Task 1

Velocity of the sound wave	v	[m/s]
Frequency of the sound wave	f	[1/s]
Wavelength of the sound wave	λ	[m]

$$v = f\lambda$$

$$f = \frac{v}{\lambda} = \frac{1{,}500\frac{\mathrm{m}}{\mathrm{s}}}{0.1\ \mathrm{m}} = 15{,}000\ \mathrm{Hz}$$

Task 2

Velocity of the sound wave in higher temperature	v_{H}	[m/s]
Velocity of the sound wave in lower temperature	v_{L}	[m/s]
Higher temperature	T_{H}	[K]
Lower temperature	T_{L}	[K]
Percentage by which the speed of sound is larger	P	[%]

$$P = \frac{v_{\mathrm{H}} - v_{\mathrm{L}}}{v_{\mathrm{L}}} \cdot 100\% = \frac{\left[\left(331\frac{\mathrm{m}}{\mathrm{s}}\right)\sqrt{\frac{\mathrm{T_H}}{273\ \mathrm{K}}} - \left(331\frac{\mathrm{m}}{\mathrm{s}}\right)\sqrt{\frac{\mathrm{T_L}}{273\ \mathrm{K}}}\right]}{\left(331\frac{\mathrm{m}}{\mathrm{s}}\right)\sqrt{\frac{\mathrm{T_L}}{273\ \mathrm{K}}}} \cdot 100\%$$

$$= \left(\frac{\sqrt{\frac{\mathrm{T_H}}{273\ \mathrm{K}}}}{\sqrt{\frac{\mathrm{T_L}}{273\ \mathrm{K}}}} - 1\right) \cdot 100\%$$

$$= \left(\sqrt{\frac{T_{\mathrm{H}}}{T_{\mathrm{L}}}} - 1\right) \cdot 100\% = \left(\sqrt{\frac{(273.15+50)\mathrm{K}}{(273.15-50)\mathrm{K}}} - 1\right) \cdot 100\% = 44.8129 \ldots \%$$

Task 3

Speed of light	c	[m/s]
Frequency of the electromagnetic wave	f	[1/s]
Wavelength of the electromagnetic wave	λ	[m]

$$c = f\lambda$$

$$\lambda = \frac{c}{f} = \frac{3 \cdot 10^8 \frac{\mathrm{m}}{\mathrm{s}}}{96.4 \cdot 10^6 \frac{1}{\mathrm{s}}} = 3.112033195 \ldots \mathrm{m}$$

Task 4

Speed of light	c	[m/s]
Frequency of the electromagnetic wave	f	[1/s]
Wavelength of the electromagnetic wave	λ	[m]
Average intensity of the electromagnetic wave	I_a	$[\mathrm{W/m^2}]$
Maximum electric field strength	E_0	$[\mathrm{V/m}]$
Permittivity of free space	ε_0	$[\mathrm{C^2/(Nm^2)}]$

a)

$$c = f\lambda$$

$$\lambda = \frac{c}{f} = \frac{3\cdot 10^{8}\frac{\mathrm{m}}{\mathrm{s}}}{400\cdot 10^{12}\frac{1}{\mathrm{s}}} = 3.112033195 \ldots \mathrm{m} = 0.000000750\ \mathrm{m} = 750\ \mathrm{nm}$$

corresponds to red light

b)

$$I_\mathrm{a} = \frac{c\varepsilon_0 E_0^2}{2} = \frac{\left(3\cdot 10^{8}\frac{\mathrm{m}}{\mathrm{s}}\right)\left(8.85\cdot 10^{-12}\frac{\mathrm{C^2}}{\mathrm{Nm^2}}\right)\left(13\frac{\mathrm{V}}{\mathrm{m}}\right)^2}{2} = 0.2243475\,\frac{\mathrm{W}}{\mathrm{m^2}}$$

Task 5

Frequency observed by the stationary person	f_{obs}	[1/s]
Frequency of the siren (sound source)	f_{s}	[1/s]
Speed of the sound wave	v_{w}	[m/s]
Velocity of the police car (Alternative 1)	v_{s}	[m/s]
Velocity of the observer (Alternative 2)	v_{obs}	[m/s]

Alternative 1: Police car is moving, observer is stationary

$$f_{\mathrm{obs}} = f_{\mathrm{s}}\left(\frac{v_{\mathrm{w}}}{v_{\mathrm{w}} \pm v_{\mathrm{s}}}\right)$$

Siren is moving towards the observer:

$$f_{\mathrm{obs}} = f_{\mathrm{s}}\left(\frac{v_{\mathrm{w}}}{v_{\mathrm{w}} - v_{\mathrm{s}}}\right)$$

$$f_{\mathrm{s}} = f_{\mathrm{obs}}\frac{v_{\mathrm{w}} - v_{\mathrm{s}}}{v_{\mathrm{w}}} = f_{\mathrm{obs}}\left(1 - \frac{v_{\mathrm{s}}}{v_{\mathrm{w}}}\right) = (397\ \mathrm{Hz})\left(1 - \frac{45\frac{\mathrm{m}}{\mathrm{s}}}{340\frac{\mathrm{m}}{\mathrm{s}}}\right) = 344.4558823529411\ldots\mathrm{Hz}$$

Alternative 2: Observer is moving, police car is stationary

$$f_{\mathrm{obs}} = f_{\mathrm{s}}\left(\frac{v_{\mathrm{w}} \pm v_{\mathrm{obs}}}{v_{\mathrm{w}}}\right)$$

Observer is moving away from the police car:

$$f_{\mathrm{obs}} = f_{\mathrm{s}}\left(\frac{v_{\mathrm{w}} - v_{\mathrm{obs}}}{v_{\mathrm{w}}}\right)$$

$$f_{\mathrm{s}} = f_{\mathrm{obs}}\frac{v_{\mathrm{w}}}{v_{\mathrm{w}} - v_{\mathrm{obs}}} = (397\ \mathrm{Hz})\frac{340\frac{\mathrm{m}}{\mathrm{s}}}{340\frac{\mathrm{m}}{\mathrm{s}} - 45\frac{\mathrm{m}}{\mathrm{s}}} = 457.55932203\ldots\mathrm{Hz}$$