Programming challenges

Solutions to the programming challenges. There are multiple ways of solving each so your solution might differ from mine.

Challenge 1

> Implement the card sorting method in Python.

Start by creating a sequence of number and shuffling it using the `random` module.

In [1]:
```
import random
```

In [2]:
```
cards = [2, 3, 4, 5, 6, 7, 8, 9, 10]
random.shuffle(cards)
print(cards)
```

```
[6, 7, 10, 2, 5, 9, 4, 3, 8]
```

The solution:

In [3]:
```
for i in range(0, len(cards) - 1):
    for j in range(i + 1, len(cards)):
        if cards[i] > cards[j]:
            # Swap the cards
            cards[i], cards[j] = cards[j], cards[i]
print(cards)
```

```
[2, 3, 4, 5, 6, 7, 8, 9, 10]
```

Challenge 2

> Compute the area on this satellite image that might correspond with vegetation. Present your results as a percentage of the image. To do that, set a threshold for the NDVI (e.g., 0.3) and count the number of pixels that are greater than the threshold.

Start by loading the Landsat 8 data and calculating the NDVI.

In [4]:
```
import numpy as np
```

In [5]:
```
scene = np.load("kilauea-landsat8.npy")

red = scene[:, :, 3].astype("float32")
nir = scene[:, :, 4].astype("float32")
ndvi = (nir - red) / (nir + red)
```

Count the number of pixels that fall above the threshold of 0.3. Then divide by the number of pixels in the image and multiply by 100 to get a percentage.

In [6]:
```
threshold = 0.3
```

Use two `for` loops and an aggregator pattern.

```
In [7]: vegetation_pixels = 0
        for row in ndvi:
            for pixel in row:
                if pixel > threshold:
                    vegetation_pixels += 1
        vegetation_percentage = 100 * vegetation_pixels / ndvi.size
        print("Vegetation present in the image (NDVI > 0.3): {:.0f}%".format(vegetat
        ion_percentage))

        Vegetation present in the image (NDVI > 0.3): 24%
```

Do the same but with only one loop (using `.ravel()` to collapse the image into a single row).

```
In [8]: vegetation_pixels = 0
        for pixel in ndvi.ravel():
            if pixel > threshold:
                vegetation_pixels += 1
        vegetation_percentage = 100 * vegetation_pixels / ndvi.size
        print("Vegetation present in the image (NDVI > 0.3): {:.0f}%".format(vegetat
        ion_percentage))

        Vegetation present in the image (NDVI > 0.3): 24%
```

Now with no for loops using `numpy.sum` and numpy's *boolean indexing*.

```
In [9]: # Adding boolean values will count the number of "True" values
        # Remember that 0 means False and 1 means True.
        vegetation_pixels = np.sum(ndvi > threshold)
        vegetation_percentage = 100 * vegetation_pixels / ndvi.size
        print("Vegetation present in the image (NDVI > 0.3): {:.0f}%".format(vegetat
        ion_percentage))

        Vegetation present in the image (NDVI > 0.3): 24%
```

Challenge 3

> Create, tests, and document (using docstrings) functions that calculate Wien's displacement law and Plank's law from Lecture 1. Each function should operate on a list of of wavelengths. Plank's law should be calculate for a list of wavelengths but a single temperature. Use these functions to reproduce the figures in Part 1 of Lecture 1.

```
In [10]: def planks_law(wavelengths, temperature, planks_const=6.626*1e-34, speed_of_
         light=299792458*1e6, boltzmann_const=1.38*1e-23):
             """
             Calculate the spectral radiance of a black body.

             This is Plank's law.

             Parameters
             ----------
             wavelengths : list
                 List of wavelengths in micrometers.
             temperature : float
                 The temperature of black body in K.
             planks_const : float
                 Plank's constant in J.s. Optional.
             speed_of_light : float
                 The speed of light in a vacumm in micrometers/s. Optional.
             boltzmann_const : float
                 The Boltzmann constant in J/K. Optional

             Returns
             -------
             spectral_radiance : list
                 List of spectral radiance for each wavelength provided in W/micromet
         er³.
             """
             spectral_radiance = []
             for wavelength in wavelengths:
                 # Divide long equations into temporary variables
                 exponential = np.exp(planks_const * speed_of_light / (wavelength * b
         oltzmann_const * temperature))
                 radiance = 2 * planks_const * speed_of_light**2 / (wavelength**5 *
         (exponential - 1))
                 spectral_radiance.append(radiance)
             return spectral_radiance
```

I used the optional arguments for the constants so that I can more easily test this function. The trick is giving simple values for the constants to check that our math is correct.

```
In [11]: wavelength = [2]
         temperature = 3
         result = planks_law(wavelength, temperature, planks_const=1, speed_of_light=
         1, boltzmann_const=1)
         expected_result = 1/(2**4 * (np.exp(1 / 6) - 1))
         print(result, expected_result)
         # To test automatically, use numpy
         assert np.allclose(result, expected_result)

         [0.34461765394359134] 0.34461765394359134
```

Now for the other one.

In [12]:
```python
def wiens_law(temperatures, wien_const= 2.897771955*1e3):
    """
    Calculate the peak wavelengths of a black body at the given temperature
s.

    This is Wien's displacement law.

    Parameters
    ----------
    temperatures : list
        The temperatures in K.
    wien_const : float
        Wien's displacement constant in K/micrometer. Optional.

    Returns
    -------
    wavelengths : list
        The peak wavelengths in micrometers.
    """
    wavelengths = []
    for temperature in temperatures:
        wavelength = wien_const / temperature
        wavelengths.append(wavelength)
    return wavelengths
```

In [13]:
```python
temperature = [3, 4, 5]
result = wiens_law(temperature, wien_const=1)
expected_result = np.divide(1, temperature)
print(result, expected_result)
assert np.allclose(result, expected_result)
```

```
[0.3333333333333333, 0.25, 0.2] [0.33333333 0.25       0.2       ]
```

Now to make the plot. We trust that our functions are correct so we can be relatively sure that any mistakes now are in the plotting code.

First, generate the data.

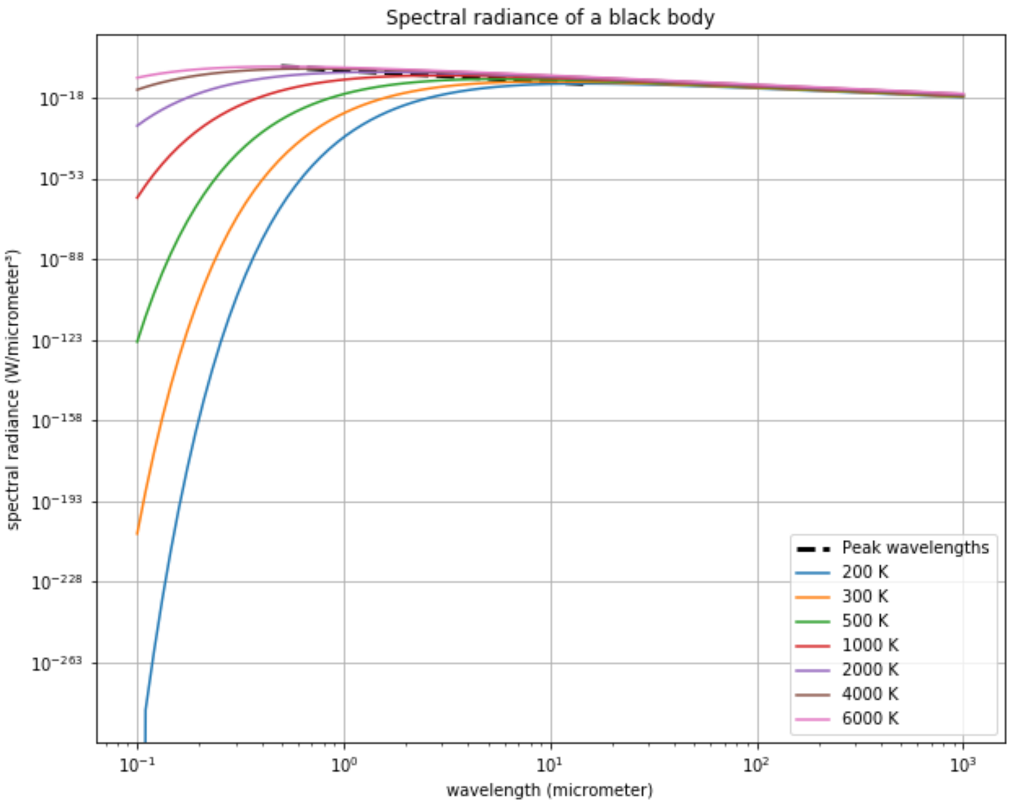
In [14]:
```python
# Generate 100 points between 10^-1 and 10^3
wavelengths = np.logspace(-1, 3, 100)  # micrometers
temperatures = [200, 300, 500, 1000, 2000, 4000, 6000]  # K

spectral_radiance_profiles = []
for temperature in temperatures:
    # A list of lists. In this case, each list is a profile of radiance vs w
avelength
    spectral_radiance_profiles.append(planks_law(wavelengths, temperature))

peak_wavelengths = wiens_law(temperatures)
peak_radiances = []
# Calculate the radiance associated with each of these wavelengths
for wavelength, temperature in zip(peak_wavelengths, temperatures):
    radiance = planks_law([wavelength], temperature)
    peak_radiances.append(radiance[0])
```

```
/home/leo/miniconda3/envs/envs258/lib/python3.7/site-packages/ipykernel_launc
her.py:28: RuntimeWarning: overflow encountered in exp
```

The trick is in getting the plot scale correct. Notice that the scale of the figure in the slide is log in x but y is also the logarithm of spectral radiance.

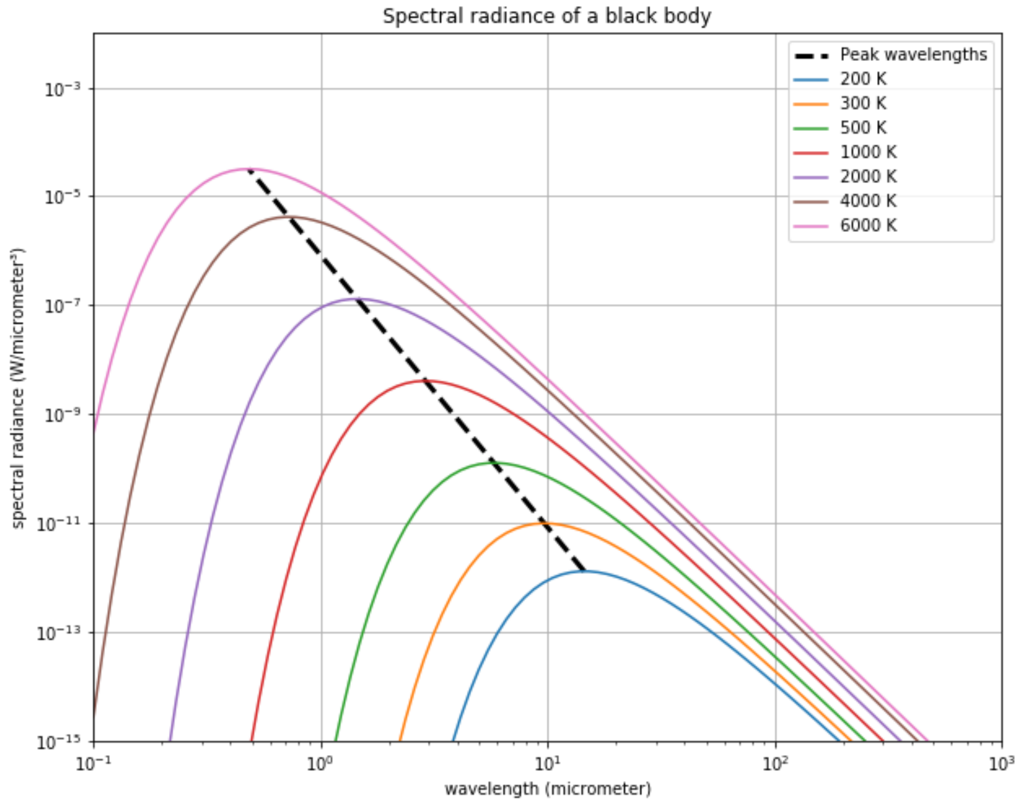
In [15]:
```python
import matplotlib.pyplot as plt
```

```
In [16]: plt.figure(figsize=(10, 8))
plt.title("Spectral radiance of a black body")
plt.plot(peak_wavelengths, peak_radiances, "--k", linewidth=3, label="Peak w
avelengths")
for profile, temperature in zip(spectral_radiance_profiles, temperatures):
    plt.plot(wavelengths, profile, "-", label="{} K".format(temperature))
plt.xscale("log")
plt.yscale("log")
plt.xlabel("wavelength (micrometer)")
plt.ylabel("spectral radiance (W/micrometer³)")
# Add the legend with the label of each line
plt.legend()
plt.grid()
plt.show()
```



Notice that in this figure, all lines go to 0.1 wavelength. In the slides, the lines terminate before 0.1. This is an indicator that figure is cropped in the y-axis. We can replicate this.

In [17]:
```
plt.figure(figsize=(10, 8))
plt.title("Spectral radiance of a black body")
plt.plot(peak_wavelengths, peak_radiances, "--k", linewidth=3, label="Peak w
avelengths")
for profile, temperature in zip(spectral_radiance_profiles, temperatures):
    plt.plot(wavelengths, profile, "-", label="{} K".format(temperature))
plt.xscale("log")
plt.yscale("log")
# Crop using ylim
plt.ylim(1e-15, 1e-2)
plt.xlim(0.1, 1000)
plt.xlabel("wavelength (micrometer)")
plt.ylabel("spectral radiance (W/micrometer³)")
plt.legend()
plt.grid()
plt.show()
```



The numbers on the y axis don't match exactly because our units are different. But the overall behaviour is the same.