



ภาคผนวก

มหาวิทยาลัยพระนคร

ภาคผนวก ก ตัวอย่างโปรแกรม Mathematica 5.1 แสดงผลของค่าไอเกนพลังงานและฟังก์ชันคลื่นภายใต้บ่อศักย์คู่สมมาตรกำลังสี่ใน 1 มิติ กรณี 5 $k = 25.0$, $\lambda = 1.0$ ที่ระดับพลังงานสถานะพื้น ($n=0$) และที่ $N = 800$

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In[1]:= xmin = 0; xmax = 5; n = 400; Δx =  $\frac{x_{max} - x_{min}}{n}$ ;
        φ1 = 1; φ2 = 1; x1 = 0; x2 = x1 + Δx; k = 25; λ = 1;

In[2]:= e = (-149.2199352779256 + -149.21993527792557`)/2
Out[2]= -149.22

E = -149.21993527792557`

In[3]:= N[Table[
        φi+1 = 2 φi - φi-1 - (Δx)2 * (e + k (xi+1 = xi + Δx)2 - λ (xi+1 = xi + Δx)4) * φi,
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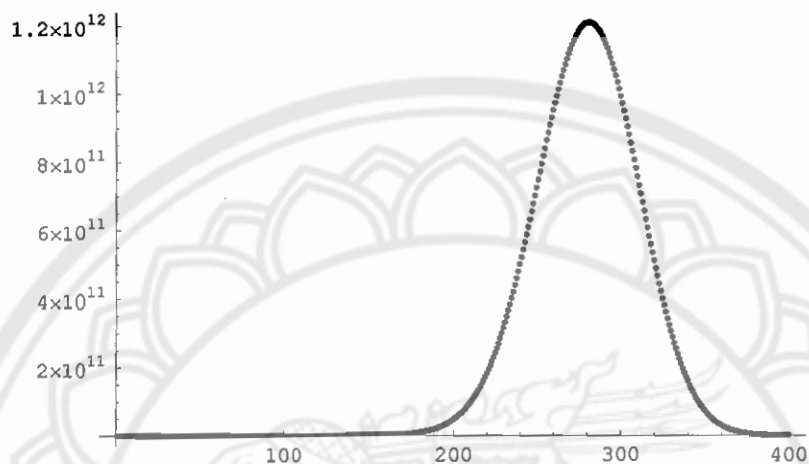
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```

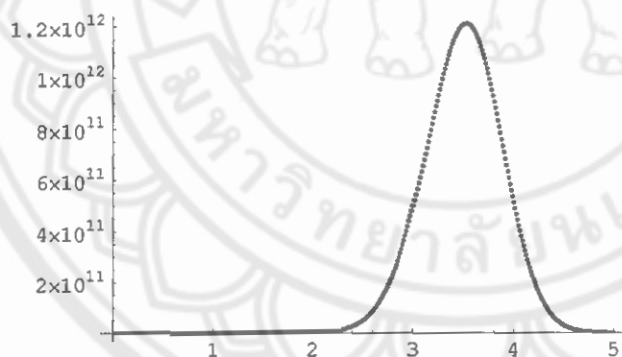
```
In[5]:= ListPlot[AA]
```



```
Out[5]= - Graphics -
```

```
In[6]:= N[Table[{x = xmin + i Δx, φi}, {i, 1, 400}]];
```

```
In[7]:= ListPlot[%]
```

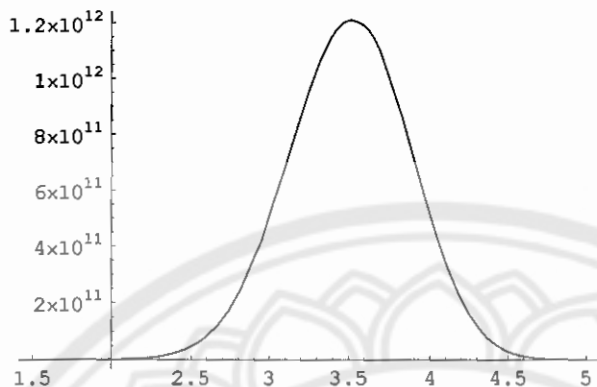


```
Out[7]= - Graphics -
```

```
In[8]:= kkk = Interpolation[%]
```

```
Out[8]= InterpolatingFunction[{{0.0125, 5.}}, <>]
```

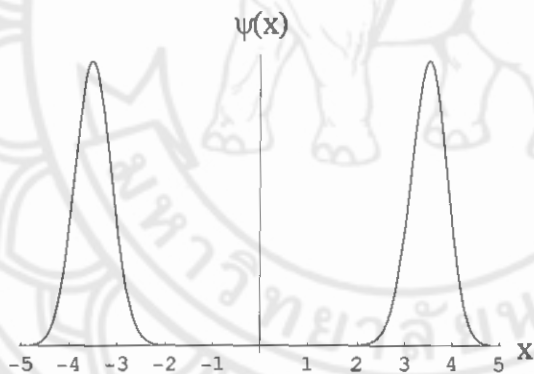
```
In[9]:= Plot[kkk[x], {x, 1.5, 5.0}]
```



```
Out[9]= - Graphics -
```

```
In[10]:= zzz[x_] := If[x >= 0, kkk[x], kkk[-x]];
```

```
In[11]:= Plot[zzz[x], {x, -4.8, 4.8}, Ticks ->
  {{{-5, "-5"}, {-4, "-4"}, {-3, "-3"}, {-2, "-2"}, {-1, "-1"},
   {0, "0"}, {1, "1"}, {2, "2"}, {3, "3"}, {4, "4"}, {5, "5"}}, None},
  AxesLabel -> {FontForm["x", {"Symbol", 15}],
  FontForm["ψ(x)", {"Symbol", 15}]}, PlotRange -> All]
```



```
Out[11]= - Graphics -
```


ภาคผนวก ข ตัวอย่างโปรแกรม Mathematica 5.1 แสดงผลของค่าไอเกนพลังงานและฟังก์ชันคลื่นภายใต้ป้อนศักย์คู่สมมาตรกำลังสี่ใน 1 มิติ กรณี 5 $k = 25.0$, $\lambda = 1.0$ ที่ระดับพลังงานสถานะกระตุ้นแรก ($n=1$) และที่ $N = 800$

```

In[1]:= xmin = 0; xmax = 5; n = 400; Δx =  $\frac{x_{\max} - x_{\min}}{n}$ ; φ1 = 0;
        N[φ2 = Δx]; x1 = 0; x2 = x1 + Δx; k = 25.0; λ = 1.0;

In[2]:= e = (-149.21993527792569 - 149.2199352779254`)^2 / 2
Out[2]= -149.22

        E = -149.21993527792554`

In[3]:= N[Table[
        φi+1 = 2 φi - φi-1 - (Δx)2 * (e + k (xi+1 = xi + Δx)2 - λ (xi+1 = xi + Δx)4) * φi,
        {i, 2, 399}]]

Out[3]= {0.0252914, 0.0386724, 0.0529546, 0.0684707, 0.0855818, 0.104686,
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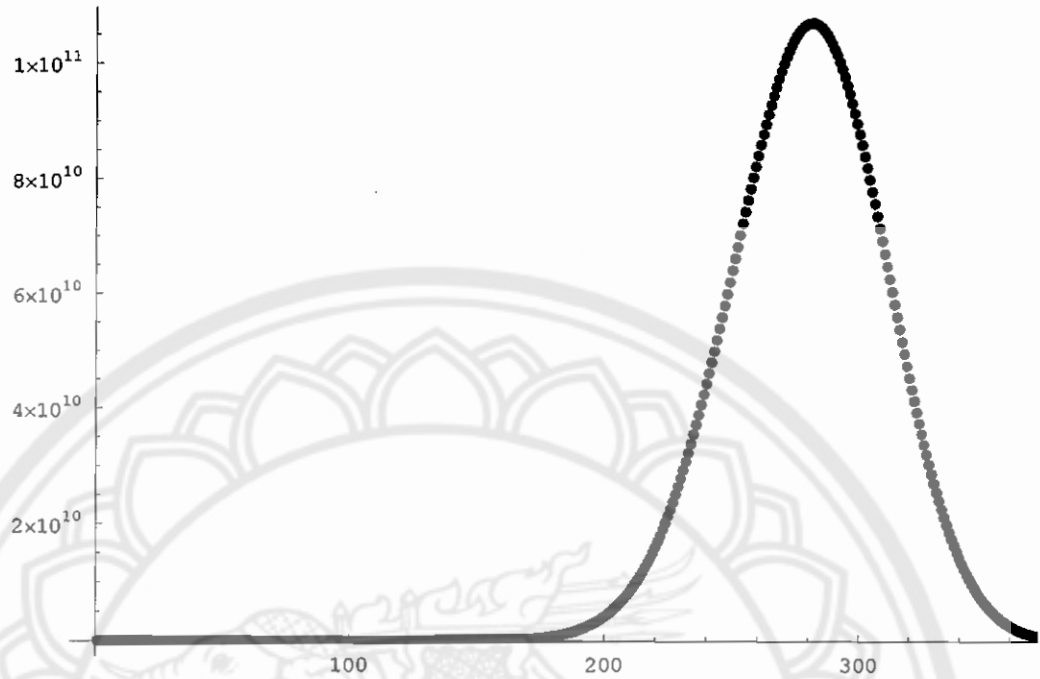
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1.4968848263264865`*^7, 9.796402638640897`*^6,
4.842918473018496`*^6, -0.026968738209689036`};

```

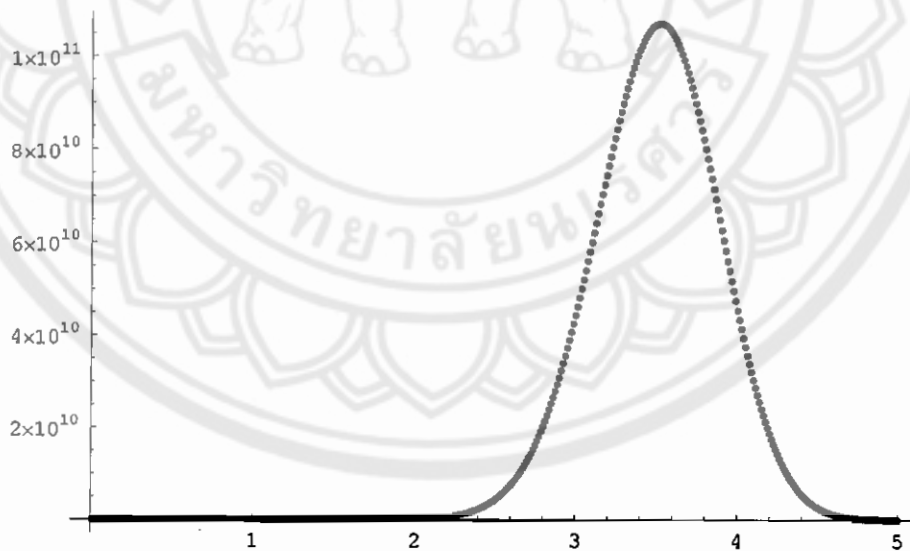
```
In[5]:= ListPlot[AA, PlotStyle -> PointSize[0.01]]
```



Out[5]= - Graphics -

In[6]:= `N[Table[{x = xmin + i Δx, φ1}, {i, 1, 400}]];`

In[7]:= `ListPlot[%]`

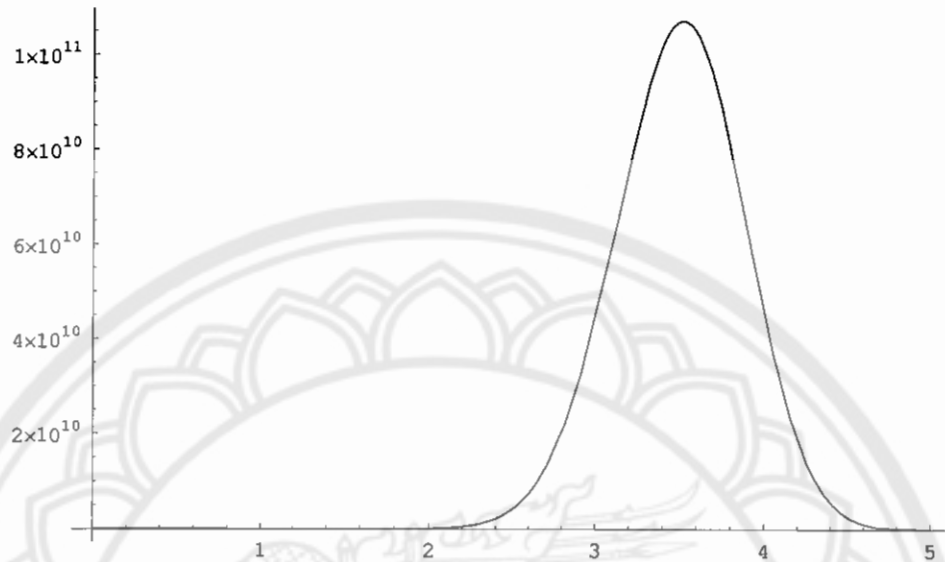


Out[7]= - Graphics -

In[8]:= `kkk = Interpolation[%]`

Out[8]= `InterpolatingFunction[{{0.0125, 5.}}, <>]`

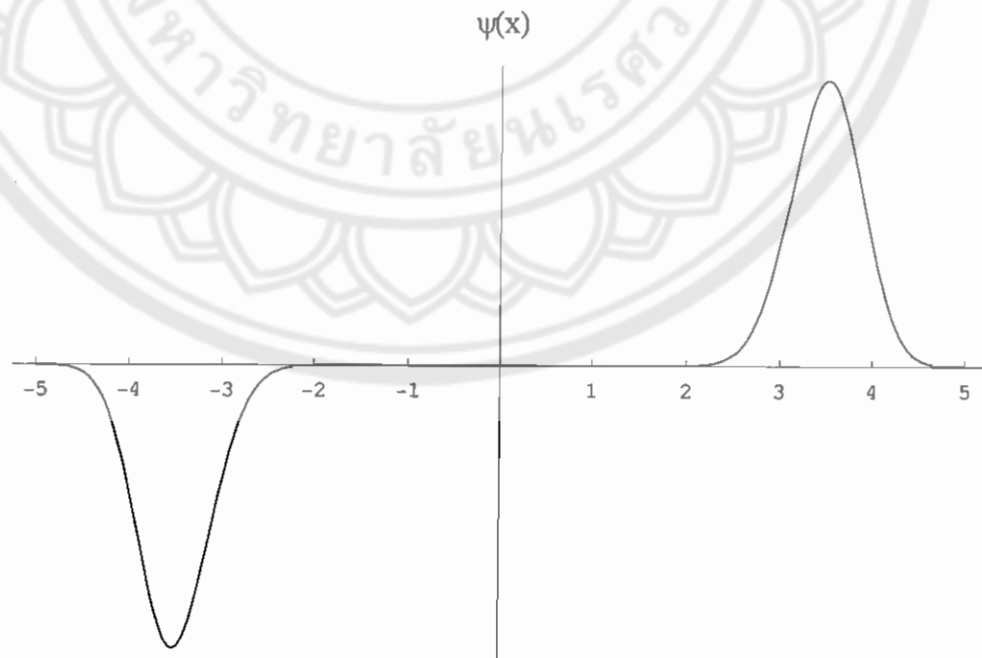
```
In[9]:= Plot[kkk[x], {x, 0, 5}]
```



```
Out[9]= - Graphics -
```

```
In[10]:= zzz[x_] := If[x >= 0, kkk[x], -kkk[-x]];
```

```
In[11]:= Plot[zzz[x], {x, -5.0, 5.0}, Ticks →
  {{{-5, "-5"}, {-4, "-4"}, {-3, "-3"}, {-2, "-2"}, {-1, "-1"},
   {0, "0"}, {1, "1"}, {2, "2"}, {3, "3"}, {4, "4"}, {5, "5"}}, None},
  AxesLabel → {FontForm["x", {"Symbol", 15}],
  FontForm["ψ(x)", {"Symbol", 15}]}, PlotRange → All]
```

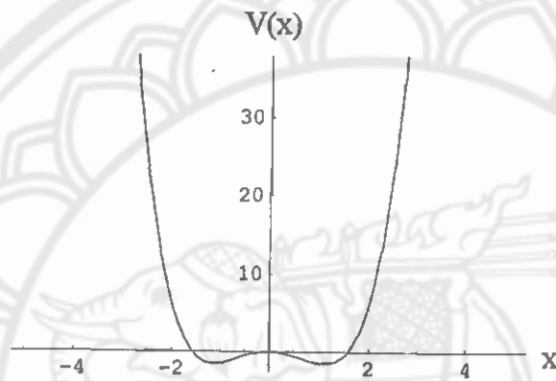


```
Out[11]= - Graphics -
```

ภาคผนวก ค กราฟฟังก์ชันคลื่นบ่อศักย์คู่สมมาตรกำลังสี่ใน 1 มิติ ทุกกรณี
แสดงโดยโปรแกรม Mathematica 5.1

```
In[1]:= Case1  
k1 = 2.5; λ1 = 1.0;  
Plot[-k1 x2 + λ1 x4, {x, -5, 5}, AxesLabel →  
{FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

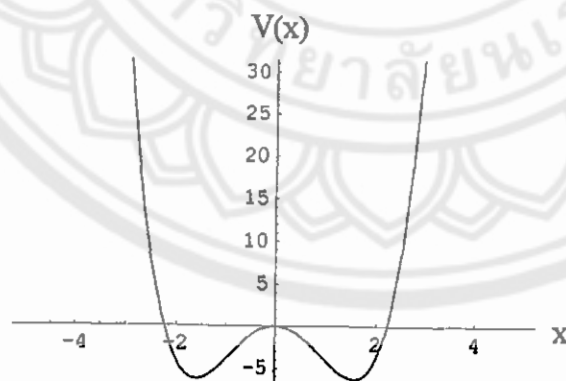
Out[1]= Case1



Out[3]= - Graphics -

```
In[4]:= Case2  
k2 = 5.0; λ2 = 1.0;  
Plot[-k2 x2 + λ2 x4, {x, -5, 5}, AxesLabel →  
{FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

Out[4]= Case2

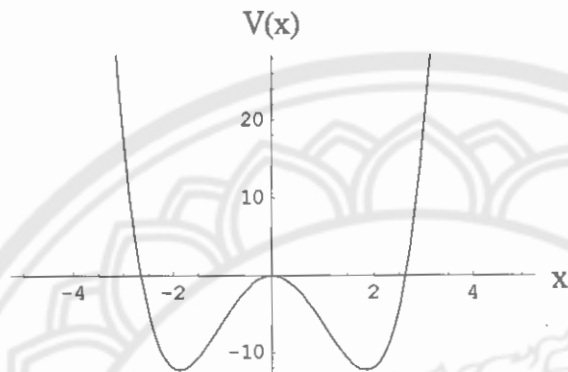


Out[6]= - Graphics -


```

In[7]:= Case3
k3 = 7.0; λ3 = 1.0;
Plot[-k3 x2 + λ3 x4, {x, -5, 5}, AxesLabel →
  {FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]]]
Out[7]= Case3

```

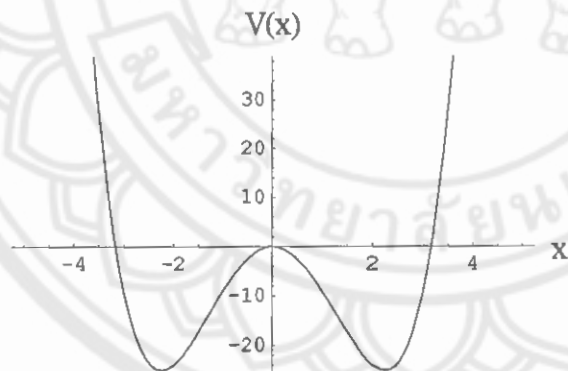


Out[9]= - Graphics -

```

In[10]:= Case4
k4 = 10.0; λ4 = 1.0;
Plot[-k4 x2 + λ4 x4, {x, -5, 5}, AxesLabel →
  {FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]]]
Out[10]= Case4

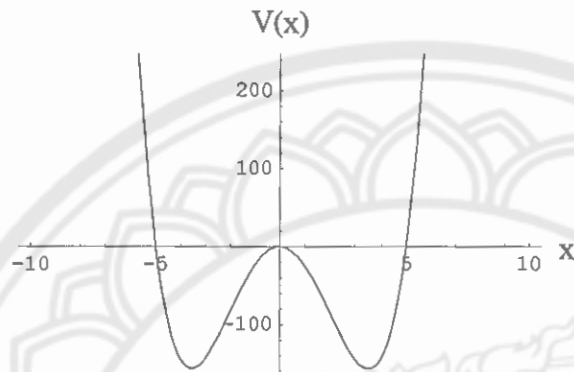
```



Out[12]= - Graphics -

```
In[13]:= Case5
k5 = 25; λ5 = 1.0;
Plot[-k5 x2 + λ5 x4, {x, -10, 10}, AxesLabel →
  {FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]]]
```

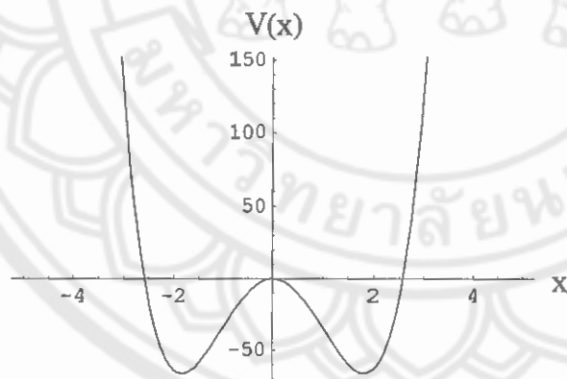
Out[13]= Case5



Out[15]= - Graphics -

```
In[16]:= Case6
k6 = 40.0; λ6 = 6.0;
Plot[-k6 x2 + λ6 x4, {x, -5, 5}, AxesLabel →
  {FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]]]
```

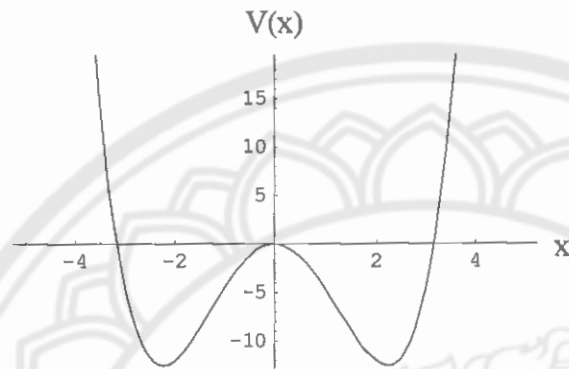
Out[16]= Case6



Out[18]= - Graphics -

```
In[19]:= Case7
k7 = 5.0; λ7 = 0.5;
Plot[-k7 x2 + λ7 x4, {x, -5, 5}, AxesLabel →
  {FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

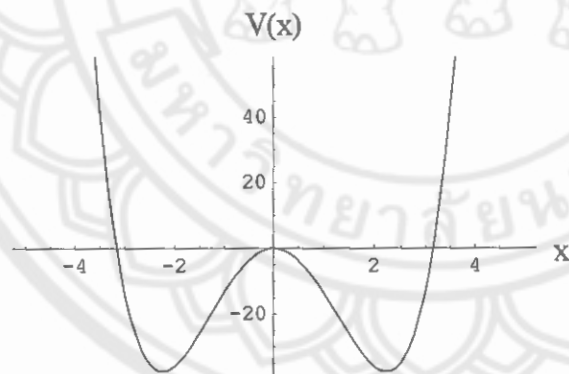
```
Out[19]= Case7
```



```
Out[21]= - Graphics -
```

```
In[22]:= Case8
k8 = 15.0; λ8 = 1.5;
Plot[-k8 x2 + λ8 x4, {x, -5, 5}, AxesLabel →
  {FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

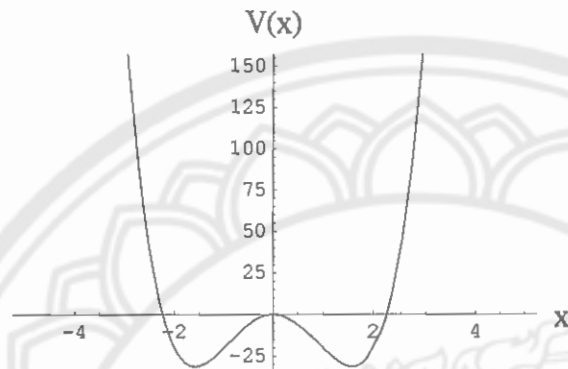
```
Out[22]= Case8
```



```
Out[24]= - Graphics -
```

```
In[25]:= Case9
k9 = 30.0; λ5 = 5.0;
Plot[-k5 x2 + λ5 x4, {x, -5, 5}, AxesLabel →
{FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

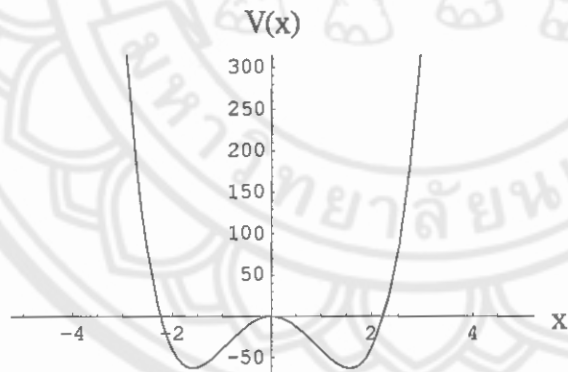
```
Out[25]= Case9
```



```
Out[27]= - Graphics -
```

```
In[28]:= Case10
k10 = 50.0; λ10 = 10.0;
Plot[-k10 x2 + λ10 x4, {x, -5, 5}, AxesLabel →
{FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

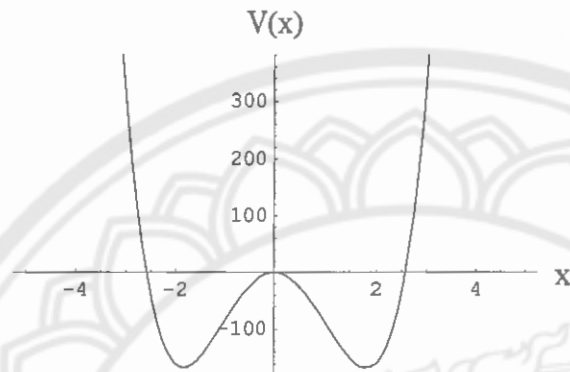
```
Out[28]= Case10
```



```
Out[30]= - Graphics -
```

```
In[31]:= Case11
k11 = 100.0; λ11 = 15.0;
Plot[-k11 x2 + λ11 x4, {x, -5, 5}, AxesLabel →
{FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

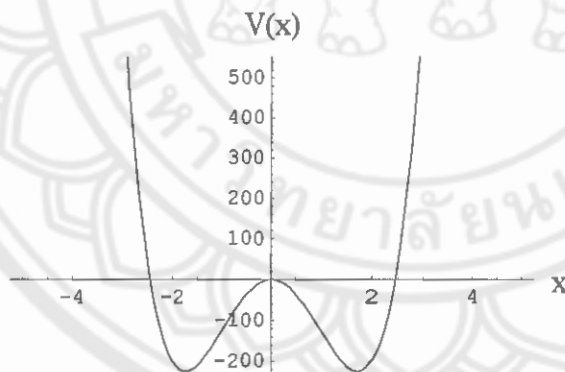
```
Out[31]= Case11
```



```
Out[33]= - Graphics -
```

```
In[34]:= Case12
k12 = 150.0; λ12 = 25.0;
Plot[-k12 x2 + λ12 x4, {x, -5, 5}, AxesLabel →
{FontForm["x", {"Symbol", 15}], FontForm["V (x)", {"Symbol", 15}]}]
```

```
Out[34]= Case12
```



```
Out[36]= - Graphics -
```