$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^7}{7!} + \cdots$ $E_b = \sigma T^4$

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$e^{i\pi} = -1$ $\frac{u}{u_\tau} = \frac{1}{\kappa}\ln\frac{yu_\tau}{\nu} + C$

USER GUIDE

Subsoil Temperature Web Application

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Atkinson Science welcomes your comments on this User Guide. Please send an email to keith.atkinson@atkinsonscience.co.uk.

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1 Introduction

You can find the Atkinson Science Subsoil Temperature web application at the web address https://atkinsonscience.co.uk/WebApps/Construction/SubsoilTemperature.aspx.

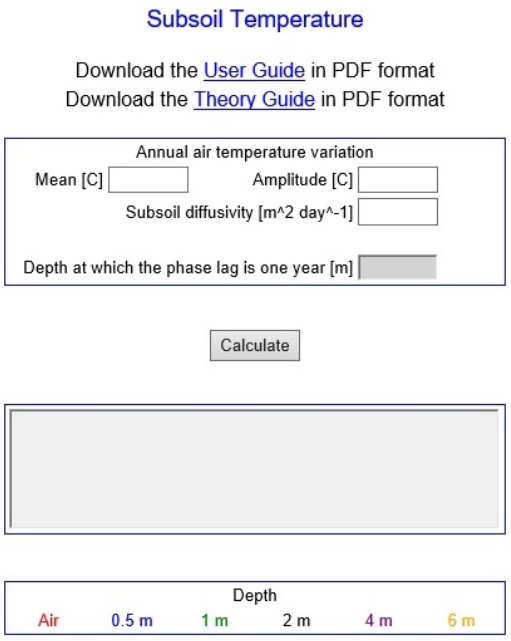
Building services engineers need to know how the temperature of the subsoil changes over the course of a year so they can assess the benefits of ground-source heat pumps or earth-air heat exchangers. The temperature changes are driven by the variation in air temperature above ground, which depends on location. The depth at which the temperature becomes constant depends on the diffusivity of the subsoil and thus the subsoil type.

The ASL Subsoil Temperature web application is a model of the temperature changes in the subsoil. The annual variation in the air temperature is assumed to be sinusoidal. For average daily temperatures in the United Kingdom this is a reasonable assumption. The highest air temperature is assumed to occur in mid-July. The scientific principles and assumptions on which the application is based are set out in the document *Subsoil Temperature Web Application*, *Theory Guide*, 22 September 2020, which can be downloaded from the Atkinson Science web site https://atkinsonscience.co.uk. The web application was created in Microsoft Visual Studio 2017.

2 User interface

The user interface of the web application is shown in Figure 1. The user enters the mean air temperature, the amplitude of the temperature variation, and the diffusivity of the subsoil. When the user clicks the Calculate button the application displays the air temperature variation and the subsoil temperature variation at depths of 0.5, 1, 2, 4 and 6 m. The temperature of the surface of the ground is assumed to be equal to the air temperature. If the user makes a mistake in entering the input data, the application issues an error message in the text box below the Calculate button.

Figure 1 User interface



In Figure 2 the user has entered temperature mean and amplitude values typical of London and a diffusivity value typical of a sandy clay soil with 15% moisture. The variation in the subsoil temperature is also sinusoidal, but the amplitude decreases with depth and the temperature becomes increasingly out of phase with the air temperature. The mean temperature at any depth is the same as the mean air temperature.

The application shows the depth at which the subsoil temperature lags behind the air temperature by one year. At this depth the amplitude of the subsoil temperature is so small that engineers often take it to be the depth at which the temperature becomes constant.

The temperature variations penetrate further into the subsoil as the diffusivity of the subsoil increases. The diffusivity of any subsoil depends very much on its moisture content. Very often the diffusivity of subsoil can double in value as it accumulates moisture.

3 Input data

Table 1 gives temperature mean and amplitude values for three locations in the United Kingdom. The data were obtained by fitting a sinusoid to monthly average measured temperature values given in *CIBSE Guide J: Weather, solar and illuminance data*, January 2002, p. 3-17.

Values of thermal diffusivity for different subsoil types can be found in *Heat Conduction with Engineering and Geological Application*, L R Ingersoll, McGraw-Hill, 1948 and in other texts on geology. Table 2 shows some values for a range of subsoil types. Note that the diffusivity values put into the web application must be expressed in the units $m^2\ day^{-1}$.

Table 1 Temperature mean and amplitude for locations in the UK

Location	Mean [C]	Amplitude [C]
London	10.8	7.0
Manchester	9.6	6.4
Edinburgh	8.6	6.0

Table 2 Thermal diffusivity of different subsoils

Subsoil type	Thermal diffusivity [$m^2\ day^{-1}$]
Chalky earth, 43% water	0.22
Quartz sand, medium fine, dry	0.23
Quartz sand, 8.3% moisture	0.38
Sandy clay, 15% moisture	0.43
Soil, very dry	0.23 – 0.35
Some wet soils	0.46 – 1.2

Figure 2 User interface with computed subsoil temperature curves