Dinamica Cuantica

```
(* --- Calculo de las funciones de onda
       en el oscilador armonico --- *)
```

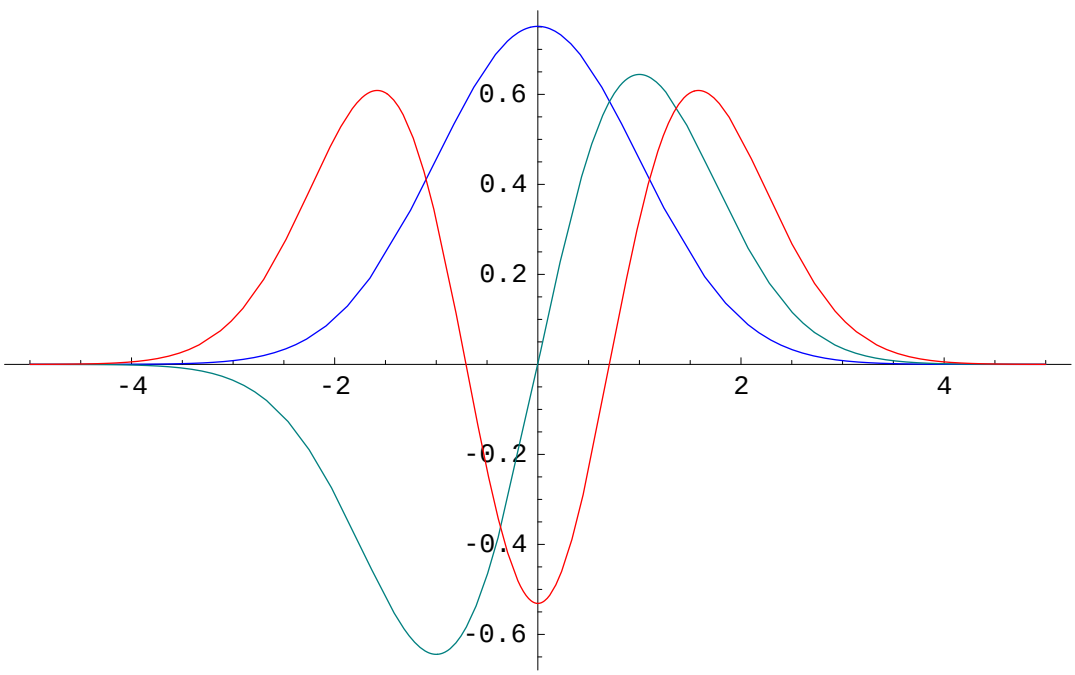
```
phi[x_, n_Integer] :=
```

$$\sqrt{\frac{1}{\sqrt{\text{Pi}} * 2^n * n!}} * \text{Exp}\left[\frac{-x^2}{2}\right] * \text{HermiteH}[n, x]$$

```
 (* ---- Energias  ---- *)

 ω = 1;
```

$$\text{Ener}[n_\text{Integer}] := \left(n + \frac{1}{2}\right) \omega;$$

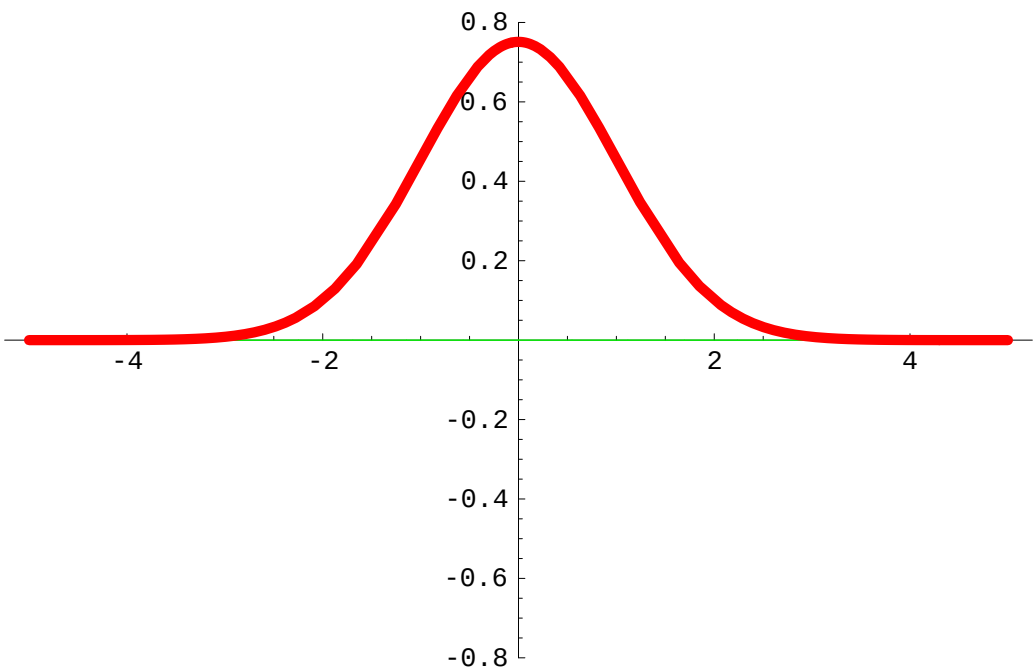
```
Plot[
  {phi[x, 0], phi[x, 1], phi[x, 2]}, {x, -5, 5},
  PlotStyle → {{RGBColor[0, 0, 1]}, {RGBColor[0, .5, .5]},
                 {RGBColor[1, 0, 0]}
               } ,
  ImageSize → 500
   ];
```



```
(* ----    evolucion temporal
  de onda estacionaria  ---- *)
```

(* doble click en cualquier figura para ver la pelicula de la evolucion *)

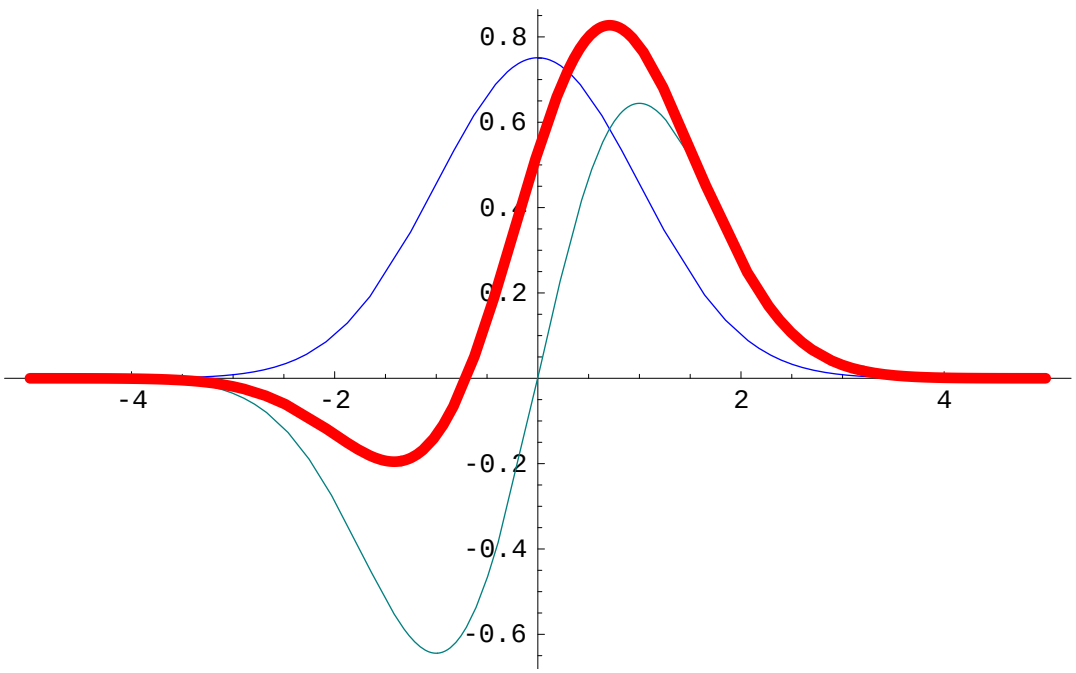
```
τ = 2 * Pi / (Ener[0]);

Table[Plot[
        {   Re[ phi[x, 0] * Exp[- I * Ener[0] * t] ] ,
         Im[ phi[x, 0] * Exp[- I * Ener[0] * t] ],
       Abs[phi[x, 0] * Exp[- I * Ener[0] * t] ]
      },
         {x, -5, 5},
         PlotRange → {-.8, .8},
        PlotStyle → {
                       {RGBColor[0, 0, 1]},
                      {RGBColor[0, 1, 0]},
                       {RGBColor[1, 0, 0], Thickness[0.01] }
                      } ,
        ImageSize → 500
        ],
       {t, 0, τ, τ / 50}
      ];
```



```
(* ---- construccion de combinacion
 lineal de dos estados estacionarios  ---- *)
```

```
c = {Sqrt[1. / 2.], Sqrt[1. / 2.]};
```

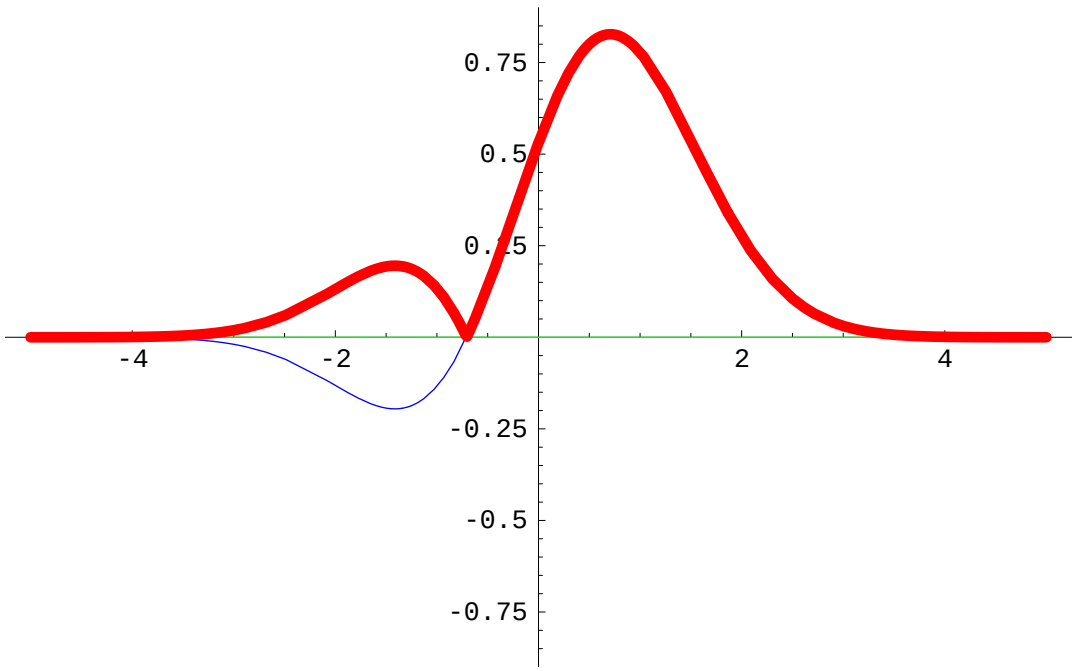
```
Plot[
  {phi[x, 0], phi[x, 1],
   c[[1]] phi[x, 0] + c[[2]] phi[x, 1]},
  {x, -5, 5},
  PlotStyle → {
               {RGBColor[0, 0, 1]     },
               {RGBColor[0, 0.5, .5]   },
               {RGBColor[1, 0, 0], Thickness [ 0.01] }
              } ,
  ImageSize → 500
 ];
```



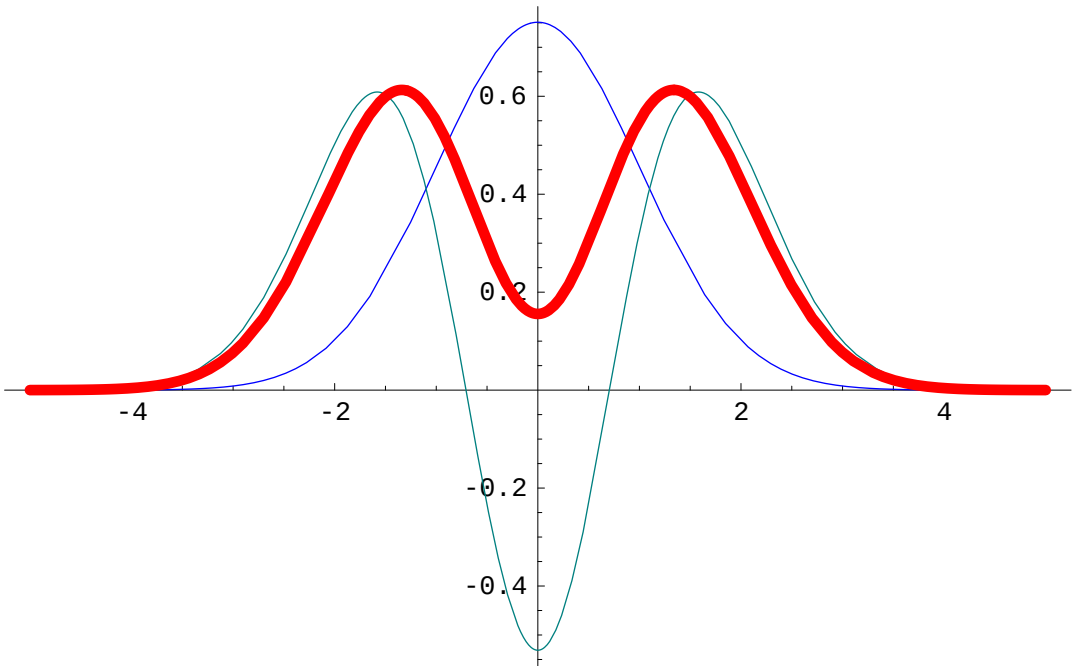
```
(* ---- evolucion temporal
  de esta combinacion lineal  ---- *)
```

(* doble click en cualquier figura para ver la pelicula de la evolucion *)

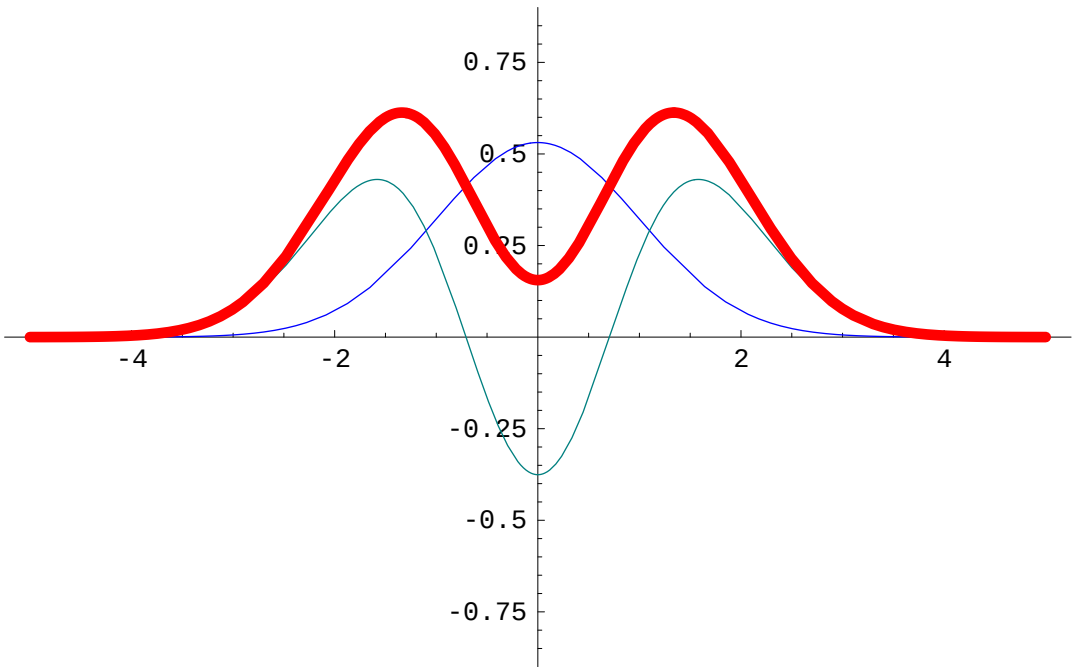
```
Table[Plot[
    {Re[c[[1]] * phi[x, 0] * Exp[-I * Ener[0] * t] + c[[2]] * phi[x, 1] * Exp[-I * Ener[1] * t]],
     Im[c[[1]] * phi[x, 0] * Exp[-I * Ener[0] * t] + c[[2]] * phi[x, 1] * Exp[-I * Ener[1] * t]],
     Abs[c[[1]] * phi[x, 0] * Exp[-I * Ener[0] * t] +
        c[[2]] * phi[x, 1] * Exp[-I * Ener[1] * t]]},
       {x, -5, 5},
     PlotRange → {-.9, .9},
    PlotStyle → {
       {RGBColor[0, 0, 1]},
       {RGBColor[0, 1, 0]},
       {RGBColor[1, 0, 0], Thickness[0.01] }
     },
    ImageSize -> 500
       ],
  {t, 0, τ, τ / 50}];
```



```
(* ---- combinacion lineal de
  funciones con misma paridad   ---- *)

c = {Sqrt[1./2.], Sqrt[1./2.]};

Plot[
  {phi[x, 0], phi[x, 2],
   c[[1]] phi[x, 0] + c[[2]] phi[x, 2]},
  {x, -5, 5},
  PlotStyle → {
               {RGBColor[0, 0, 1]     },
               {RGBColor[0, 0.5, .5]   },
               {RGBColor[1, 0, 0], Thickness [ 0.01] }
              } ,
  ImageSize → 500
 ];
```



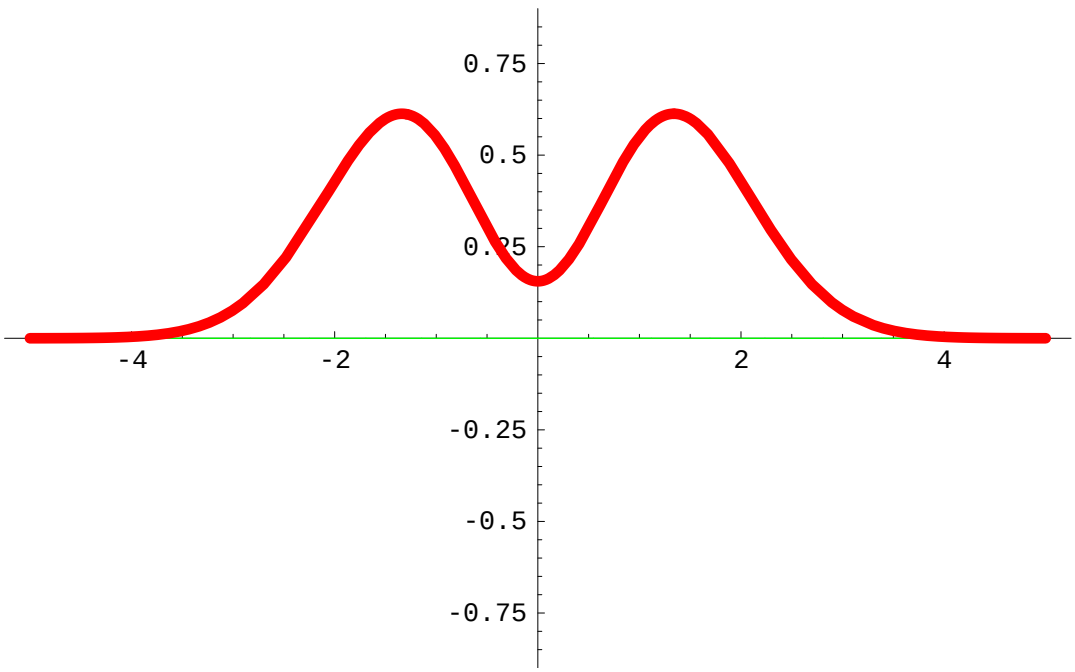
```
(* ---- evolucion temporal de la parte real ---- *)
(* doble click en cualquier figura para ver la pelicula de la evolucion  *)

τ = 2 * Pi / (Ener[0]) ; movie1 = Table[Plot[{Re[c[[1]] * phi[x, 0] * Exp[- I * Ener[0] * t] ],
        Re[c[[2]] * phi[x, 2] * Exp[- I * Ener[2] * t] ],
     Re[c[[1]] * phi[x, 0] * Exp[- I * Ener[0] * t] +
          c[[2]] * phi[x, 2] * Exp[- I * Ener[2] * t]]},
       {x, -5, 5},
       PlotRange → {-.9, .9},
      PlotStyle → {
                    {RGBColor[0, 0, 1]},
                    {RGBColor[0, 0.5, .5]},
                    {RGBColor[1, 0, 0] , Thickness[0.01] }
                  } ,
     ImageSize → 500
       ],
      {t, 0, τ, τ / 50}
     ] ;
```



```
(* ---- funciones con la misma paridad   ---- *)
(* ---- Evolucion de la onda (Real,Imaginaria y Modulo)     ---- *)
```

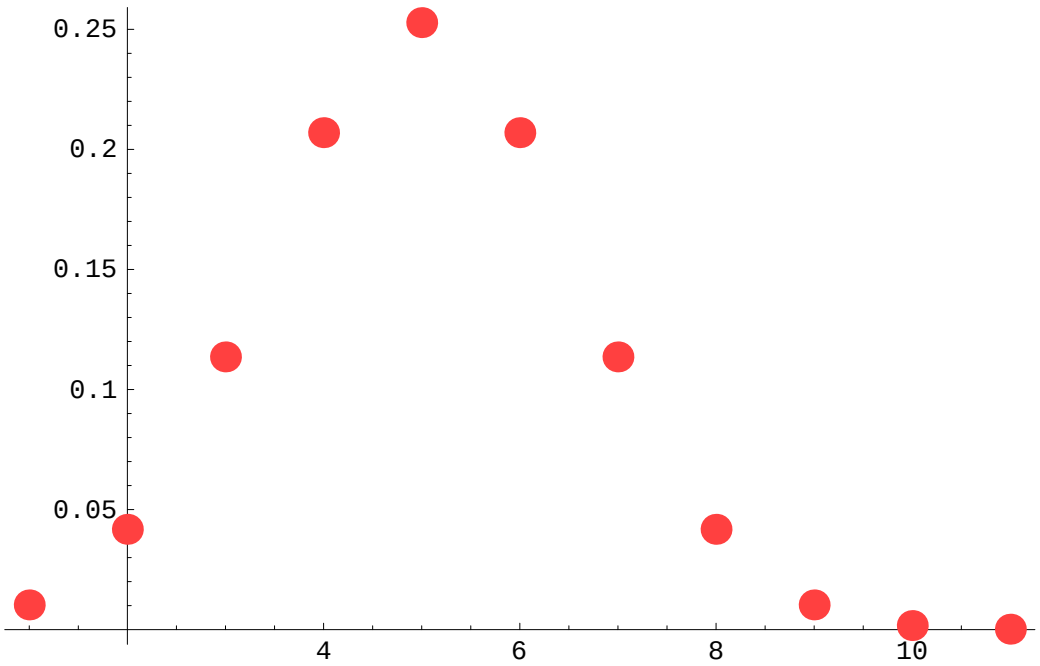
(* doble click en cualquier figura para ver la pelicula de la evolucion *)

```
Table[Plot[
    {Re[c[[1]] * phi[x, 0] * Exp[-I * Ener[0] * t] + c[[2]] * phi[x, 2] * Exp[-I * Ener[2] * t]],
     Im[c[[1]] * phi[x, 0] * Exp[-I * Ener[0] * t] + c[[2]] * phi[x, 2] * Exp[-I * Ener[2] * t]],
     Abs[c[[1]] * phi[x, 0] * Exp[-I * Ener[0] * t] +
        c[[2]] * phi[x, 2] * Exp[-I * Ener[2] * t]]},
       {x, -5, 5},
     PlotRange → {-.9, .9},
    PlotStyle → {
       {RGBColor[0, 0, 1]},
       {RGBColor[0, 1, 0]},
       {RGBColor[1, 0, 0], Thickness[0.01] }
     },
    ImageSize -> 500
       ],
  {t, 0, τ, τ / 50}];
```



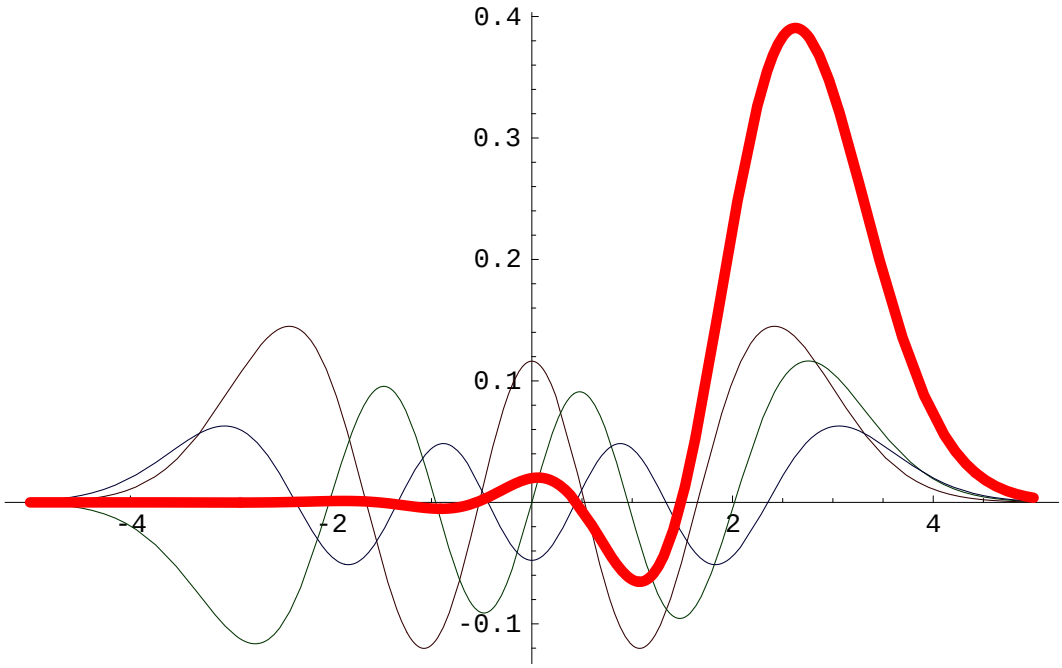

```
(* ---- Combinaciones generales
  de funciones estacionarias  ---- *)

nmin = 1;
nmax = 11;
n0 = (nmax - nmin) / 2 ;
b := Table[ Exp[ - (i - n0) ^2 / n0], {i, nmin, nmax}]
 Sumb = Sum[ (b[[n]] ) , {n, nmin, nmax}] ;

b := Table[ Exp[ - (i - n0) ^2 / n0] / Sumb, {i, nmin, nmax}]
```

```
ListPlot[  b  ,
            PlotStyle → {
                        RGBColor[1, 0.25, 0.25] , PointSize[0.03]
                           } ,
   PlotRange -> All,
   ImageSize -> 500
         ] ;
```




```
ξ[x_] :=  Sum[
                b[[n]] * phi[x, n - 1] ,
                 {n, nmin, nmax}
               ] ;
```

```
Plot[ {b[[5]] * phi[x, 4], b[[6]] * phi[x, 5], b[[7]] * phi[x, 6],  ξ[x]},  {x, −5, 5},
      PlotRange → All,
      PlotStyle −> {
                    {RGBColor[0.2, 0, 0],  Thickness[0.001] },
                    {RGBColor[0.0, 0.2, 0],  Thickness[0.001] },
                    {RGBColor[0, 0, 0.2],  Thickness[0.001] },
                     {RGBColor[1, 0, 0],  Thickness[0.01] },
                    },
      ImageSize → 500] ;
```

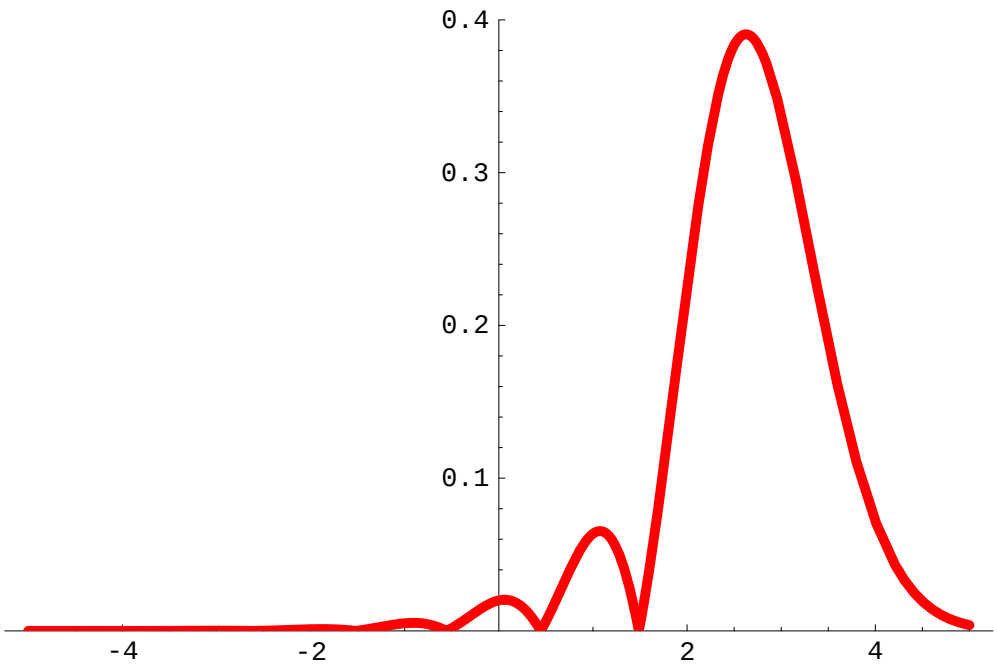



```
ξ[x_, t_] :=  Sum[
                  b[[n]] * phi[x, n - 1] * Exp[−I * Ener[n − 1] * t] ,
                   {n, nmin, nmax}
                 ] ;
```

```
(* ---- Evolucion temporal
  de esta combinacion   ---- *)
```

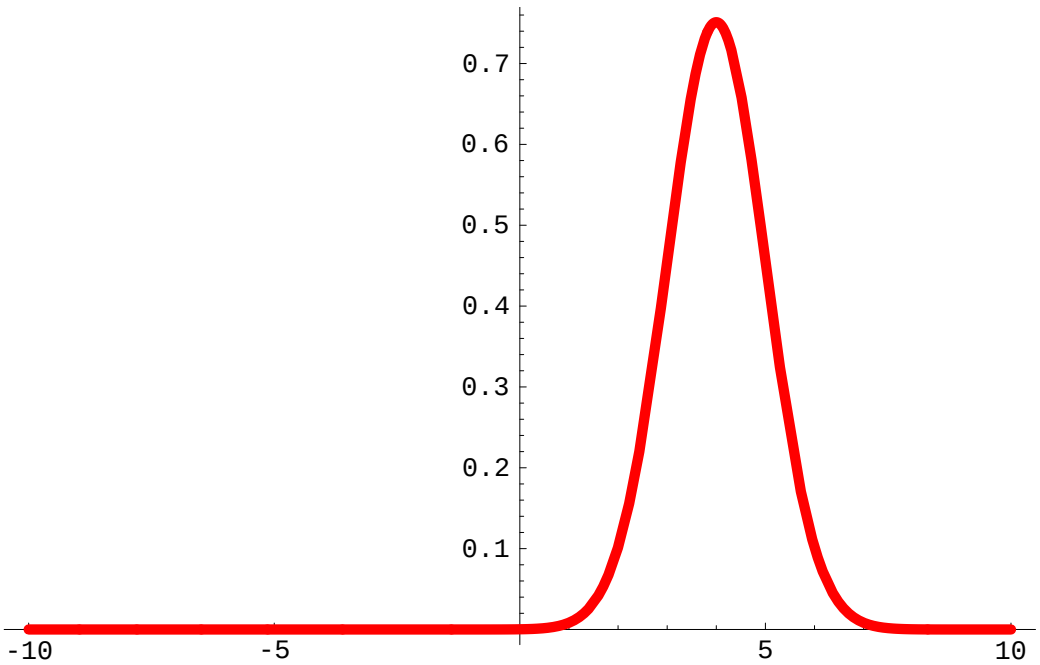
(* doble click en cualquier figura para ver la pelicula de la evolucion *)

```
τ = 1 * Pi / (Ener[0]);
 Table[Plot[
        Abs[ ξ[x, t] ],
          {x, -5, 5},
       PlotRange → {0., 0.4},
     PlotStyle → {
        {RGBColor[1, 0, 0], Thickness[0.01] }
       },
     ImageSize -> 500
         ],
   {t, 0, τ, τ / 25}];
```



```
(* ---- Estado fundamental
  con traslacion espacial   ---- *)
```

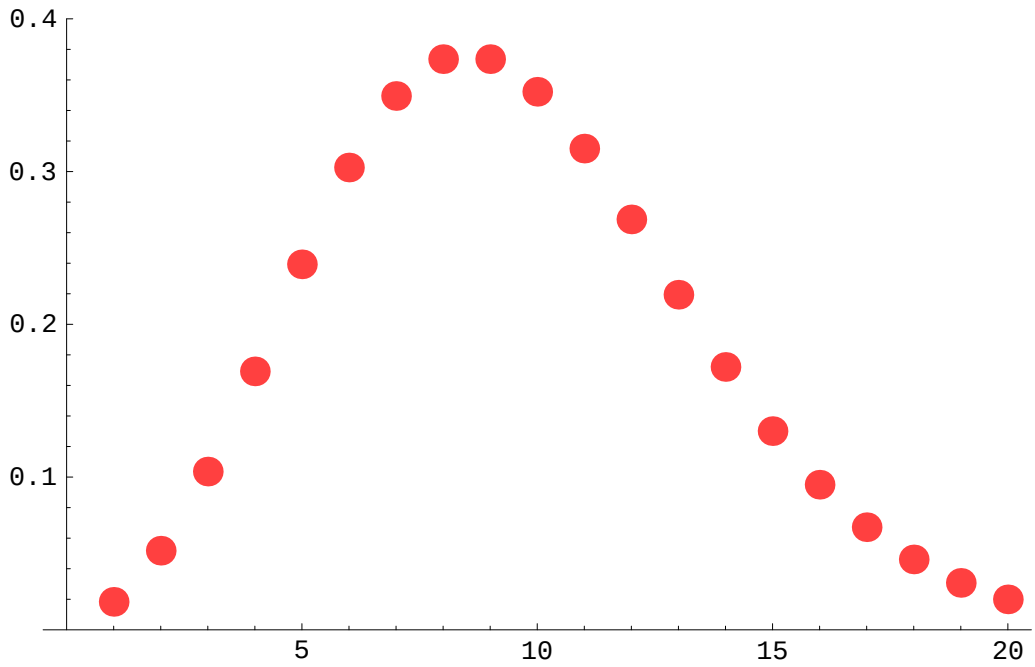
```
d = 4;
Plot[phi[x - d, 0], {x, -10, 10},
  PlotRange → All,
  PlotStyle → {RGBColor[1, 0, 0], Thickness[0.01]},
  ImageSize -> 500];
```




```
(* ---- Coeficientes de la expansion
  en estados estacionarios   ---- *)
```

```
f[n_Integer] := NIntegrate[phi[x - d, 0] * phi[x, n - 1], {x, -Infinity, Infinity}];

nmin = 1;
nmax = 20;
b := Table[ f[n], {n, nmin, nmax}];
```

```
ListPlot[  b  ,
           PlotStyle → {
                        RGBColor[1, 0.25, 0.25] , PointSize[0.03]
                          } ,
  PlotRange -> {0, 0.4},
  ImageSize -> 500
        ] ;
```




```
b[[n]]
```

```
rrr = {0.018315638888889173`, 0.051804449838926805`,
  0.10360889968207333`, 0.16919262468414065`, 0.23927450447660478`,
  0.30266096808297815`, 0.34948278277392736`, 0.3736127972169554`,
  0.37361281027655086`, 0.35224553559712785`, 0.31505798504125754`,
  0.26868235234184806`, 0.2193782220055621`, 0.1720944359903972`,
  0.1300911657910072`, 0.09500515477277238`, 0.06717878889559205`,
  0.04608426913209869`, 0.030722846088117355`, 0.019935615014398337`}
```

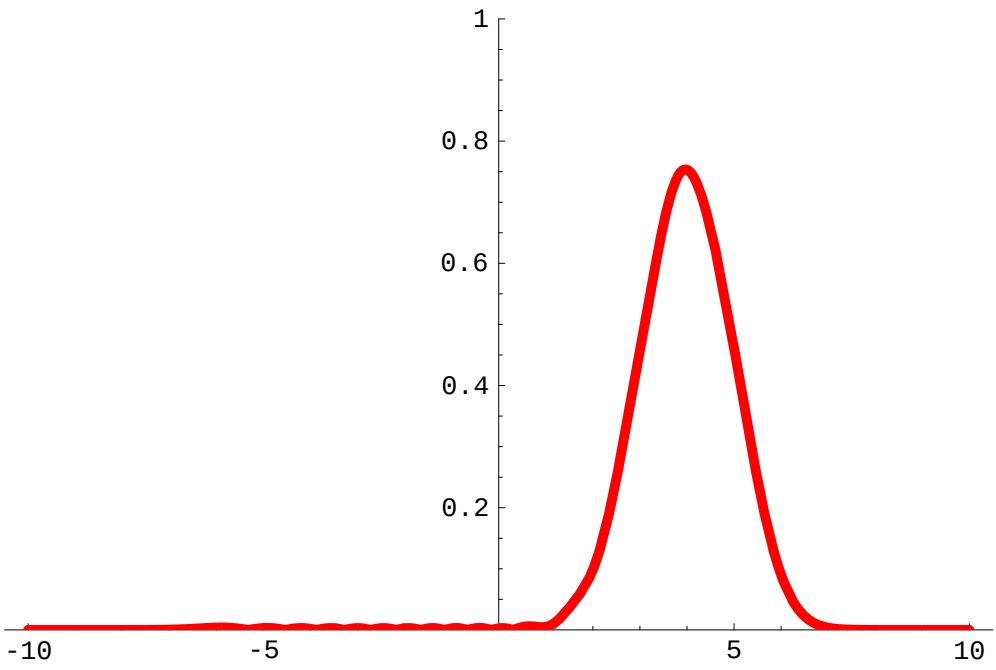
```
{0.0183156, 0.0518044, 0.103609, 0.169193, 0.239275, 0.302661,
 0.349483, 0.373613, 0.373613, 0.352246, 0.315058, 0.268682, 0.219378,
 0.172094, 0.130091, 0.0950052, 0.0671788, 0.0460843, 0.0307228, 0.0199356}
```

```
ξ[x_, t_] :=  Sum[
                rrr[[n]] * phi[x, n - 1] * Exp[-I * Ener[n - 1] * t]  ,
                 {n, nmin, nmax}
               ] ;
```

(* ---- Evolucion temporal de estado coherente ---- *)

(* doble click en cualquier figura para ver la pelicula de la evolucion *)

```
τ = 1 * Pi / (Ener[0]);
 Table[Plot[
        Abs[ ξ[x, t] ],
          {x, -10, 10},
       PlotRange → {0., 1},
     PlotStyle → {
        {RGBColor[1, 0, 0], Thickness[0.01] }
       },
     ImageSize -> 500
         ],
   {t, 0, τ, τ / 25}];
```




```
(*   HTMLSave["coherentes.html", "coherentes.nb"]  *)
```