Tuesday exercise 1

Consider a model that computes the solar energy flux (mW h^{-1} cm^{-2}) as a function of interception angle ϕ (degrees):

$$Z = \frac{185 \cdot \phi}{35 + \phi}$$

The interception angle can only be measured with limited accuracy. Assume here that it satisfies a normal distribution with a mean value of 28.0 degrees and standard deviation of 5.5 degrees.

We now wish to analyse how the uncertainty about the interception angle propagates to the solar energy flux. Analytical approaches are not easily derived because the model used is not linear or quadratic. Therefore we will use a Monte Carlo approach. For this we need to draw samples from the normal distribution. We will generate these samples using a pseudo-random number generator. This will be done using a simple R script, in which we also analyse the uncertainty propagation and visualise results.

Open RStudio, copy the R script below and run it. Make sure you understand each step (it is really easy!).

```
# Plot solar energy as a function of interception angle
phi <- seq(0,50,0.01)
z <- 185*phi/(35+phi)
plot(phi,z, type="l",lwd=2,col="darkgreen")

# Monte Carlo uncertainty propagation
n <- 100
phi_sample <- rnorm(n,28,5.5)
z_sample <- 185*phi_sample/(35+phi_sample)
mean(z_sample)
sd(z_sample)
hist(phi_sample, col="LightBlue", main="phi")
hist(z_sample, col="Orange", main="z")
```

Answer the following questions:

1. How large is the uncertainty in the solar energy flux?
2. Try out different values of n. What is the effect of that?
3. Is the uncertain solar energy flux normally distributed? Why (not)?
4. Could we also analyse uncertainty propagation with the Taylor series method? Would the result be the same? Feel free to check!