Magnetic Kicker

The objective is to see whether a magnetic kicker is a possible alternative to a stripline as the dark current kicker.

From Lecture 2 of 2000 USPAS Tucson.AZ lecture, the loop integral
LoopIntegra[B . dl/(μ μ_0)] But the part of the field that is in AIR or Vaccum μ = 1 with the rest of the B in the iron approximately zero, only the B field that is
parallel to path and in AIR contributes and so μ = 1 and independent of the iron! The result is

$$n\,\text{Idipole} = B\,h/\mu_0$$

where h = half gap, $\mu_0 = 4\pi\, 10^{-7}$ H/m, B is in Teslas, h in metres.

Note that the USPAS explanation is rather lousy for why we have h/2. In reality because we have 2 wires in the magnet, we actually have B/2 per wire and so

nIdipole = B/2 gap/μ0 = B h/μ0

Let us assume that the dipole is OUTSIDE the beampipe. If we want to maintain a 2.5" ID, then from SentroTech
www.sentrotech.com/ceramictube.php
the OD is 2.75" so h is

```
In[1]:= h = 2.75 / 2. 2.54 10^-2; (*m*)
```

```
In[2]:= μ0 = 4 π 10^-7 ; (*H/m*)
```

Next we need to know how strong the B field is. From the calculations done using kicker1.nb, we need to deflect the beam at 5 MeV/c by about 20 mrad, i.e.

```
In[3]:= θ = 20 10^-3 ; (*rad*)
```

From formual of Bdl = θ E/c (See page 61 of Edwards and Syphers) we have

```
In[4]:= En = 5 10^6 ; (*V*)
        c = 3 10^8 ; (* m/s*)
```

```
In[5]:= Bdl = θ En / c // N
```

```
Out[5]= 0.000333333
```

in units of Tm. If the length of the kicker $dl = 25\, 10^{-2}$ m then we have a value for B.

```
In[6]:= dl = 25 10^-2 ;
```

```
In[7]:= B = Bdl / dl
```

```
Out[7]= 0.00133333
```

From here we can calculate the current for n turns, so NIdipole is

```
In[8]:=  NIdipole = B h / μ0

Out[8]=  37.0566
```

This is a very small value for current!

If we assume that we assume that we have a 6.25Ω system like the D48 kicker system in the Tevatron

```
In[9]:=  Z0 = 6.25; // N
```

then the voltage needed is

```
In[10]:=  VNdipole = NIdipole Z0 // N

Out[10]=  231.604
```

Again this is not ridiculously large, c.f. cables which can operate at 60kV.

Therefore, the peak power is

```
In[11]:=  Ppeak = NIdipole VNdipole

Out[11]=  8582.44
```

I will do the magnetic time constant two ways to see if they agree

Magnet Time Constant

There is a formula from Lecture 5 page 5 about the magnet time constant. This tells us how fast a pulsed magnet can ramp. The formula is
$\tau = \mu\mu_0 \, d^2 / \rho$ where
τ is the time constant, d is the half width of the laminations, ρ is the electrical resistivity of the yoke material.

If we assume that ρ is for ferrite

```
In[12]:=  μ = 1000;
          ρ = 10^4; (* Ω m *)
```

Assume that the thickness of the ferrite is 1 inch

```
In[14]:=  d = 25.4 10^-3 ; (* m *)
```

We have

In[15]:= $\tau = \mu\,\mu0\,d^2/\rho$ // N

Out[15]= 8.10732×10^{-11}

This should be sufficiently fast .08 ns!

Second way for calculating the time constant

The inductance of the magnet.
From the way we are going to configure the system, we will have 2 power supplies that look at each wire separately. And so each wire will have 1/2 the B field and so
LoopIntegral[B/2.ds]/I = L. From the expected configuration of the pulsed magnet system, the area is
B/2*(halfwidth*length)/I = L
B/2*h*dl/I = L
OR
L = μ0 dl/2

In[16]:= Ls = μ0 dl / 2. // N

Out[16]= 1.5708×10^{-7}

In[17]:= Ls = B h dl / 2. / NIdipole

Out[17]= 1.5708×10^{-7}

Capacitance can be calculated from $Z_0 = \mathrm{Sqrt}[\mathrm{Ls}/\mathrm{Cs}]$

In[18]:= Cs = Ls / Z_0^2

Out[18]= 4.02124×10^{-9}

Fill time comes from Sqrt[Ls Cs]

In[19]:= τf = Sqrt[Ls Cs]

General::spell1 : Possible spelling error: new symbol name "τf" is similar to existing symbol "τ". More…

Out[19]= 2.51327×10^{-8}

This does not agree with the formula for Magnet Time constant by a large factor! However, if we believe this formula because we can actually derive this, we can calculate the average power

Power

The peak power has been calculated previously as Ppeak

```
In[20]:= Ppeak
Out[20]= 8582.44
```

The repetition rate is 3MHz which is

```
In[21]:= Trep = 1 / (3 10^6) // N
Out[21]= 3.33333×10^-7
```

Therefore the average power is

```
In[22]:= Pave = Ppeak τf / Trep // N

General::spell1 :
 Possible spelling error: new symbol name "Pave" is similar to existing symbol "Save". More…

Out[22]= 647.1
```

which is really small!!!!

Stripline

Let us compare the power requirements of a stripline with 50Ω impedance. The formula for kick angle versus potential difference across the plate is:
$\theta k = \frac{2}{p\,d} Vk\,l$ using the variables defined above

```
In[23]:= dplates = 3 10^-2;

In[24]:= Vk = θ En dplates / (2 dl)
Out[24]= 6000
```

which means that each stripline sees Vk/2 volts

The peak power is (assuming 50Ω impedance) for 2 striplines is

```
In[25]:= Zs = 50;
```

In[26]:= $Pspeak = 2\left(\frac{Vk}{2}\right)^2 \Big/ Zs$ // N

```
General::spell1 :
 Possible spelling error: new symbol name "Pspeak" is similar to existing symbol "Ppeak". More…

Out[26]= 360000.
```

The average power comes from the fill time of the stripline which we assume to be 1 ns (to travel 25cm) from the launch point, and hold for about 1ns (actually much less), so

```
In[27]:= τsfill = 2 10^-9;
```

In[28]:= **Psave = τsfill / Trep Pspeak**

```
General::spell1 :
 Possible spelling error: new symbol name "Psave" is similar to existing symbol "Pave". More…
```

Out[28]= 2160.

Comparison between stripline and magnet

Ratio of power between stripline/magnet in terms of peak power is

In[29]:= **Pspeak / Ppeak**

Out[29]= 41.9461

Ratio of average power between stripline/magnet is

In[30]:= **Psave / Pave**

Out[30]= 3.33797

Ratio of fill time between stripline/magnet is

In[31]:= **τsfill / τf**

Out[31]= 0.0795775