1. **Loading and Cleaning Data:**

```python
import pandas as pd
import numpy as np
```

- **Why:** These are necessary libraries for handling data. `pandas` is used for reading and cleaning data, while `numpy` helps manipulate numeric arrays.

```python
filenames = ['HR_01.txt', 'HR_02.txt', 'SL_01.txt', 'SL_02.txt', 'SK_01.txt',
```

- **Why:** These represent the EEG data files you are working with. Each file contains raw EEG data for different subjects.

```python
def load_eeg_data(filename):
    data = pd.read_csv(filename, delimiter=',', skiprows=4)  # Adjust skiprows
    numeric_data = data.select_dtypes(include=[np.number])
    return numeric_data.to_numpy()
```

- **How:** This function reads the data from each file, skips non-relevant rows at the top, and extracts only numeric data columns.
- **Why:** EEG data usually contains both numeric and non-numeric rows (like headers, metadata), which we filter out.

```python
eeg_data = {name: load_eeg_data(name) for name in filenames}
print(eeg_data['HR_01.txt'].shape)
```

- **Why:** Loads and stores EEG data fi l files in a dictionary, and prints the shape to verify data loading.

2. **Bandpass Filtering:**

```python
from scipy.signal import butter, filtfilt
```

- **Why:** `butter` designs a Butterworth filter, and `filtfilt` applies it to the data.

```python
def butter_bandpass(lowcut, highcut, fs, order=4):
    nyquist = 0.5 * fs
    low = lowcut / nyquist
    high = highcut / nyquist
    b, a = butter(order, [low, high], btype='band')
    return b, a
```

- **How:** Creates a bandpass filter to keep frequencies between `lowcut` and `highcut`.
- **Why:** EEG signals have useful frequency ranges (0.5 Hz to 50 Hz), and this filter helps isolate them.

```python
def apply_bandpass_filter(data, lowcut, highcut, fs, order=4):
    b, a = butter_bandpass(lowcut, highcut, fs, order=order)
    return filtfilt(b, a, data, axis=0)
```

- **Why:** This function applies the bandpass filter to EEG data for noise removal and signal clarity.

```python
filtered_eeg_data = {name: apply_bandpass_filter(data, lowcut, highcut, sampli
print(filtered_eeg_data['HR_01.txt'].shape)
```

- **How:** Filters each EEG data set and stores it.
- **Why:** Ensures only relevant frequer s are retained for later analysis.

3. **Feature Extraction using FFT:**

```python
def compute_fft(data, fs):
    n = len(data)
    freqs = np.fft.fftfreq(n, 1/fs)
    fft_values = np.fft.fft(data)
    fft_magnitude = np.abs(fft_values)
    return freqs[:n // 2], fft_magnitude[:n // 2]
```

- **How:** Converts time-domain EEG signals into the frequency domain using the Fast Fourier Transform (FFT).
- **Why:** EEG analysis often focuses on frequency components (like alpha, beta waves), which are extracted using FFT.

```python
def bandpower(data, freqs, low, high):
    idx_band = np.logical_and(freqs >= low, freqs <= high)
    return np.mean(data[idx_band])
```

- **Why:** Calculates the power (strength) of a specific frequency band, allowing us to quantify brainwave activity.

```python
bands = {'delta': (0.5, 4), 'theta': (4, 8), 'alpha': (8, 12), 'beta': (12, 30)
features = {}
for name, data in filtered_eeg_data.items():
    feature_matrix = []
    for channel in range(data.shape[1]):
        freqs, fft_magnitude = compute_fft(data[:, channel], sampling_rate)
        feature_vector = [bandpower(fft_magnitude, freqs, low, high) for band,
        feature_matrix.append(feature_vector)
    features[name] = np.array(feature_matrix)
```

- **Why:** Breaks EEG data into differen quency bands (delta, theta, etc.) for each channel and extracts meaningful features from them.

### Feature Extraction with FFT & Power Spectrum:

1. **Fast Fourier Transform (FFT):**
   - Converts EEG signals from the time domain to the frequency domain.
   - Breaks complex brainwave signals into their component frequencies.
   - Allows identification and analysis of brainwave patterns like alpha, beta, delta, theta, and gamma waves.
2. **Frequency Domain Analysis:**
   - Enables the study of how much of each frequency is present in the EEG data.
   - Reveals specific brainwave activities that correspond to different cognitive or mental states.
3. **Power Spectrum Analysis:**
   - Measures the power (strength) of different frequency components.
   - Identifies the most prominent brainwave activities by calculating the power in specific frequency bands.
4. **EEG Frequency Bands:**
   - **Delta (0.5 – 4 Hz):** Deep sleep, unconsciousness.
   - **Theta (4 – 8 Hz):** Light sleep, meditation.
   - **Alpha (8 – 12 Hz):** Relaxation, calm focus.
   - **Beta (12 – 30 Hz):** Active thinking, concentration.
   - **Gamma (30 – 50 Hz):** High-level cognitive processing.
5. **Bandpower Calculation:**
   - Computes the average power in specific frequency bands (delta, theta, alpha, beta, gamma).
   - Helps quantify brainwave activities and allows comparison between cognitive states.
6. **Extracted Features:**
   - Feature matrix includes bandpower values for each EEG channel.
   - Useful for machine learning models to classify different mental states.