```
(*1*)
Sz = {{1, 0, 0}, {0, 0, 0}, {0, 0, -1}}
Sx = 1 / √(2) {{0, 1, 0}, {1, 0, 1}, {0, 1, 0}}
Sy = 1 / √(2) {{0, -I, 0}, {I, 0, -I}, {0, I, 0}}
```

```
{{1, 0, 0}, {0, 0, 0}, {0, 0, -1}}
```

$$\left\{\left\{0, \frac{1}{\sqrt{2}}, 0\right\}, \left\{\frac{1}{\sqrt{2}}, 0, \frac{1}{\sqrt{2}}\right\}, \left\{0, \frac{1}{\sqrt{2}}, 0\right\}\right\}$$

$$\left\{\left\{0, -\frac{i}{\sqrt{2}}, 0\right\}, \left\{\frac{i}{\sqrt{2}}, 0, -\frac{i}{\sqrt{2}}\right\}, \left\{0, \frac{i}{\sqrt{2}}, 0\right\}\right\}$$

```
H[B_, Bz_, λ_] := B * (Sx + Sy) + Bz * Sz + λ * Sx.Sx
hamiltonian = H[1, 1, 1]
```

$$\left\{\left\{\frac{3}{2}, \frac{1-i}{\sqrt{2}}, \frac{1}{2}\right\}, \left\{\frac{1+i}{\sqrt{2}}, 1, \frac{1-i}{\sqrt{2}}\right\}, \left\{\frac{1}{2}, \frac{1+i}{\sqrt{2}}, -\frac{1}{2}\right\}\right\}$$

```
Eigenvalues[hamiltonian // N]
```

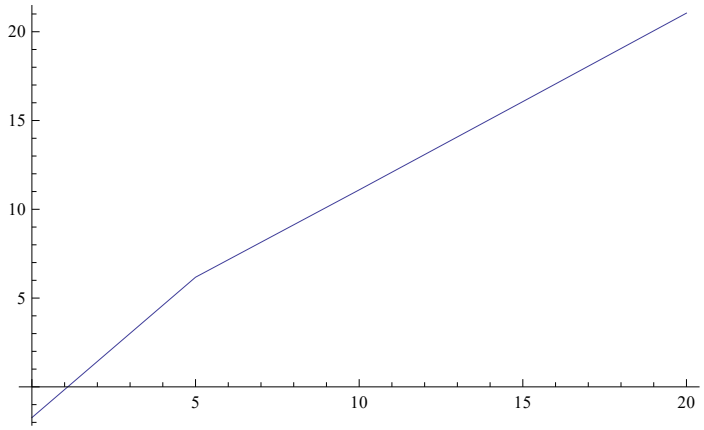
```
{2.48119, -1.17009, 0.688892}
```

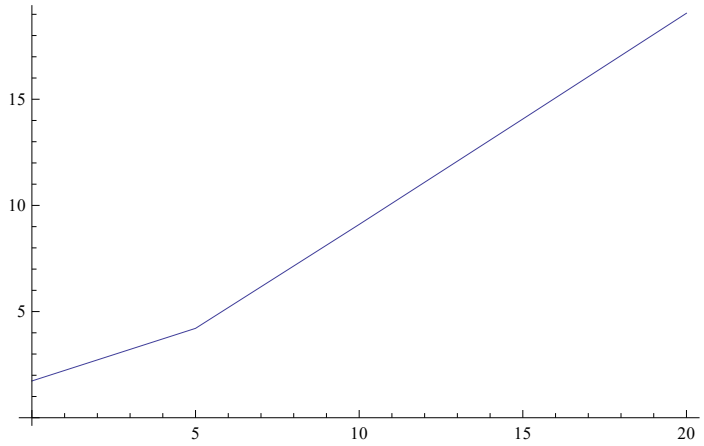
```
Eigenvectors[hamiltonian // N]
```

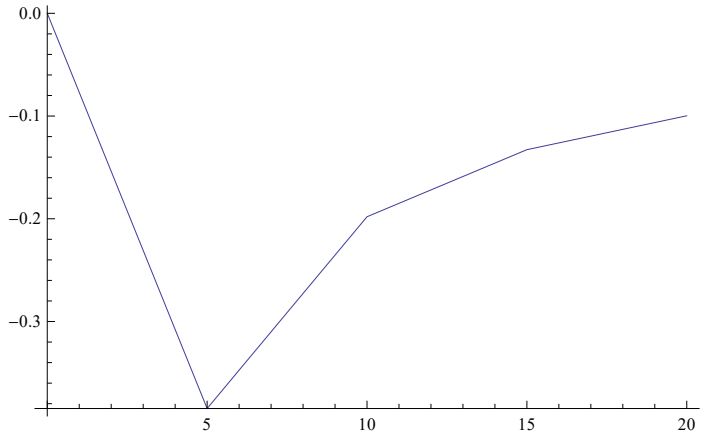
```
{{-0.429974 + 0.580577 i, -0.608075 + 0.197545 i, -0.263199},
 {-0.190206 - 0.175298 i, -0.268992 + 0.392946 i, 0.840434},
 {0.0985568 + 0.633586 i, 0.13938 - 0.587393 i, 0.473706}}
```

```
λ0 = Eigenvalues[H[1, 1, 0] // N];
λ5 = Eigenvalues[H[1, 1, 5] // N];
λ10 = Eigenvalues[H[1, 1, 10] // N];
λ15 = Eigenvalues[H[1, 1, 15] // N];
λ20 = Eigenvalues[H[1, 1, 20] // N];

ListPlot[{{0, λ0[[1]]}, {5, λ5[[1]]},
  {10, λ10[[1]]}, {15, λ15[[1]]}, {20, λ20[[1]]}}, Joined → True]
ListPlot[{{0, λ0[[2]]}, {5, λ5[[2]]}, {10, λ10[[2]]},
  {15, λ15[[2]]}, {20, λ20[[2]]}}, Joined → True]
ListPlot[{{0, λ0[[3]]}, {5, λ5[[3]]}, {10, λ10[[3]]},
  {15, λ15[[3]]}, {20, λ20[[3]]}}, Joined → True]
```

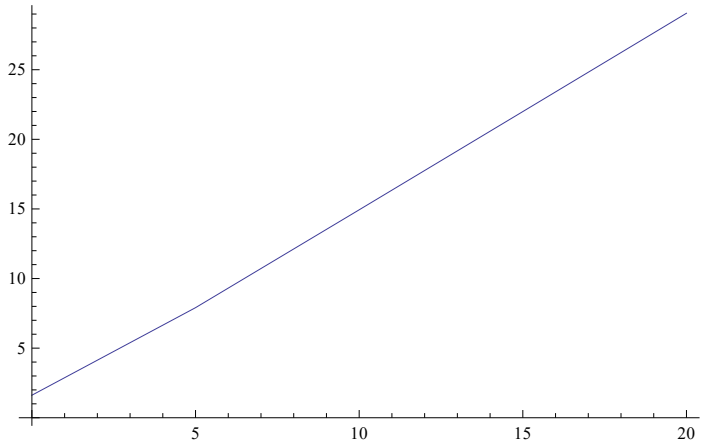

20
15
10
5
5
10
15
20

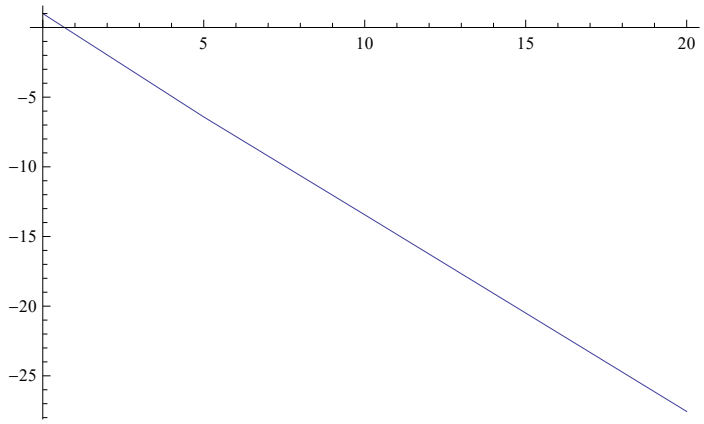

15
10
5
5
10
15
20

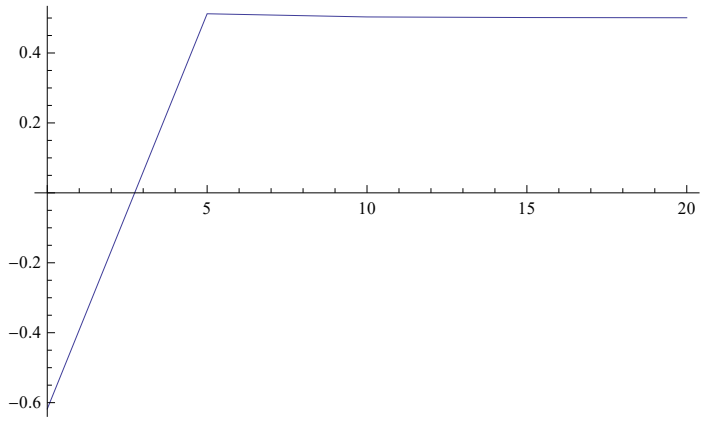

0.0
−0.1
−0.2
−0.3
5
10
15
20

```
B0 = Eigenvalues[H[0, 1, 1] // N];
B5 = Eigenvalues[H[5, 1, 1] // N];
B10 = Eigenvalues[H[10, 1, 1] // N];
B15 = Eigenvalues[H[15, 1, 1] // N];
B20 = Eigenvalues[H[20, 1, 1] // N];

ListPlot[{{0, B0[[1]]}, {5, B5[[1]]},
  {10, B10[[1]]}, {15, B15[[1]]}, {20, B20[[1]]}}, Joined → True]
ListPlot[{{0, B0[[2]]}, {5, B5[[2]]}, {10, B10[[2]]},
  {15, B15[[2]]}, {20, B20[[2]]}}, Joined → True]
ListPlot[{{0, B0[[3]]}, {5, B5[[3]]}, {10, B10[[3]]},
  {15, B15[[3]]}, {20, B20[[3]]}}, Joined → True]
```

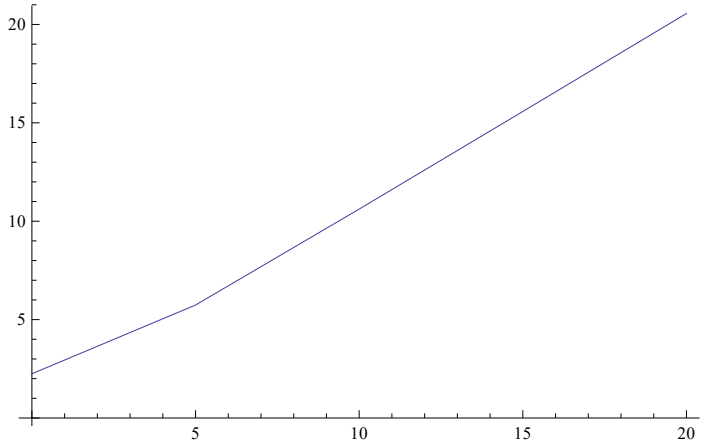


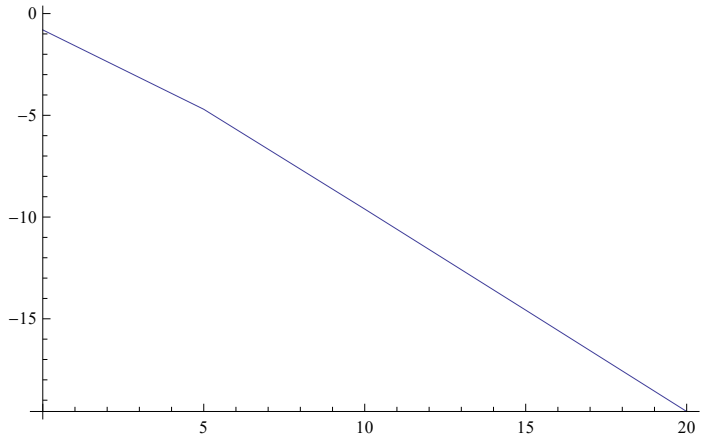


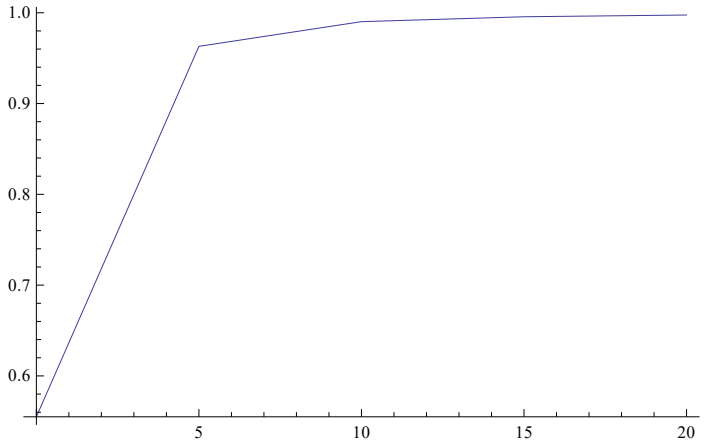


```
Bz0 = Eigenvalues[H[1, 0, 1] // N];
Bz5 = Eigenvalues[H[1, 5, 1] // N];
Bz10 = Eigenvalues[H[1, 10, 1] // N];
Bz15 = Eigenvalues[H[1, 15, 1] // N];
Bz20 = Eigenvalues[H[1, 20, 1] // N];

ListPlot[{{0, Bz0[[1]]}, {5, Bz5[[1]]},
  {10, Bz10[[1]]}, {15, Bz15[[1]]}, {20, Bz20[[1]]}}, Joined → True]
ListPlot[{{0, Bz0[[2]]}, {5, Bz5[[2]]}, {10, Bz10[[2]]},
  {15, Bz15[[2]]}, {20, Bz20[[2]]}}, Joined → True]
ListPlot[{{0, Bz0[[3]]}, {5, Bz5[[3]]}, {10, Bz10[[3]]},
  {15, Bz15[[3]]}, {20, Bz20[[3]]}}, Joined → True]
```








```
(*2*)
Eigenvalues[Sy]
Eigenvectors[Sy]
```

```
{-1, 1, 0}
```

$$\left\{\left\{-1, i\sqrt{2}, 1\right\}, \left\{-1, -i\sqrt{2}, 1\right\}, \{1, 0, 1\}\right\}$$

```
psi0 = Transpose[{{1, 0, 1}}]
```

```
{{1}, {0}, {1}}
```

```
U[t_, B_, Bz_, λ_] := MatrixExp[-I * H[B, Bz, λ] * t]

λ = 0
psi = psi0
Sxs = {}
Sys = {}
Szs = {}
Es = {}
For[t = 0, t < 10, t++,
 {
  psi = U[t, 1, 1, λ].psi,
  Print[ConjugateTranspose[psi].Sx.psi],
  AppendTo[Sxs, ConjugateTranspose[psi].Sx.psi],
  AppendTo[Sys, ConjugateTranspose[psi].Sy.psi],
  AppendTo[Szs, ConjugateTranspose[psi].Sz.psi],
  AppendTo[Es, ConjugateTranspose[psi].H.psi]
 }
]
ListPlot[Sxs]
ListPlot[Sys]
ListPlot[Szs]
ListPlot[Es]
```