1) Calculate the energy of a photon of violet light, $\lambda = 400\text{nm}$.

$$E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34}\text{Js} \times 2.9979 \times 10^{8}\text{m/s}}{4.0 \times 10^{-7}\text{m}} = 4.96 \times 10^{-19}\text{J}$$

which corresponds to 1.62 eV.

2) Peak wavelength of the blackbody spectrum of the human body: Using Wien's law:

$$\lambda_{\text{peak}} = \frac{0.0029\text{mK}}{310K} = 9.35 \times 10^{-6}\text{m} = 9.35\mu\text{m}$$

Which is in the thermal infrared.

3) A blackbody has $T = 3000\text{K}$ and a surface area of 10m^2. What is the power output? Using the Stefan-boltzmann equation:

$$P = A\sigma T^4 = 10\text{m}^2 \times 5.670 \times 10^{-8}\text{Wm}^{-2}\text{K}^{-1} \times (3000\text{K})^4 = 4.59 \times 10^{7}\text{W}$$

4) The energy of the photon, $E_\lambda = E_3 - E_2 = 12.087\text{eV} - 10.196\text{eV} = 1.891\text{eV} = 3.029 \times 10^{-19}\text{J}$. Now,

$$\lambda = \frac{hc}{E_\lambda} = 6.558 \times 10^{-7}\text{m} = 655.8\text{nm}$$

which is in the red part of the spectrum.

5) Band structure in the spectrum of the CN molecule. We are given that CN has a vibrational frequency of $\nu = 6.20612 \times 10^{13}\text{Hz}$ and a moment of inertia $I = 7.36297 \times 10^{-47}\text{Js}^2$. Find the energies and wavelengths corresponding to certain specified transitions between vibrational and rotational states.

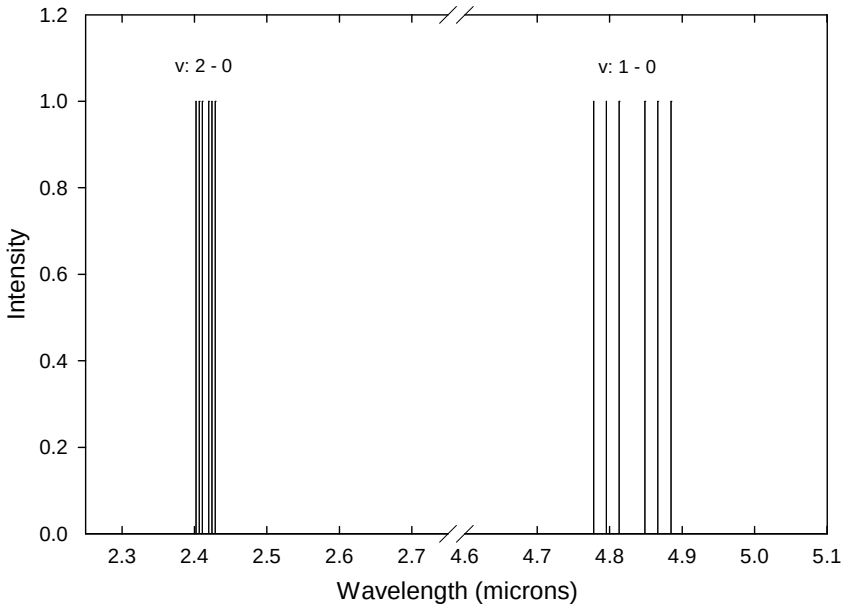

Figure 1: The ro-vibrational spectrum of the $v : 1 \rightarrow 0$ and $v : 2 \rightarrow 0$ bands of CN in the near infrared.

For the first set of transitions ($v : 1 \rightarrow 0$), we have

$$E_{\text{lower}} = h\nu(0 + \frac{1}{2}) + \frac{\hbar J_l(J_l + 1)}{2I}$$

$$E_{\text{higher}} = h\nu(1 + \frac{1}{2}) + \frac{\hbar J_h(J_h + 1)}{2I}$$

and a similar set for the $v : 2 \rightarrow 0$ transitions. Plugging in, we get the following results:

```
v: 1 -> 0
   J: 3 -> 2  E = 4.157535e-20J lambda = 4.777941 microns
   J: 2 -> 1  E = 4.142431e-20J lambda = 4.795362 microns
   J: 1 -> 0  E = 4.127326e-20J lambda = 4.812911 microns
   J: 2 -> 3  E = 4.066909e-20J lambda = 4.884411 microns
   J: 1 -> 2  E = 4.082013e-20J lambda = 4.866337 microns
   J: 0 -> 1  E = 4.097118e-20J lambda = 4.848397 microns
```

```
v: 2 -> 0
   J: 3 -> 2  E = 8.269757e-20J lambda = 2.402060 microns
   J: 2 -> 1  E = 8.254652e-20J lambda = 2.406456 microns
   J: 1 -> 0  E = 8.239548e-20J lambda = 2.410867 microns
   J: 2 -> 3  E = 8.179131e-20J lambda = 2.428675 microns
   J: 1 -> 2  E = 8.194235e-20J lambda = 2.424199 microns
   J: 0 -> 1  E = 8.209340e-20J lambda = 2.419738 microns
```

see Figure 1 for a plot of this spectrum.