in quotations is treated as part of a \LaTeX formula provided the **LaTeX formula** checkbox is ticked. Anything outside quotations is treated as a variable name and the value of the variable is used. Remember that you are using GeoGebra and a space means multiply. It cannot mean two different things so a different symbol must be used to tell GeoGebra that concatenation is required instead of multiplication. The required symbol is $+$. What this means is that to combine things inside and outside quotations you need to join the two things with a $+$.

Select the text tool and click on the screen. Type the following into the window:

`"y = " + a + "x ^ 2 + " + b + "x + " + c`

and ensure the **LaTeX formula** box is checked. Click Apply and your dynamic text will appear on the screen looking like

$$y = 2x^2 + 1x + 3$$

Let us look at the text we entered in a bit more detail. The first bit, `"y = "`, just creates the first part of the formula $y =$. This is closed with the double quote character. The next part is outside quotes. The `+` sign instructs GeoGebra to join what follows to the previous text. What follows is the symbol a which now means the value stored in the variable a , in this case the number 2. Again we follow with another `+` to tell GeoGebra to join more text to this string. The next piece of text, `"x ^ 2 + "`, will appear as x^2+ because this time the `+` is inside quotes and is only a string with no meaning. Next we pass outside the quotes to type `+ b +` which instructs GeoGebra to get the value of the variable b and display it and then join on more text. This next is `"x + "` which will appear as $x+$. Finally we type `+ c` to show the value of the variable c . Move the sliders for a , b and c to see that the values of the text change accordingly.

The Scalar Product

This example will demonstrate how to create an applet to calculate the scalar product of two vectors as shown in Figure 7. The user will be able to move the two vectors and

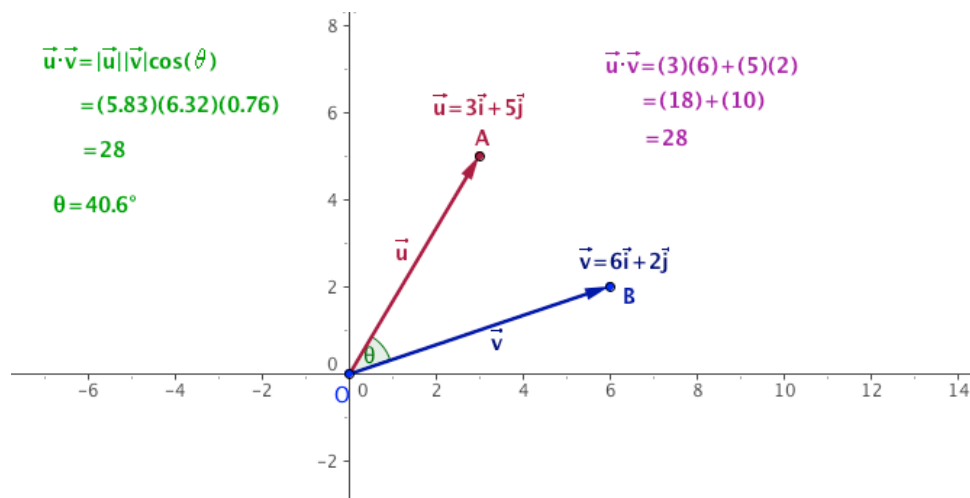


Figure 7: Calculation of the scalar product

see the scalar product being calculated. The text is dynamic and will reflect the actual values of the vectors. The text is the most difficult part of this applet. The steps are as follows:

- Create the points A , B and O ,
- Create the vectors OA and OB ,
- Create the angle θ ,
- Generate the text.

In the **Input** field type in $\mathbf{A} = (3, 5)$. Press the **Enter** key and the point A is constructed. Colour it as you please. Now type in $\mathbf{B} = (6, 2)$ to construct the point B . Finally construct the origin as $\mathbf{O} = (0, 0)$.

In the **Input** field type $\mathbf{u} = \mathbf{Vector}[\mathbf{O}, \mathbf{A}]$. Notice that after you have typed in the first two letters of the word “Vector” the entire word appears. If you hit the **Enter** key at this point the cursor will be positioned between the two brackets. This is an example of command completion. It can help speed up your inputs. Next type in $\mathbf{v} = \mathbf{Vector}[\mathbf{O}, \mathbf{B}]$. With the two vectors constructed you can now use the **Selection Arrow** to change their properties. Fix the colour and line thickness to your choice. In the **Basic** tab of the **Properties** dialog box deselect the check-box **Show Label** in each of the vectors. You will want to display your vector as \vec{u} rather than u . You will also want to control its position. A good trick here is to create an invisible point and attach a name to it. In the **Input** field type $\mathbf{C} = \mathbf{A}/2$. This creates a point at the centre of the segment

[OA]. Select the text tool and click anywhere on the page. Into the window type \vec{u} and make sure that the checkbox for a LaTeX Formula is checked. Click on the **Apply** button and you will see the text \vec{u} on the screen. Double-click the text to open the Properties dialog and click on the **Position** tab to see a dialog box similar to the one in Figure 8. The **Starting Point** will be blank. Scroll down until you have the text

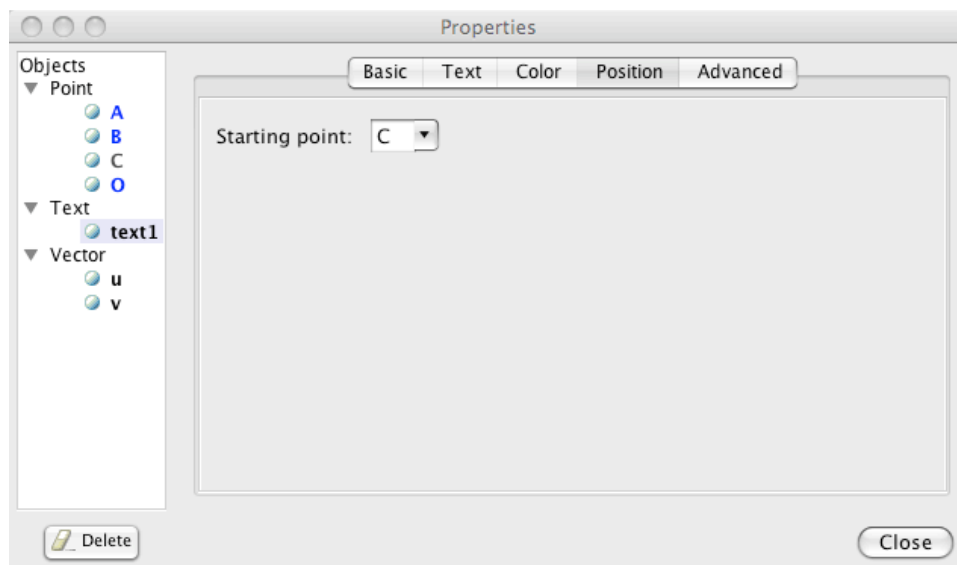


Figure 8: Positioning text

starting at the point C . Now use the **Selection Arrow** to move the text, \vec{u} , until you are happy with its position. Double-click the point C to open the **Properties** dialog. Under the **Basic** tab deselect the two check boxes for **Show Object** and **Show Label**. The point C is now invisible. If you move the point A the text, \vec{u} , moves with the centre of the vector as was desired. Use the same method to position the text, \vec{v} , at the centre of the vector OB .

The next step is to label the points A and B with dynamic text. You will attach a label like $\vec{u} = x\vec{i} + y\vec{j}$ to the point A where the x and y will be the actual coordinates of the point. The x -coordinate of a point A is given, in the **Input** field, by $x(A)$. Similarly you can get the y -coordinate as $y(A)$. Select the text tool. Ensure that the **LaTeX formula** checkbox is ticked. Type in

$$"\vec{u} = " + (x(A)) + " \vec{i} + " + (y(A)) + " \vec{j}"$$

The Quadratic example in the previous section explains in more detail the structure of the above input if you find it difficult to understand. Click on the **Apply** button. You should see on the screen

$$\vec{u} = 3\vec{i} + 5\vec{j}$$

if you still have the point A at $(3, 5)$. As you move A the values will change. Next use the **Selection** arrow to double-click on the text you have just created. When the **Properties** window opens click on the **Position** tab. Choose the text to start at the

point A . Close the window and adjust the position of the text. So far everything seems fine. However there is still a problem that we referred to in the last section. Drag the point A below the x -axis, say to the point $(3, -5)$. The label becomes

$$\vec{u} = 3\vec{i} + -5\vec{j}$$

This really does not look good. We will fix this problem in two stages. The first thing to do is use the **Selection** arrow to double-click and bring up the **Properties** window again. This time, click on the **Advanced** tab. Into the slot under the message **Condition to show object type**

$$y(A) \geq 0$$

You will get the symbol \geq by scrolling down under the degree ($^\circ$) symbol. What you have just done ensures that the text string

$$\vec{u} = x\vec{i} + y\vec{j}$$

will only appear if $y \geq 0$. This is the first stage completed.

The next step is to create an appropriate text string to appear only if the point A is below the x -axis. To do this you will use $\text{abs}(y(A))$ which will return $|y|$. Again use the text tool and check the **Latex formula** box. Then type

$$\text{"\vec{u} = " + (x(A)) + "\vec{i} - " + (abs(y(A))) + "\vec{j}"}$$

to get the text string

$$\vec{u} = x\vec{i} - y\vec{j}$$

Attach this string to the point A . Click on the **Advanced** tab and ensure that this string is only visible if

$$y(A) < 0.$$

Use a similar procedure to create appropriate text for the vector \vec{v} .

The next thing to do is to draw the angle $\angle BOA$. Select the **Angle** tool. Click on the points B, O and A in that order. Recall that the default measure of angle is anti-clockwise. If A is $(3, 5)$ and B is $(6, 2)$ then you will probably see the marked angle and the label $\alpha = 46^\circ$ appear on the screen. Select the **Selection** tool and double-click on the angle to open the **Properties** window. In the **Basic** tab deselect the **Show label**. If you like change the name to θ . Play with the **Color, Style** and **Decoration** windows until the angle appears the way you like it.

Finally you need to enter the text block

$$\begin{aligned} \vec{u} \cdot \vec{v} &= (3)(6) + (5)(2) \\ &= (18) + (10) \\ &= 28 \end{aligned}$$

where the numbers are dynamic and will change as the vectors move. Without doing a short course on L^AT_EX the easiest approach is to treat the three lines of the array

of equations as different text blocks. You can then fix them on the screen to give the impression that they form one text block. Select the **Text** tool and click anywhere in the drawing pad. Check the **Latex formula** box. Enter

$$\text{"\vec{u} \cdot \vec{v} = ("+(x(A))+")("+(x(B))+") + ("+(y(A))+")("+(y(B))+")"}$$

If the coordinates of A and B are unchanged this should appear on the screen as

$$\vec{u} \cdot \vec{v} = (3)(6) + (5)(2)$$

Recall that the quotation marks occur in pairs. Anything inside quotation marks is treated as a string and typeset as symbols. Anything outside the quotation marks is treated as a variable and its value is substituted. Place this text block on the screen where you want it to be and fix its position in the **Properties** dialog window.

The next line of text will be entered as

$$\text{" = ("+(x(A) x(B))+") + ("+(y(A) y(B))+")"}$$

The space between $x(A)$ and $x(B)$ is critically important as it tells GeoGebra to multiply the two variables together. Similarly for $y(A)$ and $y(B)$. The result on the screen should be

$$= (18) + (10)$$

again subject to the x and y values of A and B . Place this text carefully lining up the “=” signs in the two equations.

The final line of text in this trio of equations should be entered as

$$\text{" = " + (x(A) x(B) + y(A) y(B))}$$

which should appear as

$$= 28$$

Again carefully place this text and fix it in position. As you move the points A and B the values of the vectors \vec{u} and \vec{v} will change. Your dynamic text should reflect each of these changes.

We will now show how to enter the text on the left of the applet as shown in Figure 7. This text block shows how to calculate the scalar product using the lengths of vectors and the angle between the them. To ease typing we will first define two new numbers. In the **Input** field enter

$$e = \text{Length}[u]$$

which will create the number $e = |\vec{u}|$. Additionally enter

$$f = \text{Length}[v]$$

which will create the number $f = |\vec{v}|$. These new variables will save on typing. The first line of text now becomes

$$\text{"\vec{u} \cdot \vec{v} = |\vec{u}| |\vec{v}| \cos(\theta)"}$$

which will appear as

$$\vec{u} \cdot \vec{v} = |\vec{u}| |\vec{v}| \cos(\theta)$$

Position this on the screen and fix it.

The second line of text is entered as

$$" = (" + \mathbf{e} + ") (" + \mathbf{f} + ") (" + (\cos(\theta)) + ") "$$

You will get the letter θ by scrolling down under α . Subject to the points A and B having the values in Figure 7 the text should appear on the screen as

$$= (5.83)(6.32)(0.76)$$

Line up this equation under the first and fix it in position when you are happy with it.

The third equation is very simple. Enter it as

$$" = " + (\mathbf{e} \mathbf{f} \cos(\theta))$$

Note that only the “=” symbol is inside quotation marks. Note also the spaces between \mathbf{e} , \mathbf{f} and $\cos(\theta)$ because you want these three variables multiplied together. The text appears on the screen as

$$= 28$$

Finally you can place the value of the angle. Select the text tool. Check the **Latex formula** box and enter

$$" \theta = " + \theta$$

I have not said anything here about colour, line thickness, fill etc. These are all personal choices and you should play around with them.