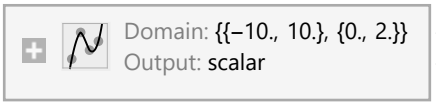
```
(* Free Particle - Broadening of Wave-Pocket *)

hbar = 1; m = 1; L = 10; T = 2; alp = 2; k0 = 0;
sol = NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x], psi[x, 0] ==
    Exp[-alp x^2 / 2 + I k0 x], psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

{{psi → InterpolatingFunction[]}}

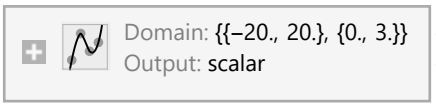
$\frac{1}{2}$

```
Table[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → All], {t, 0, T, .1}]

aniwav = Animate[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {-0.4, 1}],
  {t, 0, T}, AnimationRunning → False]

Export["C:\Documents and Settings\amma\Desktop\animate.gif", aniwav]

hbar = 1; m = 1; L = 20; T = 3; alp = 2; k0 = 3;
sol = NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x], psi[x, 0] ==
    Exp[-alp x^2 / 2 + I k0 x], psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

{{psi → InterpolatingFunction[]}}

5

```
Table[Plot[Abs[psi[x, t] /. sol],
  {x, -L, L}, PlotRange → All, PlotLabel → t], {t, 0, T, .1}]

aniwav = Animate[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {-0.4, 1}],
  {t, 0, T}, AnimationRunning → False]

Export["C:\Documents and Settings\amma\Desktop\samp_02.gif", aniwav]
```

```
hbar = 1; m = 1; L = 150; T = 120; x0 = 60; V0 = 1; alp = 0.1; k0 = 1;
V[x_] := V0 (1 + Tanh[20 x]) / 2
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
   psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x], psi[-L, t] == 0,
   psi[L, t] == 0}, psi, {t, 0, T}, {x, -L / 2, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

```
{{psi → InterpolatingFunction[ Domain: {{-150., 150.}, {0., 120.}}
                               Output: scalar ]}}
```

```
0.525
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {0, 1.2}],
   Plot[V[x], {x, -L / 2, L}, PlotRange → All,
    PlotStyle → {Dashed, Red, Thickness[0.006]}]], {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_03.gif", aniwav]
```

```
hbar = 1; m = 1; L = 150; T = 60; x0 = 20; V0 = 1; alp = 0.1; k0 = 2;
V[x_] := V0 (1 + Tanh[20 x]) / 2
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
   psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
   psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

```
{{psi → InterpolatingFunction[ Domain: {{-150., 150.}, {0., 60.}}
                               Output: scalar ]}}
```

```
2.025
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {0, 1.2}],
   Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_04.gif", aniwav]
```

```
C:\Documents and Settings\amma\Desktop\samp_04.gif
```

```
hbar = 1; m = 1; V0 = 1; alp = 0.02;
en = V0;
krb = Sqrt[ (2 m en / hbar^2) - alp / 2 ]
```

```
1.41067
```

```
hbar = 1; m = 1; L = 150; T = 100; x0 = 20; V0 = 1; alp = 0.02; k0 = krb;
V[x_] := V0 (1 + Tanh[20 x]) / 2
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
   psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
   psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

```
{{psi → InterpolatingFunction[ Domain: {{-150., 150.}, {0., 100.}}
                               Output: scalar ]}}
```

```
1.
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {0, 1.2}],
    Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_045.gif", aniwav]
```

```
C:\Documents and Settings\amma\Desktop\samp_045.gif
```

>>> >>> >>> >>> >>>

```
hbar = 1; m = 1; L = 220; T = 110; x0 = 20; V0 = 1; Lv = 20; alp = 0.1; k0 = 1;
V[x_] := V0 (Tanh[20 x] - Tanh[20 (x - Lv)]) / 2
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
    psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
    psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

{{psi → InterpolatingFunction[Domain: {{−220., 220.}, {0., 110.}} Output: scalar]}}

```
0.525
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {0, 1.2}],
    Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_05.gif", aniwav]
```

C:\Documents and Settings\amma\Desktop\samp_05.gif

```
hbar = 1; m = 1; V0 = 1; Lv = 20; alp = 0.1;
nn = 2; en = V0
krb = Sqrt[(2 m en / hbar^2) - alp / 2]
```

```
1
```

```
1.39642
```

```
hbar = 1; m = 1; L = 220; T = 110; x0 = 20; k0 = krb;
V[x_] := V0 (Tanh[20 x] - Tanh[20 (x - Lv)]) / 2
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
    psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
    psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

{{psi → InterpolatingFunction[Domain: {{−220., 220.}, {0., 110.}} Output: scalar]}}

```
1.
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {0, 1.2}],
    Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_06.gif", aniwav]
```

C:\Documents and Settings\amma\Desktop\samp_06.gif

```
hbar = 1; m = 1; V0 = 1; Lv = 20; alp = 0.002;
nn = 8; en1 = V0 + nn^2 Pi^2 hbar^2 / (2 m Lv^2) // N
krb1 = Sqrt[(2 m en1 / hbar^2) - alp / 2]
nn = 9; en2 = V0 + nn^2 Pi^2 hbar^2 / (2 m Lv^2) // N
krb2 = Sqrt[(2 m en2 / hbar^2) - alp / 2]
```

```
1.78957
```

```
1.8916
```

```
1.9993
```

```
1.9994
```

```
hbar = 1; m = 1; L = 200; T = 100; x0 = 80; k0 = (krb1 + krb2) / 2
V[x_] := V0 (Tanh[20 x] - Tanh[20 (x - Lv)]) / 2
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
   psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
   psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

```
1.9455
```

```
{{psi → InterpolatingFunction[ Domain: {{-200., 200.}, {0., 100.}}
                               Output: scalar ]}}
```

```
1.89298
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {0, 1.2}],
    Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_07.gif", aniwav]
```

```
C:\Documents and Settings\amma\Desktop\samp_07.gif
```

```
hbar = 1; m = 1; L = 200; T = 100; x0 = 80; k0 = krb1;
V[x_] := V0 (Tanh[20 x] - Tanh[20 (x - Lv)]) / 2
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
   psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
   psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

```
{{psi → InterpolatingFunction[ Domain: {{-200., 200.}, {0., 100.}}
                               Output: scalar ]}}
```

```
1.78957
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {0, 1.2}],
    Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_08.gif", aniwav]
```

```
C:\Documents and Settings\amma\Desktop\samp_08.gif
```

```
hbar = 1; m = 1; V0 = -0.2; Lv = 20; alp = 0.002;
nn = 5; en1 = V0 + nn^2 Pi^2 hbar^2 / (2 m Lv^2) // N
krw1 = Sqrt[(2 m en1 / hbar^2) - alp / 2]
nn = 6; en2 = V0 + nn^2 Pi^2 hbar^2 / (2 m Lv^2) // N
krw2 = Sqrt[(2 m en2 / hbar^2) - alp / 2]
```

```
0.108425
```

```
0.464597
```

```
0.244132
```

```
0.698043
```

```
hbar = 1;
m = 1;
L = 200;
T = 250;
x0 = 70;
k0 = Sqrt[(2 m (en2 - 0.06) / hbar^2) - alp / 2]
V[x_] := V0 ((1 + Tanh[20 x]) / 2 - (1 + Tanh[20 (x - Lv)]) / 2)
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
   psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
   psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

```
0.606023
```

```
{{psi → InterpolatingFunction[ Domain: {{-200., 200.}, {0., 250.}}
                               Output: scalar ]}}
```

```
0.184132
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {-0.3, 1.2}],
    Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]
```

```
Export["C:\Documents and Settings\amma\Desktop\samp_09.gif", aniwav]
```

```
hbar = 1; m = 1; L = 180; T = 200; x0 = 70; k0 = krw2;
V[x_] := V0 ((1 + Tanh[20 x]) / 2 - (1 + Tanh[20 (x - Lv)]) / 2)
sol =
 NDSolve[{I hbar D[psi[x, t], t] == (-hbar^2 / (2 m)) D[psi[x, t], x, x] + V[x] psi[x, t],
   psi[x, 0] == Exp[-alp (x + x0)^2 / 2 + I k0 x],
   psi[-L, t] == 0, psi[L, t] == 0}, psi, {t, 0, T}, {x, -L, L}]
en = hbar^2 (alp / 2 + k0^2) / (2 m)
```

```
{{psi → InterpolatingFunction[ Domain: {{-180., 180.}, {0., 200.}}
                               Output: scalar ]}}
```

```
0.244132
```

```
aniwav = Animate[Show[Plot[Abs[psi[x, t] /. sol], {x, -L, L}, PlotRange → {-0.3, 1.2}],
    Plot[V[x], {x, -L, L}, PlotRange → All, PlotStyle → {Dashed, Red, Thickness[0.006]}]],
  {t, 0, T}, AnimationRunning → False]

Export["C:\Documents and Settings\amma\Desktop\samp_10.gif", aniwav]
```