King Fahd University of Petroluem and Minerals
Department of Physics

Particle Physics (PHYS 441)
(041)

Solutions of HW # 3

Q.1 : "Problem # 4.38 in Griffiths"

In the interconversion interaction

$$A \leftrightarrows B,$$

① the charge is conserved.
② Baryon number is conserved.
③ Lepton number is conserved.
④ The particles should have the same mass → antiparticles of each other.

But if A is the antiparticle of B, then their Lepton numbers and baryon numbers are opposite to each other

⇒ A, B should be mesons

Since charge is conserved and the charge of the charged particle is opposite to its antiparticle ⇒ A, B are neutral

→ A, B are neutral mesons

Particles of this form has been found in

$(K^0, \bar{K}^0)$; $(B^0 (d\bar{b})$; $\bar{B}^0 (b\bar{d}))$; $(B_s^0 (s\bar{b})$; $\bar{B}_s^0 (b\bar{s}))$
$(D^0 (c\bar{u})$; $\bar{D}^0 (u\bar{c}))$

Continue Q.1

Neutron and antineutron do not mix because they are baryons.

The strange vector mesons K^{0*} & $\bar{K}^{0*}$ satisfy all of the above 4-requirements. However K^{0*} and $\bar{K}^{0*}$ can decay to lighter strange particles, e.g $\bar{K}^{0*} \to K\pi$, strongly with life time of the order 10^{-23}.

Numerical Analysis

- **Expressing the intensities in terms of a dimensionless parameter $\tau = t/\tau_S$, one finds that**

```
IK0 = 1/4 (Exp[-τ] + Exp[-τs τ/τL] + 2 Exp[-τ/2 - τs τ/(2 τL)] Cos[ΔM τ]);
```

Out[8]= $\frac{1}{4}\left(e^{-\tau} + e^{-0.00172727\,\tau} + 2\,e^{-0.500864\,\tau}\,\mathrm{Cos}[0.474\,\tau]\right)$

```
IK0bar = 1/4 (Exp[-τ] + Exp[-τs τ/τL] - 2 Exp[-τ/2 - τs τ/(2 τL)] Cos[ΔM τ]);
```

Out[13]= $\frac{1}{4}\left(e^{-\tau} + e^{-0.00172727\,\tau} - 2\,e^{-0.500864\,\tau}\,\mathrm{Cos}[0.474\,\tau]\right)$

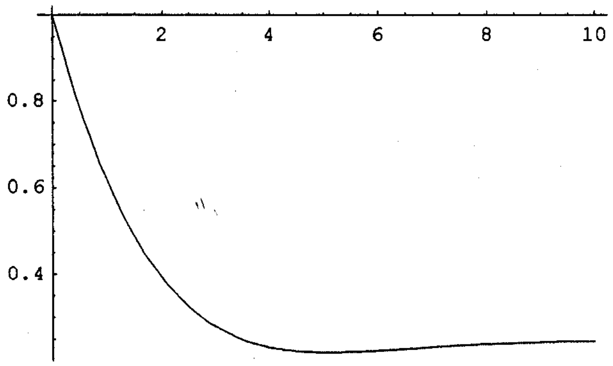
- **Define $\Delta M = \Delta m.\tau_S$**

- ## Part (1)

```
In[3]:= ΔM = .474;
In[4]:= τs = 0.893 * 10^-10;
In[5]:= τL = 0.517 * 10^-7;
```

- **Plot of IK0**

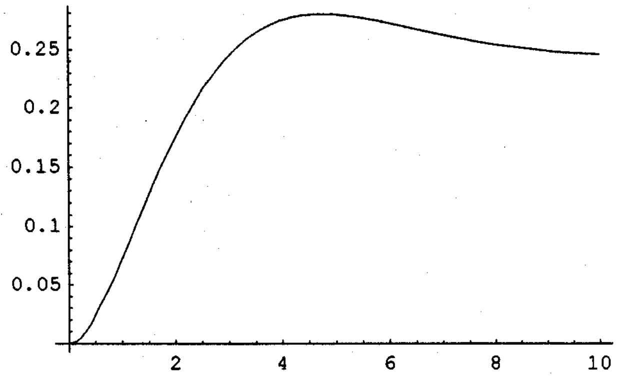
```
In[17]:= p1 = Plot[IK0, {τ, 0, 10}, PlotRange → All]
```



Out[17]= - Graphics -

- **Plot of IK0bar**

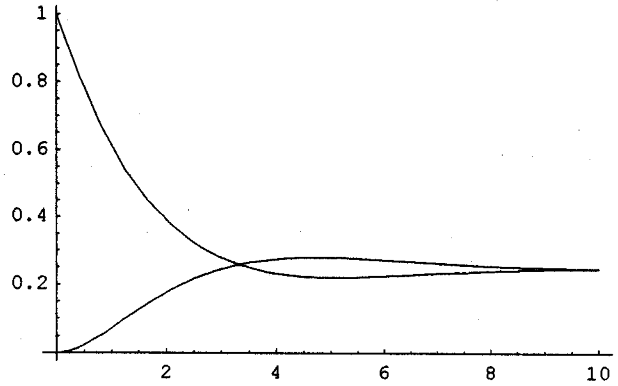
```
In[18]:= p2 = Plot[IK0bar, {τ, 0, 10}, PlotRange → All]
```




```
Out[18]= - Graphics -
```

◆ Plot of both IK0 and IK0bar

In[19]:= `Show[{p1, p2}]`



Out[19]= - Graphics -

Part (2):

Notice that $\Gamma = \frac{1}{\tau}$ and since $\Gamma_S >> \Gamma_L$,

one can take $\Delta\Gamma = \Gamma_S$. For (i) choose $\Delta m = 0.0474\,\Delta\Gamma$ and for (ii) choose $\Delta m = 4.74\,\Delta\Gamma$

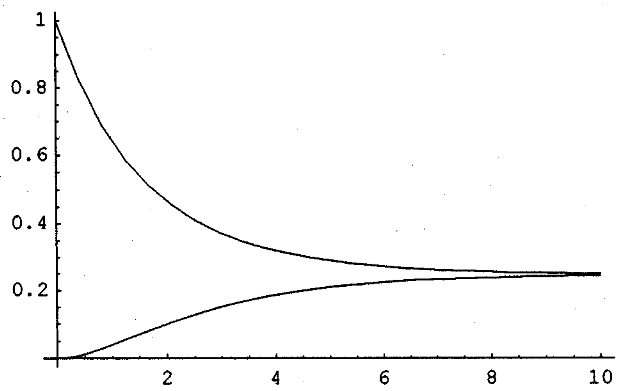
Case (i)

In[20]:= `ΔM = .0474;`

In[24]:= $IK0 = \frac{1}{4}\left(Exp[-\tau] + Exp\left[-\frac{\tau_S\,\tau}{\tau_L}\right] + 2\,Exp\left[-\frac{\tau}{2} - \frac{\tau_S\,\tau}{2\,\tau_L}\right] Cos[\Delta M\,\tau]\right);$

In[25]:= $IK0bar = \frac{1}{4}\left(Exp[-\tau] + Exp\left[-\frac{\tau_S\,\tau}{\tau_L}\right] - 2\,Exp\left[-\frac{\tau}{2} - \frac{\tau_S\,\tau}{2\,\tau_L}\right] Cos[\Delta M\,\tau]\right);$

In[26]:= **Plot[{IK0, IK0bar}, {τ, 0, 10}, PlotRange → All]**



Out[26]= - Graphics -

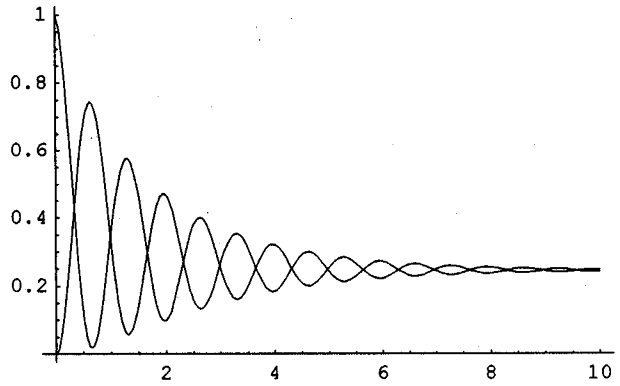
◆ Case (ii)

In[27]:= **ΔM = 4.74;**

In[28]:= $$\mathbf{IK0} = \frac{1}{4}\left(\mathrm{Exp}[-\tau] + \mathrm{Exp}\left[-\frac{\tau_S\,\tau}{\tau_L}\right] + 2\,\mathrm{Exp}\left[-\frac{\tau}{2} - \frac{\tau_S\,\tau}{2\,\tau_L}\right]\mathrm{Cos}[\Delta M\,\tau]\right);$$

In[29]:= $$\mathbf{IK0bar} = \frac{1}{4}\left(\mathrm{Exp}[-\tau] + \mathrm{Exp}\left[-\frac{\tau_S\,\tau}{\tau_L}\right] - 2\,\mathrm{Exp}\left[-\frac{\tau}{2} - \frac{\tau_S\,\tau}{2\,\tau_L}\right]\mathrm{Cos}[\Delta M\,\tau]\right);$$

In[30]:= **Plot[{IK0, IK0bar}, {τ, 0, 10}, PlotRange → All]**



Out[30]= - Graphics -

- **We see that for case (i) there is no oscillation, while in case (ii) there is.**

◆ Part (3):

For $B^0 - B^0$, one expect that $\Delta m > \Delta\Gamma$,

while for $D^0 - D^0$, one expect that $\Delta m < \Delta\Gamma$