BiotSavart

Magnetic field calculator

Version 2.2 User's Guide

Ripplon Software

Please let us know what you think of **BiotSavart**. Suggestions for improvements are always welcome! Direct correspondence regarding **BiotSavart** to:

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Contents

1 Introduction

1.1 Features

BiotSavart is a general purpose interactive program to calculate magnetic fields resulting from collections of current-carrying conductors. Features of the program are

- general conductor shapes
  - filamentary loop
  - cylindrical solenoid (thick, thin, or pancake)
  - revolved surface
  - filamentary wire of arbitrary path
  - racetrack coil
- conductor descriptions can be entered interactively or read from files
- two or three-dimensional graphical display of the conductor configuration
- calculation of vector field profile along a specified trajectory
- two-dimensional profiling of field with contour plot
- calculated field profiles may be written to disk for post-processing
- field profiles update automatically when changes are made to conductors or currents

1.2 What you need

Version 2.2 of BiotSavart requires a computer running MacOS system 7 or 8 and at least 1 MB of application memory. Versions exist for PowerPC and 68K machines.

2 Using the program

2.1 Starting and quitting

To start BiotSavart, open (or double-click) the application icon. Alternatively, you can open an existing BiotSavart document. The conductors described in the document will be displayed on the **Configuration** window. Field probes, if any, will not be recalculated, in order to allow you to modify the configuration before embarking on a time-consuming computation.

In order to exit BiotSavart, choose **Quit** (⌘**Q**) from the **File** menu. If the configuration has been changed since it was last saved, you will be asked whether or not to save the changes.

2.2 Adding conductors

If there is no configuration window, create one by choosing **New** (⌘**N**) from the **File** menu.

Conductors are added to the configuration using the **Config** menu. Conductor types are **Loop**, **Solenoid**, **Revolved**, **Wire**, and **Racetrack**. Whenever you add a conductor an edit dialog window will appear to allow you to change the specifications (this is described in detail in section 5). After modifying the conductor, register the changes using the **Set** button. The **Done** button is the same as **Set**, but also dismisses the edit dialog.

Conductors may also be read from other BiotSavart documents or your own files using the **Read file...** command on the **Config** menu. This command will prompt for a file to read, and extract from it the conductor descriptions and current supply values. Probes are not extracted. Section 9 describes how to make your own conductor files.

2.3 Selecting conductors

To select a conductor, click on its picture on the configuration window. The name of the conductor will appear at the bottom of the window. Clicking with the shift key depressed adds the conductor to the selection list (if it is already selected, this removes it from the list). Selected objects are drawn red. You can also tell which conductors are selected by looking at the **Modify** menu – the name of each selected conductor will be checkmarked.

2.4 Deleting conductors

Selected conductors can be deleted by selecting **Cut** (⌘**X**) or **Clear** from the **Edit** menu.

2.5 Modifying conductors

In order to make changes to a conductor, you must create an edit window for the conductor. There are several ways to do this. The fastest is to double-click the conductor on the configuration window. Choosing the conductor by name from the **Modify** menu will accomplish the same thing. Also, if one or more conductors is selected, the **Modify** command (⌘**I**) on the **Edit** menu will create an edit window for each selected conductor.

Changes to the conductor dialog parameters do not take effect until they are registered with the configuration by using the **Set** or **Done** buttons. Note that this registers the changes with the configuration database, but writes nothing to disk unless the **Autosave** option is set. Changes may be discarded before saving by using the **Cancel** button to dismiss the dialog.

The name of the conductor may be changed when its edit window is active by using the **Change Name...** command on the **Edit** menu.

2.6 Probing the field

To measure and display the magnetic field, you create field probes using the **Config** menu. There are two types of probes: **Linear**, a one-dimensional probe, and **Planar**, a two-dimensional probe. When a probe is created an edit window appears containing the description of the probe and the format of the display of the calculated field profile. For the Linear probe, the specification includes a description of the path through space along which the field is to be calculated. The motion commands are documented in section 8.

Each probe has a result window in which it displays the calculated field profile. The name of the window is the name of the field probe preceded by the symbol Π (for product).

Selection, deletion, and modification of probes is done in the same manner as conductors.

2.7 Saving the configuration

In order to save a new or modified configuration to disk, use the **Save** command (⌘**S**) on the **File** menu. If you are working on an existing BiotSavart document, then this will overwrite the old version of the file. If instead you wish to save the configuration under a new name, then use the **Save As...** command.

2.8 Field calculation

After making changes to the configuration, you will want to recompute the magnetic field, to update the field probe displays. To do this, use the **Recompute** command (⌘**R**) on the **Field** menu. This command is only enabled when the field needs to be recalculated.

If **AutoRecompute** is enabled, the program will recalculate the field whenever a conductor or probe in modified, e.g., from an edit dialog. Selecting **AutoRecompute** from the **Field** menu toggles it between enabled (ticked) and disabled (not ticked).

If you want to modify several conductors or probes before recalculation, disable **AutoRecompute**, make and save the modifications, and then trigger the recalculation by re-enabling **AutoRecompute** or by using the **Recompute** command (⌘**R**).

During the field calculation, the cursor will be cycling through an action sequence. This indicates that the program may be interrupted by holding down the ⌘ button and typing a period (.).

2.9 Current supplies

The current passing through the wires of a conductor is determined by its current supply. The present version of **BiotSavart** requires conductors to have an external current supply. The use of external current supplies greatly accelerates magnetic field recalculation when only the currents are changed. There can be several conductors wired to the same supply.

There is one object, with default name "Current", which keeps track of all the currents. To modify the currents, use the **Modify** menu to summon an edit dialog for this object.

The **Current** object also allows you to specify a bias magnetic field (section 7).

3 Menus

3.1 File menu

New If no configuration window exists, creates a new one. There can only be one configuration window.

Open Open a configuration file.

Close Close the configuration (if a window is active other than the configuration window, that window is closed).

Save Write the changed configuration to the file.

Print... Nothing fancy, but prints the configuration picture.

When a probe result window is active, the **Export Data...** command can be used to write the calculated field to a specified file.

3.2 Edit menu

The functioning of the **Edit** menu depends on which type of BiotSavart window is the active one. When the configuration window is the active one:

Cut (⌘X) Copies selected objects to the clipboard and deletes them.

Copy (⌘C) Copies selected objects to the clipboard.

Paste (⌘V) Objects on the clipboard are loaded into the configuration.

Clear Deletes the selected objects.

Select All (⌘A) Selects all objects in the configuration.

Select None Clears the selection list.

Duplicate (⌘D) Duplicates the selected objects.

Modify (⌘I) Creates a edit window for each selected object.

Visible Makes selected objects visible.

Invisible Makes selected objects invisible.

Name... Allows you to specify a name for each selected object.

If no objects are selected, then **Copy** places a copy of the picture in the configuration window onto the clipboard.

When an object's edit window is active, then the **Edit** menu can be used to **Cut**, **Copy**, and **Paste** text. Also, the **Visible**, **Invisible**, and **Name...** commands can be used (they apply only to the object belonging to the window in this case).

When a probe result window is active, then the **Copy** command copies a picture of the graph to the clipboard. It is not possible to copy the calculated field data. Export it to a file instead, using **Export data...** on the **File** menu.

3.3 Config menu

The **Config** menu is used to add conductors or probes to the configuration. It is also used to read conductors from other BiotSavart documents.

The **Make conductor** submenu creates conductors, or sources of magnetic field:

Loop Circular filamentary loop, with fields calculated exactly using Elliptic Integrals.

Solenoid Cylindrical solenoid. Fields are calculated by breaking the solenoid up into loops and summing the loop fields.

Revolved Cylindrically symmetric current sheet obtained by revolving a polygon about the symmetry axis. The surface current density produces the field of a permanent magnet of the specified shape. Fields are calculated as a sum over loops.

Wire Creates a string of filamentary segments, specified by a sequence of motion commands for a shuttle. These commands include straight segments and radiused turns. Fields are calculated by summing the exact fields from the segments.

Racetrack Creates a planar racetrack conductor. Fields are calculated by decomposing the Racetrack into a bundle of wires.

The **Make probe** submenu creates objects which measure the magnetic field:

Linear Creates a one-dimensional field probe, which calculates the magnetic field along a specified trajectory and plots the (vector) field profile.

Planar Creates a two-dimensional field probe, which calculates the magnetic field on a specified flat surface and displays a contour plot of the field magnitude.

Other commands on the **Config** menu are

Read File... Reads the conductors from an existing BiotSavart document or user-generated file (see section 9).

AutoSave If ticked, changing a conductor or probe via an edit dialog will result in a write of the entire configuration to disk. Normally off.

3.4 Modify menu

The names of all objects (current supply caretaker, conductors, and probes) appear on the **Modify** menu. Selecting a name from the menu selects the object and creates an edit dialog for you to modify it. The current supply caretaker is only accessible through this menu.

This menu also shows the selection list: the names of selected objects in the configuration are ticked.

3.5 Field menu

The **Field** menu controls the recalculation of magnetic field. There are two menu items:

AutoRecompute If ticked, the program will recalculate the magnetic field whenever a conductor or probe is altered. Selecting AutoRecompute will toggle it between ticked and not ticked. Ticking it when the field needs to be recalculated will initiate the recalculation.

Recompute (⌘R) Used to trigger recalculation if AutoRecompute is not ticked. The Recompute command will only be enabled when the field needs to be recalculated. Use this manual trigger if you want to make changes to several conductors between recalculations.

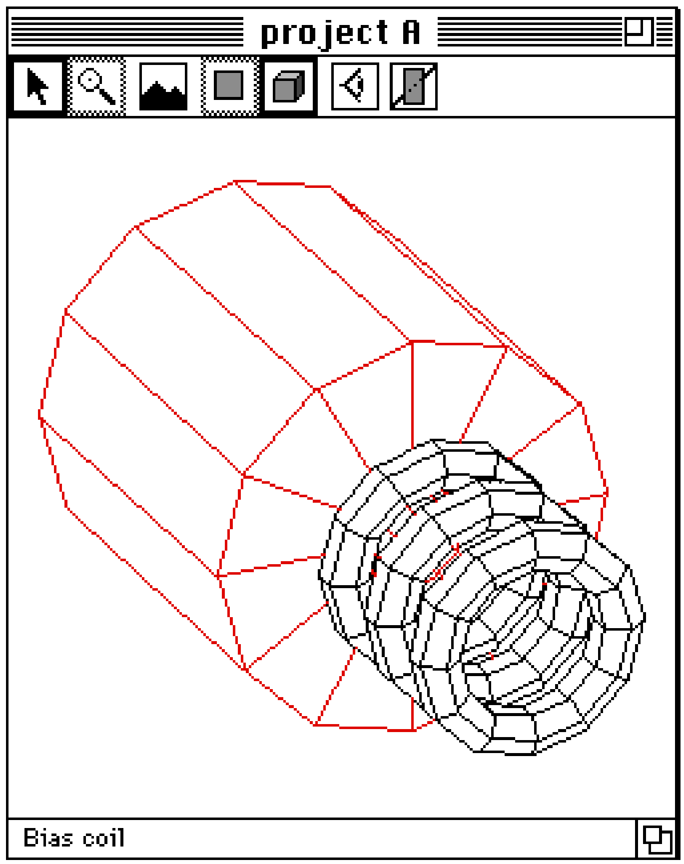
3.6 Windows menu

Permits activation of windows which may or may not be visible. The first window listed is the configuration window. Other windows are listed (case-insenstive) alphabetically.

4 Windows

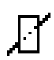
4.1 Configuration window

There is one configuration window, which displays a picture of the conductor configuration you are working on:



The title of the window is the name of the configuration file.

At the top of the window are several controls:

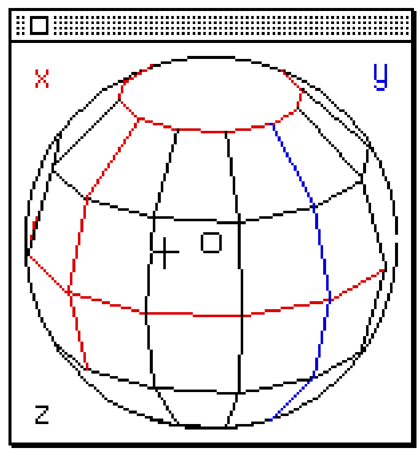
	Sets the configuration window to select mode. The cursor will be the usual arrow, and can be used to select an object by clicking at it. The selected object will be colored red. Double-click an object to edit it.
	Sets the configuration window to zoom mode. The cursor will be a magnifying glass. Specify the zoom rectangle on the picture by moving to the upper left hand corner of the rectangle, depressing the mouse button, dragging to the lower right corner, and then releasing the button. The picture will zoom in on the rectangle. Clicking without dragging will zoom in on the point specified. Clicking the mouse with the shift key depressed zooms out instead of in.
	Zooms back out so that all of the objects are visible.
	Sets two-dimensional display mode.
	Sets three-dimensional display mode.
	(3D mode only) Launches a viewing direction choice window. Changing the view direction zooms the view out so that all conductors are visible.
	(3D mode only) Removes the hidden lines from the drawing. This can be time consuming. Note that later changing the viewing direction will put the lines back in, but that zooming will not.

Objects are selected by clicking on them. When an object is selected, its name appears at the bottom of the configuration window and the object is colored red. Clicking on an object with the shift key depressed adds it to the selection list, permitting selection of more than one object. Shift-clicking a selected object removes it from the selection list. The names of all conductors and probes are listed in the **Modify** menu, with selected objects ticked. With the configuration window active, selected objects can be cut, pasted to or copied from the Clipboard, or deleted or duplicated, using the **Edit** menu. Selecting **Modify** (⌘**I**) from the **Edit** menu creates edit windows for the selected object(s). To select and edit a single object, one can just double-click on it. If an object is not visible, the **Modify** menu can always be used to bring up an edit window. This also selects the object.

Using the **Print...** command on the **File** menu, the picture may be printed. No effort has been made to have **BiotSavart** produce report-quality printed output, however. It is recommended that to produce a report you copy the picture to a word processor document. The **Copy** command, with no objects selected, copies the picture to the clipboard. Also note that a conductor copied to the clipboard is a text object which specifies the conductor. To copy the text description of the entire configuration to the clipboard, do **Select All**, then **Copy**.

4.2 ViewSet window

The **ViewSet** window is used to set the direction from which we view a three-dimensional picture. This window, which is summoned using the eye icon on the graphics window, displays a globe with lines of latitude and longitude. To set the viewing direction drag the small rectangle on the globe. To align with a coordinate axis, click on the coordinate label (click with shift key depressed to look from the other side).



4.3 Edit dialog windows

Modification of a particular conductor or probe is done through its Edit window, which is summoned by double-clicking the object on the configuration window or by using the **Modify** menu. The name of the edit window is the name of the object being modified. The use of edit windows is described in section 5.

To change current supply values, summon an edit window for the **Current** object (this can only be done via the **Modify** menu).

4.4 Probe result windows

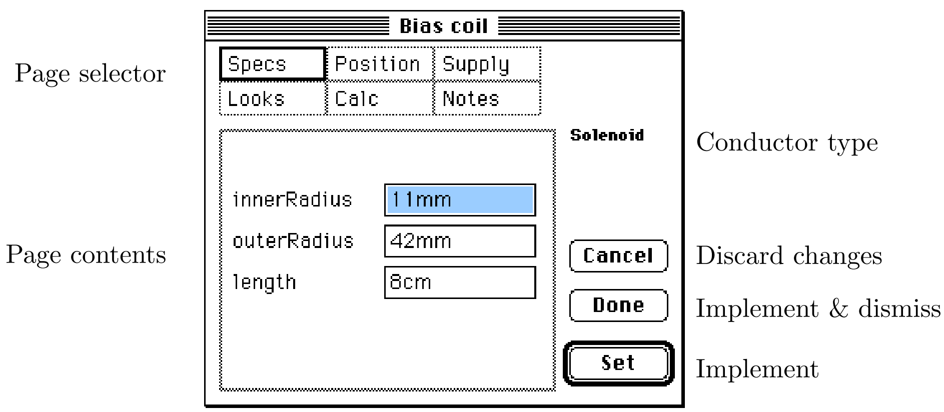
The results of magnetic field probes are plotted in probe windows. The name of the probe window is the name of the probe object preceded by the symbol Π. The format of the plots is specified in the dialog window of the probe itself.

When the probe result window is active, the field profile may be written to disk using the **Export Data...** command on the **File** menu.

For more details, see section 8.

5 The edit dialog in detail

The edit dialog contains a number of pages of information, which depend on the type of object being edited. For example, here is the edit dialog window for a **Solenoid**, turned to the **Specs** page:

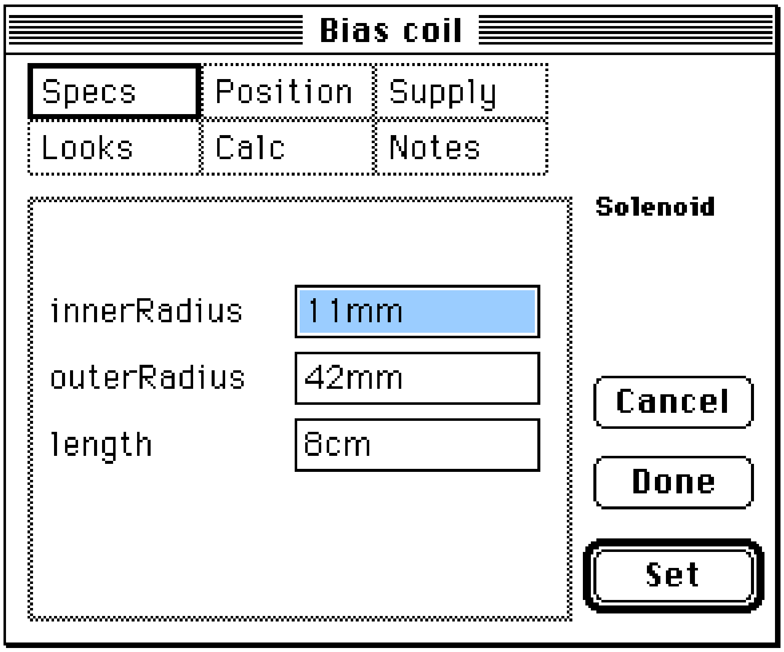


The title of the edit dialog window is the name of the object being edited. Below the title bar is the page selector, which controls which page of information is displayed. To the right of the page contents is an indication of the type of object being edited.

The control buttons are: **Set** (to implement the changes you have made to the dialog boxes), **Done** (to implement the changes and close the dialog window), and **Cancel** (to throw away the changes and close the dialog window). Note that **Set** changes the object irrevocably; **Cancel** only discards unimplemented changes.

In the above picture, the edit dialog is set to the first page, **Specs**. We will now go through all of the pages for a **Solenoid**, to see how things are set up.

5.1 Page Specs - general specifications

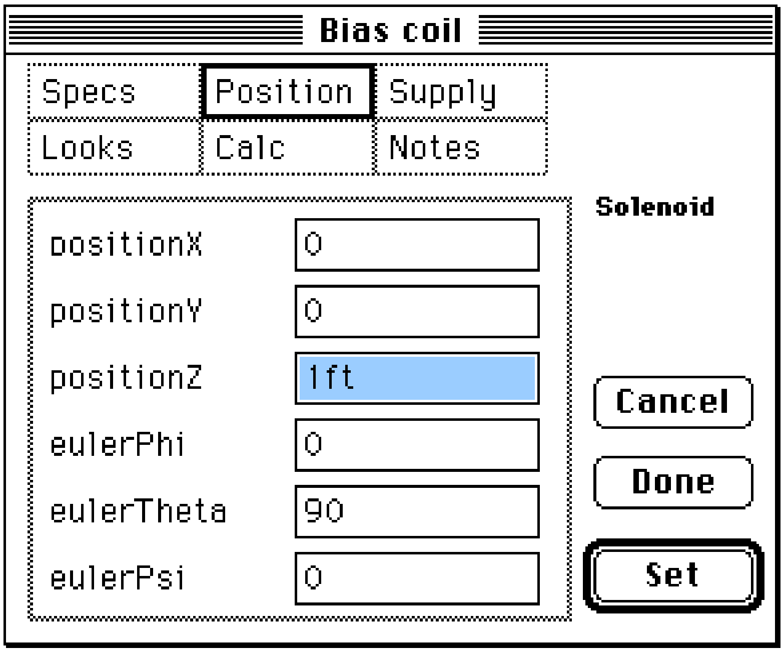


The size and shape of the object is specified on the **Specs** page of the edit dialog. For a **Solenoid**, these specifications are the inner and outer radius of the coil, and its length (a thin solenoid has the inner radius equal to the outer radius, a pancake solenoid has length equal to zero). All of these parameters can have units.

	m	cm	mm	ft	in
Recognized units: (default is `m`)	meter	0.01m	0.001m	12in	2.54cm

Other objects can have rather different **Specs** pages. For instance, the **Wire** conductor has a text pane where you describe the path of the wire through space.

5.2 Page Position - position and orientation



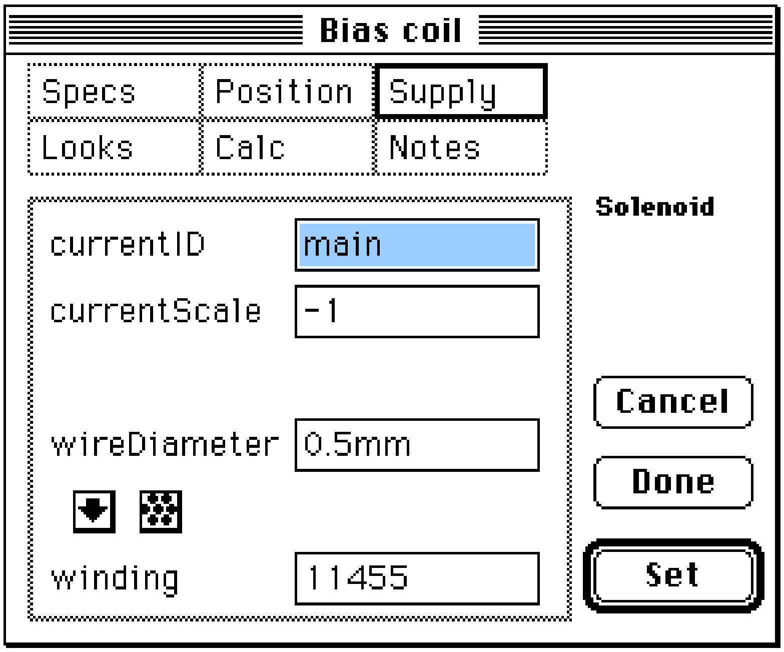
The position of the conductor is specified by giving the laboratory frame coordinates of the reference point of the conductor (for instance, the center of a solenoid, or the origin of the object coordinate system for a wire). As shown above, these coordinates can have units.

The orientation of the conductor is specified by three Euler angles, denoted as follows:

ϕ	`eulerPhi`	rotate object about z-axis
θ	`eulerTheta`	rotate about object x-axis (i.e., bow towards object $-y$ direction)
ψ	`eulerPsi`	rotate about new object z-axis

For an axially symmetric conductor such as a loop or solenoid, ψ has no effect on the calculated magnetic field. The Euler angle parameters are specified in degrees. The conductor is rotated about the origin of its own coordinate system.

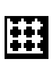
5.3 Page Supply - the flow of current



The **Supply** page is where you specify which current supply to use for the object. The name of the supply (no embedded blanks) should be entered in the `currentSupply` box. An overall scale factor for the current is specified by the `currentScale`. This can be set to -1 to reverse the connections. The current supplies themselves are set by bringing up an edit window for the **Current** object (using the **Modify** menu).

To indicate a number of windings use the `winding` parameter.

For bulky conductors (Solenoid and Racetrack) the `wireDiameter` parameter also appears on the **Supply** page. The `winding` can be calculated from the `wireDiameter` or visa versa. To specify which way the calculation goes, click the arrow button till it points the right way. The wire packing which is used in this calculation is determined by the setting of the packing button:

 Square packing. The number of turns is calculated from the `wireDiameter` by dividing the cross sectional area by the square of `wireDiameter`, rounding to the nearest integer. In the inverse calculation

`wireDiameter` is not, of course, rounded to an integer.

 Hexagonal packing. The way round wires like to be wound, a bit tighter than square packing (the number of windings is a factor $2/\sqrt{3}$ larger).

Note that the packing button is only used to determine the relation between `winding` and `wireDiameter`, and does not change the grid of pseudo-conductors which is used to calculate the field of a bulky conductor; this is always a rectangular grid.

5.4 Page Looks - object appearance

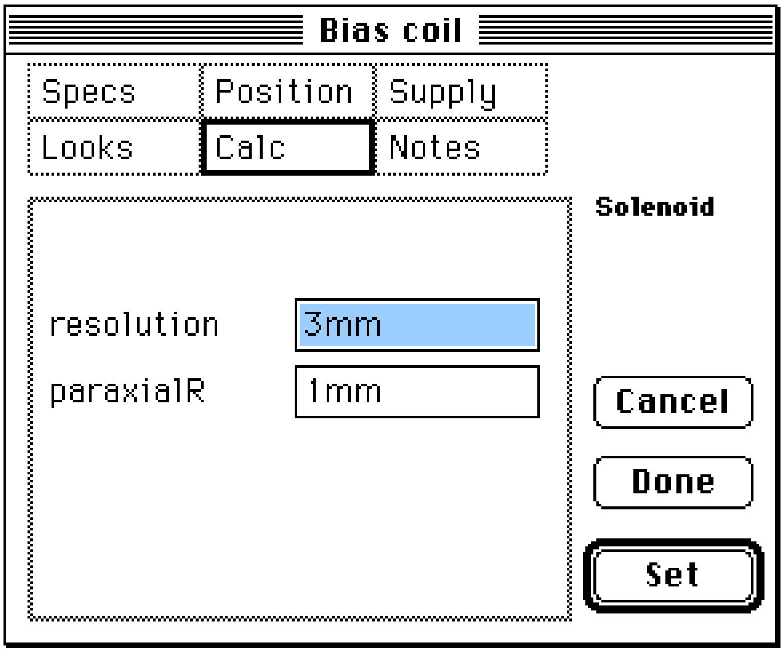
The **Looks** page is where the appearance of the object is controlled. Nothing here will change the calculation of the magnetic field.

The `visible` checkbox changes the visibility status of the object on the configuration window.

With the solenoid in the "standard" (i.e., default) orientation and the configuration window on 2D drawing mode, the `drawLoops` checkbox will cause the calculation loops to be drawn.

The number of angular steps used to draw the solenoid is given by the `nphi` command. A range of angles, `phi0` to `phi1` may be specified to draw a "cut-away" view. This does not change the magnetic field, which is always that of a complete solenoid.

5.5 Page Calc - field calculation

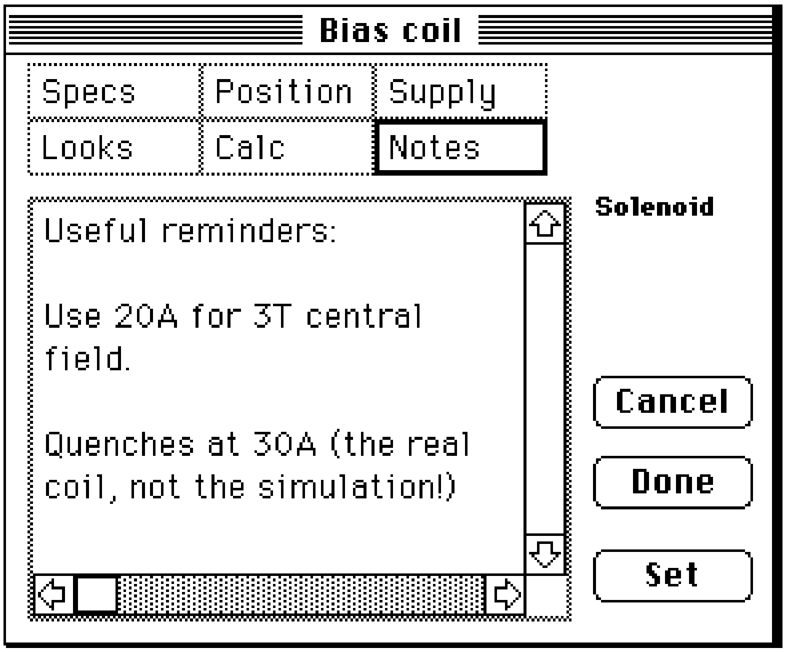


The details of the field calculation are specified by parameters on the **Calc** page.

In general, the field is found by decomposing the solenoid into loops and summing the loop fields. The finesse of this decomposition is set by the `resolution` parameter. The resolution should be chosen wisely; too large a value will give unrealistic fields, too small may make the calculation unbearably slow.

Near the axis it is possible to use an expansion in ρ (the distance to the axis) which is exact in the limit that ρ tends to zero. The parameter `paraxialR` is the value of ρ where the calculation switches to sum-over-loops. With `paraxialR` zero, the expansion is used only on axis. With `paraxialR` negative, the loops calculation is always used.

5.6 Page Notes - user comments



Every object has a **Notes** page, where you can keep comments, parameters, etc. for future reference.

6 Edit dialogs by object

6.1 Loop

Specs page A table of `radius`, `altitude`, and `winding` for a set of coaxial loops. The `altitude` is just the z-coordinate of the loop in the object frame. Both `radius` and `altitude` can have units. All loops have the same wire diameter.

Looks page Although the field due to the loop is calculated using Complete Elliptic Integrals, the loop is drawn using straight segments or, if `wireDiameter` is not zero, using planar polygons. The number of segments drawn is set by the `nphi` parameter, the range of angles is set by `phi0` and `phi1` (these angles are in degrees). The number of steps around the wire cross section is set by `nzeta`. None of the parameters on this page has any effect on the calculated magnetic field.

Calc page The `wireDiameter` parameter, which has two effects. First, the wire is drawn with the specified thickness. Second, the field divergence associated with a filamentary conductor is avoided, since the field is calculated assuming uniform current density within the wire (actually, BiotSavart assumes a linear field gradient in the wire, which is equivalent in the limit that the wire diameter is much smaller than the loop diameter.)

6.2 Solenoid

Specs page The `innerRadius`, `outerRadius`, and `length` of the solenoid. All quantities can have units. For a thin solenoid, enter the same dimension for `innerRadius` and `outerRadius`. For a pancake coil set `length` to zero.

Current page The `wireDiameter` parameter appears here, and can be used to calculate the `winding` parameter, or visa versa. The arrow button indicates the direction of calculation and the packing button can be set to square or hexagonal packing.

Looks page The number of segments used to draw the solenoid is set by the `nphi` parameter and for cut-away views the range of angles drawn is set by `phi0` and `phi1`. These parameters do not influence the magnetic field.

Calc page The `resolution` parameter determines how many (pseudo)loops are used to calculate the magnetic field: the coil cross section is divided by `resolution`. For distances to the axis, ρ, smaller than `paraxialR`, a cubic expansion in ρ is used. If `paraxialR` is negative, the sum-over-loops calculation is always used.

6.3 Revolved

The **Revolved** conductor type is a cylindrically symmetric current sheet obtained by revolving a polygon about an axis. Since the revolved object is used to represent a body uniformly magnetized parallel to its axis, the surface current density is proportional to $\cos\theta$, where θ is the angle between the axis and the surface normal. The current obtained from the current supply is interpreted as the magnetization $\mu_0 M$ in tesla.

Description of the edit dialog pages:

Specs page On this page of the edit dialog, you describe the two-dimensional polygon which defines the cross section of the object. The description language is given below.

Supply page The current supply current (multiplied by `currentScale` and by `winding`) is interpreted as the magnetization $\mu_0 M$ of the body, in tesla.

Looks page The revolved polygon is drawn using `nphi` angular steps. The value of `nphi` has no effect on the magnetic field.

Calc page The `wireDiameter` appears here. There are no wires, of course, but this parameter is the diameter of the calculation loops, and can be used to smooth the field variations at the surface of the sheet. The `reverse` checkbox can be used to reverse the order of polygon vertices.

Now we discuss how to describe the polygon on the **Specs** page.

First you must specify the density of loops which will be used in the calculation of the magnetic field, by the command

```
resolution 0.5 mm
```

Units are optional; the default unit is meter.

Next, specify the polygon by giving the starting point and sequence of motions in the (x, z) plane. For example, a truncated cone with an on-axis hole:

```
start 2 0 mm
goto 8 -6 mm
goto 1 -6 mm
goto 1 0 mm
close
```

The `resolution` can be changed during the specification to allow some parts of the polygon to be described by a higher density of loops. The polygon should be specified *clockwise* in the x-z plane. If you specify it counterclockwise, however, you can use the `reverse` checkbox on the **Calc** page. It is possible to describe a multi-piece magnet with a second sequence of commands beginning with `start`.

6.4 Wire

Specs page A text description of the current path in three-dimensional space. For this description object coordinates are used, *before* Euler angle rotation and translation to the final position of the object in the laboratory frame. The path language is described below.

Calc page The `wireDiameter` is used to suppress divergence of magnetic fields near the conductor. This does not affect the appearance of the wire on the configuration window; it is always drawn as a filament.

Now we consider how to describe the path of the wire, on the **Specs** page.

We begin a wire by giving the starting point (in object coordinates)

```
start 2 0 0 cm ; we begin here
```

The units apply to all components of the vector. As always, the default length unit is meters. Note that a semicolon means that the rest of the line is a comment.[1] To draw a straight line segment we simply say where to go:

```
goto 0.5 0 0 cm
```

To make an arc, we can specify a center and normal. For example, if we are in the x-y plane and want to turn about the z-axis, we set

```
center 0 0 0
normal 0 0 1
```

and then turn, starting at the present position. Before making the arc, we must first specify the finesse of the turn:

```
dtheta 20 ; stepsize in degrees
```

Then the `turn` command is used to create the arc:

[1] Do not use this for important information; use the **Notes** page instead.

```
turn 90 ; angle in degrees
```

Another way to make an arc is use the `axis` command, which uses two points to specify an axis. For example, to make the axis of rotation parallel to the z-axis, but passing through $x = y = 2\,\text{cm}$, the command is

```
axis 2 2 0 cm 2 2 1 cm
```

The distance between the two points is immaterial (and note that the units of a vector apply to all three components). After an `axis` command, the `turn` command makes an arc about the specified axis.

A helix is simply a turn with pitch. The pitch is specified by giving the length per turn

```
pitch 1mm
```

Since the main use of `pitch` is to make multi-turn windings, the `turn` command will accept turn units:

```
turn 5t
```

Finally, to close the wire (this is optional) the command is

```
close
```

6.5 Racetrack

Racetracks are used in particle accelerators and neutral atom traps. Biot-Savart implements planar racetracks.

Specs page The dimensions of the racetrack are specified by the `length` of the straight sections (bars), the `span` (distance between bar axes), the `width` of the conductor (in its plane) and its `height` (out of plane). The turns at the ends of the racetrack are semicircular. This is approximated, both in drawing and field calculation, by finite angular steps. The number of steps in the semicircle is given by the `nturn` parameter. The field computation time is proportional to `nturn+2`, so it is best to use a small number unless an accurate depiction of the end fields is desired.

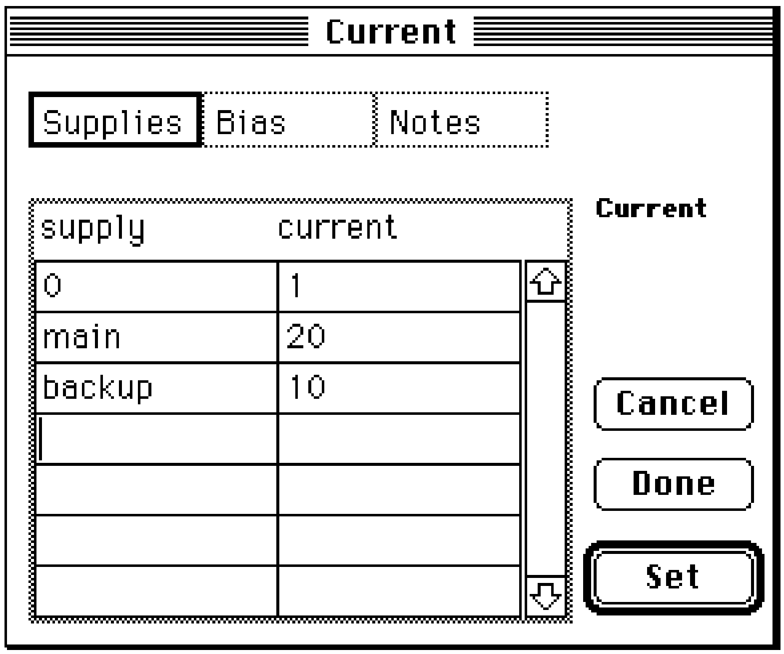
Current page The `wireDiameter` parameter appears here, and can be used to calculate the `winding` parameter, or visa versa, just as for a solenoid.

Looks page Checking the `drawWires` box causes the calculation wires to be drawn.

Calc page The magnetic field is calculated by subdividing the racetrack into filamentary wires. The finesse of the subdivision is given by the parameter `resolution`. The number of calculation wires is the coil cross section divided by the square of `resolution` (so choose it wisely). Suppression of field divergence near the wires inside the conductor is automatic.

7 Current supplies

There exists an invisible object whose task it is to keep track of the settings of the various current supplies connected to the conductors of the configuration. To change the settings of the current supplies, bring up an edit window for this object using the Modify menu.



In a new configuration, the default current supply, called "0", is set at one ampere. The current supply names can be any text not containing blanks (or braces). Several conductors can use the same current supply; if so, they are wired in series.

The `bias` parameter (on the **Bias** page) specifies a uniform bias field (in Tesla, in the z direction) which is to be applied to the configuration.

Once you have modified the Current object, implement the changes using the **Set** or **Done** buttons. If **AutoRecompute** is enabled, the magnetic field will be recalculated immediately to reflect the new current supply and bias field settings.

8 Field probes

The field probes are used to investigate the magnetic field profile. Probes are made in the same way as conductors, by choosing the appropriate type from the **Config** menu. Field probes have associated with them a window which displays the calculated field graphically. The name of the window is the name of the probe object preceded by the symbol Π, meaning product. This section describes the parameters for the field probes, which control both the placement of calculated points and the plotting of the results.

8.1 Linear probe

This probe calculates the magnetic field along a specified trajectory, and plots the result. The field unit is tesla. To set the points at which the field is calculated enter a path on the **Specs** page, like the following:

```
resolution 1 mm ; spacing of points
start 0 0 0 ; starting point
goto 1.3 0 0 cm ; first segment
resolution 0.5mm ; spacing for second segment
goto 1.3 0 2 cm ; second segment
```

Points are placed uniformly on each segment, with points on the starting and ending position, such that the points are no further apart than the present `resolution`.

The plot itself is controlled from the **Plot** and **Scale** pages. By default, the field magnitude $|\vec{B}|$ is plotted versus the distance s along the line. The x, y, or z components of the field can be plotted as well, with the abscissa given by either x, y, z, or the arclength s. Normally the plot is scaled to show all the data. This can be changed by specifying a range on the **Scale** page or by zooming directly on the probe result window.

8.2 Linear probe result window

The linear probe result window shows a graph of the calculated magnetic field. In selection mode (cursor an arrow) clicking on a point on a curve tells you the field value. In zoom mode you can zoom in on any part of the graph.

Double click on the axis labels to jump to the probe dialog, in order to change what is plotted or manually change the plot range.

With the result window active, you can use the **Export Data...** command (on the **File** menu) to write the calculated data to a file. You will be prompted for the name of the file to be written. Each line of the file consists of seven tab-delimited floating point numbers:

$$x \quad y \quad z \quad B_x \quad B_y \quad B_z \quad B$$

8.3 Planar probe

This probe calculates the magnetic field on a flat surface specified by two displacement vectors $\vec{u}$ and $\vec{v}$. To specify the grid of probe positions specify the resolution in the $\vec{u}$ and $\vec{v}$ directions on the **Grid** page of the probe edit window, and the vectors $\vec{u}$ and $\vec{v}$ on the **Specs** page.

On the **Plot** page you can choose whether the contour plot will be drawn in a separate probe result window. On the **Looks** page you can specify to draw the contours on the configuration window. Drawing in both places is also a possibility:

On the contour plot result window, clicking the mouse will give the (bi-linearly interpolated in the grid) field value. Clicking with the shift key depressed gives the value of the nearest contour.

Only one component or the magnitude of the magnetic field may plotted at a time. On the **Plot** page of the edit window you select which.

On the **Scale** page, you select the range (`bmin`, `bmax`). The default plot range is the entire range of calculated fields. If `autoscaling` is on, these parameters will be determined from the calculated fields. The contour spacing is the parameter called `contour`. If you specify `contour` as zero, the contour spacing will be one tenth of the range. Contours always start at the lower limit of the range, `bmin`.

9 BiotSavart document format

This section describes the format of the cofiguration file. It is also the format of the clipboard contents if you copy objects there.

The configuration file is a plain text file. The file contains a list of object descriptions. Each description is a word giving the type of object, followed by a brace-delimited character string opening on the same line and continuing till the matching brace. The character string contains the defining commands for the object, typically starting with the object's name:

type {
    `name` {*the name*}
    ...further commands...
}

In the present software, the *type* is one of the recognized object types (`Current`, `Loop`, `Solenoid`, `Revolved`, `Wire`, `Racetrack`, `Linear`, or `Planar`). If the *type* is not recognized, the text between curly brackets which follows it will simply be ignored. The commands depend upon the type of the object, and are described in the next section.

The format of a command line is

```
command param
```

where `param` is a parameter. String parameters are quoted by braces instead of quotes (which can't be nested). Multiline strings are possible – once a string is opened with a left brace, it continues until the matching brace is found. For instance, the `comment` command contains the contents of the Notes page of the dialog box:

```
comment {User's notes, in file braces are
    written like this:  \} to avoid confusion.
}
```

9.1 Commands

In the following n denotes an integer, x, y, etc. are floating point numbers (possibly with units), $\vec{v}$ a two or three-dimensional vector (possibly with units at the end), and b is a Boolean value (0 or 1). Commands are not case sensitive (i.e., `positionx` and `positionX` are the same command).

Object (Commands common to all objects)

`name` {*the name*}	object name
`comment` {*notes...*}	the contents of the **Notes** page
`positionX` x	origin of object coordinate frame
`positionY` y	
`positionZ` z	
`eulerPhi` ϕ	Euler angles (degrees)
`eulerPsi` ψ	
`eulerTheta` θ	
`visible` b	draw object? ($b = 0$ suppresses drawing)

Current

`supplies` {*supply table*}	see section 9.2
`bias` B_0	bias field (z direction)

Conductor (Commands common to all conductors)

`currentSupply` *name*	current supply name
`currentScale` x	current supply scale factor
`winding` x	number of turns
`wireDiameter` x	wire diameter
`nPhi` n	steps used to draw a circle
`phi` ϕ_0 ϕ_1	drawing range (degrees)

Loop

`nZeta` n	steps to draw wire circumference
`loops` {*loop data*}	see section 9.2

Solenoid

`innerRadius` x	
`outerRadius` x	
`length` x	
`resolution` x	used for calculation loop spacing
`paraxialR` r	near-axis threshold for cubic expansion
`drawLoops`	show loops used in calculation (2-D)

Revolved

`path` {*2-D path...*}	See below for path commands
`drawLoops`	show loops used in calculation (2-D)
`reverse`	reverse polygon defined by `path`

2-D path (used by **Revolved**)

`resolution` x	loop spacing for later segements
`start` $\vec{v}$	starting position (object coordinates)
`goto` $\vec{v}$	
`center` $\vec{v}$	center for turn
`dtheta` $\Delta\theta$	used if `resolution` zero
`turn` θ	θ in degrees
`close`	close polygon

Wire

`path` {*3-D path...*}	See below for path commands

3-D path (used by **Wire** and **Linear**)

`resolution` x	marker spacing for later segments (only meaningful for **Linear**)
`start` $\vec{v}$	starting position (object coordinates)
`goto` $\vec{v}$	line segment to new position
`axis` $\vec{v}_1$ $\vec{v}_2$	define axis for rotations
`center` $\vec{v}$	define center
`normal` $\vec{v}$	define normal
`pitch` x	pitch, in advance/revolution
`dtheta` $\Delta\theta$	stepsize for turns, degrees
`turn` θ	turn through angle θ, degrees
`turn` x `t`	turn through x turns
`close`	close wire (optional)

Racetrack

`length` x	length of straight section
`span` x	distance between straights
`width` x	width width of conductor (in plane)
`height` x	height (out of plane)
`resolution` x	controls subdivision into wires
`nturn` n	number of segments in end turn

Linear

`path` {*3-D path...*}	
`xRange` x_1 x_2	set plotting range $x_1 < x < x_2$ m
`yRange` B_1 B_2	set plotting range $B_1 < B < B_2$ tesla
`plot` *yvars* `vs` *xvar*	*yvars* is one or more of `bx`, `by`, `bz`, or `b` *xvar* is one of `x`, `y`, `z`, or `s`

Planar

`grid` n_u n_v	grid mesh
`uX` x	x-component of $\vec{u}$
`uY` x	...etc.
`uZ` x	
`vX` x	
`vY` x	
`vZ` x	
`plotrange` B_1 B_2	set plotting range $B_1 < B < B_2$ tesla
`contour` x	set contour spacing to x tesla
`apartWindow` b	plot in separate window?
`drawContour` b	draw contour on configuration window?
`drawGrid` b	draw grid on configuration window?

9.2 Source code examples

The **Loop** and **Current** objects are examples of objects which include a table as part of their definitions. To represent a table we use nested strings. For example, to have two loops, one of 2cm radius at $z = 1\,\mathrm{cm}$ carrying 0.3A and one with opposite current of 3cm radius at $z = -5\,\mathrm{mm}$, we have

```
Loop {
    name {Two loop object}
    currentSupply mySupply
    loops {
        { {2cm} {1cm} {1} }
        { {3cm} {-5mm} {-1} }
    }
}
Current {
    supplies {
        { {mySupply} {0.3} }
    }
}
```

For objects with a path description, e.g., the path of a **Wire** through space, the path commands are in the string which is the argument of the `path` command:

```
Wire {
    name {a short wire}
    path {start 0 0 0
goto 1 0 1 cm
    }
}
```

10 Compatibility issues

10.1 Application signature

The signature of BiotSavart 2.2 (`BioT`) is not the same as that of BiotSavart 2.1 (`Biot`). We did not register with Apple in time (oops)! The new signature is official, but the fact that files created by BiotSavart 2.1 have a different signature means that BiotSavart 2.2 will not be started up when you double-click version 2.1 data files.

We have built in the following remedy: if you drag version 2.1 data files onto the 2.2 application, it will upgrade their signature. You can do this with more than one file at a time (only one will be opened, yet all signatures will be upgraded).

10.2 Old configuration files

BiotSavart 2.1 data files had a different way of specifying objects. Version 2.2 should be able to read these files. A number of things to watch out for:

- The number of windings was not a distinct concept from current scale in version 2.1, and now this is fixed you may need to change these parameters for your old conductors.
- With version 2.2, you do not get to edit the configuration file directly, and the comments you added with version 2.1 will be swept into the **Notes** page of the object's edit dialog which will be a bit confusing.

If you encounter any incompatibilities that we have overlooked and which should be fixed, please let us know!