Homework 4 Ryan Cayne

1. a) Planck's Law does not depend on the material and there is no radiation being detected from other sources.

b) This can throw off the measurement because there is light being detected from other sources.

# PlancksLaw

In [1]:

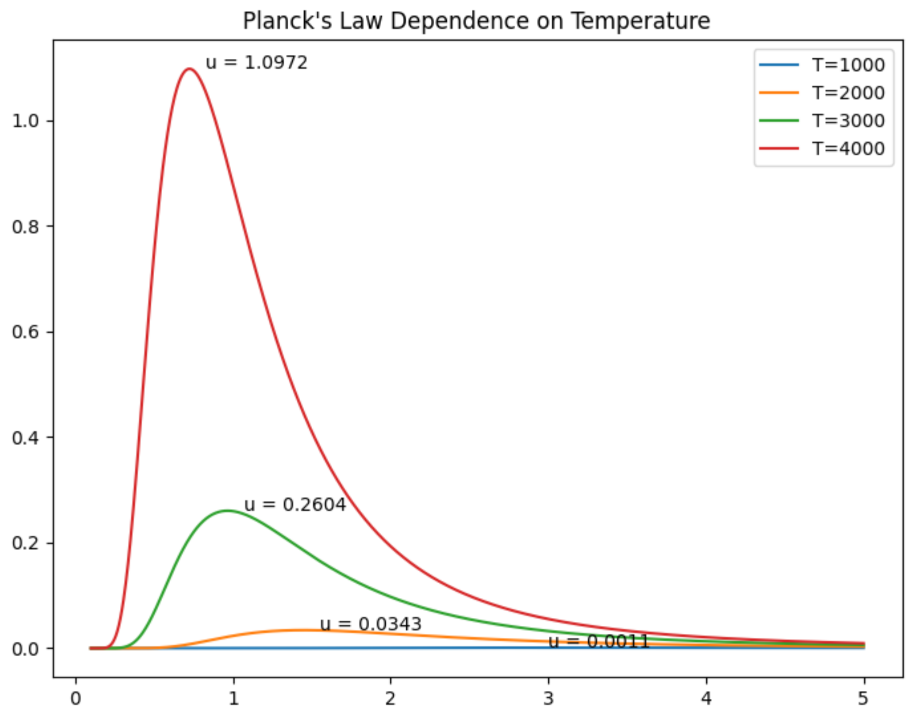
```
import numpy as np
%matplotlib inline
import matplotlib.pyplot as plt

hc = 1.23984
kb = 8.617333 * 10**-5
```

## 2.¶

In [2]:

```
l1= np.linspace(0.1, 5, 1000)
t = [1000*i for i in range(1, 5)]
u = []
fig = plt.figure(0)
ax = fig.add_axes([0,0,1,1], title='Planck\'s Law Dependence on Temperature')
for i in range(4):
    u.append(8 * np.pi * hc / (l1 ** 5 * (np.exp(hc / (kb * l1 * t[i])) - 1)))
    ax.plot(l1, u[i], label='T={}'.format(t[i]))
    lmax = int(np.argmax(u[i]))
    ax.annotate("u = {:.4f}".format(u[i][lmax]), (l1[lmax] + 0.1, u[i][lmax]))
    ax.legend()
plt.savefig("fig1")
```

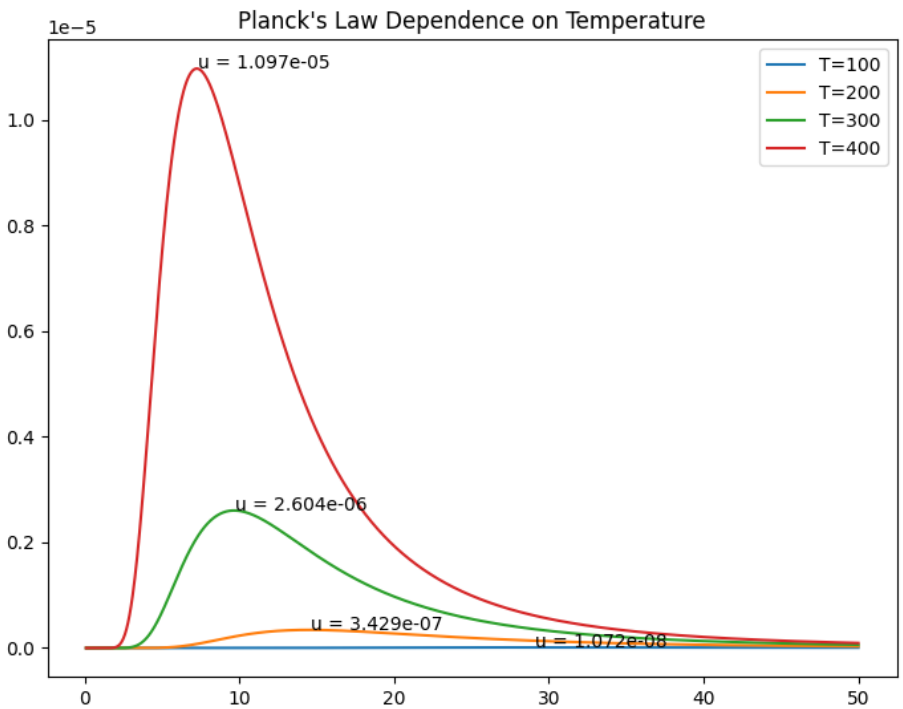



# 3.¶

In [3]:

```
l2= np.linspace(0.1, 50, 1000)
for i in range(1,5):
    t.append(100*i)
fig = plt.figure(1)
ax = fig.add_axes([0, 0, 1, 1], title='Planck\'s Law Dependence on Temperature')
for i in range(4,8):
    u.append(8 * np.pi * hc / (l2 ** 5 * (np.exp(hc / (kb * l2 * t[i])) - 1)))
    ax.plot(l2, u[i], label='T={}'.format(t[i]))
    lmax = int(np.argmax(u[i]))
    ax.annotate("u = {:.3e}".format(u[i][lmax]), (l2[lmax] + 0.1, u[i][lmax]))
    ax.legend()
plt.savefig("fig")
```

```
C:\Users\coyne\AppData\Local\Temp\ipykernel_15024\3256522897.py:7: RuntimeWarning: overflow
  u.append(8 * np.pi * hc / (l2 ** 5 * (np.exp(hc / (kb * l2 * t[i])) - 1)))
```




# 4.¶

In [4]:

```
for i in range(4):
    print("{:.4e}".format(l1[np.argmax(u[i])] * t[i]/1000000))
for i in range(4):
    print("{:.4e}".format(l2[np.argmax(u[i+4])]*t[i+4]/100000))
```

```
2.8958e-03
2.8977e-03
2.9045e-03
2.8917e-03
2.8971e-02
2.8971e-02
2.8921e-02
2.8971e-02
```

# 5.¶

In [5]:

```
for i in range(8):
    if i < 4:
        etotal = np.trapz(u[i], l1)*2.998*10**14/4
    else:
        etotal = np.trapz(u[i], l2)*2.998*10**14/4
    sigma = etotal/(t[i]**4)
    print("{:.3f}".format(sigma))
```

```
0.224
0.324
0.343
0.349
0.224
0.324
0.343
0.349
```

6. a) $\lambda_{max} = \frac{2.898 \times 10^{-3}\ m \cdot K}{(37+273)\ K}$

$= 9.35 \times 10^{-6}\ m$

$= 9.35\ \mu m$

b) $1 - \frac{37+273}{39+273} = 1 - \frac{310}{312}$

$= 0.61\%$ smaller

7. a) $e_{total} = a\sigma T^4$ $\quad a = 1$

$= 5.67 \times 10^{-8} \frac{W}{m^2 K^4} \cdot (3000\ K)^4$

$= 4.59 \times 10^{6}\ \frac{W}{m^2}$

b) $e_{total} \cdot A = 75\ W$

$A = \frac{75\ W}{4.59 \times 10^{6} \frac{W}{m^2}}$

$= 0.0000163\ m^2$

$= 16.3\ mm^2$

8. a) $E = hf$ $\quad \lambda = \frac{c}{f}$

$= 4.14 \times 10^{-15}\ eV/Hz \cdot 5 \times 10^{14}\ Hz$

$= 2.07\ eV$

$= 2.07 \times 10^{-6}\ MeV$

$\lambda = \frac{2.998 \times 10^{8}\ m/s}{5 \times 10^{14}\ /s}$

$= 5.996 \times 10^{-7}\ m$

$= 599.6\ nm$

b) $f = 10^{10}\ Hz$

$E = 4.14 \times 10^{-15}\ eV/Hz \cdot 5 \times 10^{14}\ Hz$

$= 4.14 \times 10^{-5}\ eV$

$= 4.14 \times 10^{-11}\ MeV$

$\lambda = \frac{2.998 \times 10^{8}\ m/s}{10^{10}\ Hz}$

$= 2.998 \times 10^{-2}\ m$

$= 2.998 \times 10^{7}\ nm$

c) $p = \frac{h}{\lambda}$

$= \frac{4.136 \times 10^{-15}\, eV \cdot s}{5 \times 10^{-7}\, m}$

$= 8.272 \times 10^{-9}\, \frac{eV}{m/s} \cdot \frac{c}{c}$

$= 2.48 \times 10^{-6}\, \frac{MeV}{c}$

9. $E = Nhf =$

$N = \frac{100\,000}{6.626 \times 10^{-34} \cdot 9.4 \times 10^{5}}$

$= 1.61 \times 10^{32}$ photons per second

10. a) $K = hf - \phi$

$2.23\, eV = 4.14 \times 10^{-15}\, eV \cdot s \cdot \frac{c}{3 \times 10^{-7}\, m} - \phi$

$\phi = 2.23\, eV + 4.14\, eV$

$= 6.37\, eV$

b) $V_s = \frac{K}{e}$

$= 2.23\, V$

11. a) $E = \frac{hc}{\lambda_0}$

$\lambda_0 = \frac{hc}{E}$

$= \frac{4.14 \times 10^{-15}\, eV \cdot s \cdot 2.998\, m/s}{300000\, eV}$

$= 4.12 \times 10^{-12}\, m$

$\lambda' = \frac{h}{m_e c}(1 - \cos\theta)$

$= \frac{4.14 \times 10^{-15}\, eV \cdot s}{5.11 \times 10^{5}\, eV} \cdot 2.998 \times 10^{8}\, m/s\, (1 - \cos(35^\circ)) + \lambda_0$

$= 4.56 \times 10^{-12}\, m$

$\lambda' - \lambda_0 = 4.39 \times 10^{-13}\, m$

b) $E' = \frac{hc}{\lambda'}$

$= \frac{4.14 \times 10^{-15}\, eV \cdot s \cdot 2.998\, m/s}{4.56 \times 10^{-12}\, m}$

$= 2.72\, MeV$

c) $K_e = E - E'$

$= 300000\,eV - 272187\,eV$

$= 27813.2\,eV$

12. if $E' = 0$

$E' = hf'$

$= \frac{hc}{\lambda'}$

$0 = \frac{hc}{\lambda'}$

This implies $\lambda' = \infty$ which isn't possible.

13. $E = E' + K$

$E - E' = 30\,keV$

$\frac{hc}{\lambda_0} - \frac{hc}{\lambda'} = 30\,keV$

$\frac{hc}{\lambda_0} - \frac{hc}{\frac{h}{m_e c}(1-\cos 180°) + \lambda_0} = 30\,keV$

$\ell = \lambda_0$

$a = hc = 1.241 \times 10^{-6}$ $\quad b = \frac{2 \cdot h}{m_e c}$

$= 5.40 \times 10^{-29}$

$\frac{a}{\ell} + \frac{a}{b+\ell} = c$ $\quad c = 30000$

$\frac{a(b+\ell)+a\ell}{\ell(b+\ell)} = c$

$ab + 2a\ell = cb\ell + c\ell^2$

$-c\ell^2 + (2a - cb)\ell + ab = 0$

$\ell = \frac{2a - cb \pm \sqrt{4a^2 \cancel{-4abc} + c^2b^2 \cancel{+4abc}}}{2c}$

$= \frac{2a - cb \pm \sqrt{4a^2 + c^2b^2}}{2c}$

$\lambda_0 = 8.27 \times 10^{-11}\,m$

14. $u(f,T) = \frac{8\pi h f^3}{c^3}\left(e^{hf/k_B T} - 1\right)^{-1}$

$f = \frac{c}{\lambda}$ $\quad df = \frac{c}{\lambda^2} d\lambda$

$u(f,T)\,df = u(\lambda,T)\,d\lambda$

$u(\lambda,T) = \frac{8\pi h}{\lambda^3}\left(e^{hc/k_B\lambda T} - 1\right)^{-1} \cdot \frac{c}{\lambda^2}$

$= \frac{8\pi hc}{\lambda^5}\left(e^{hc/k_B\lambda T} - 1\right)^{-1}$