```
STUDENT > # Compute force vs time for static eccentricity
STUDENT > # airgap flux density 59,000 lines per square inch
STUDENT > # radius to airgap = 12"
STUDENT > # length of airgap = 12"
STUDENT > # eccentricity parameter 0.1
STUDENT > # plots are in Newtons
STUDENT > # For 2 pole machine, there is dc component plut large
          2*LF component +
STUDENT > # as number of poles increase, 2*LF component decreases,
          dc remains the same
STUDENT >
STUDENT >
STUDENT > # Initialize stuff
STUDENT > restart;
STUDENT > pi:=evalf(Pi):
STUDENT > with(inttrans):
STUDENT >
STUDENT > dV:=R*g*h*dtheta;
```

$$dV := R\,g\,h\,dtheta$$

```
STUDENT >    #dV = differential volum element
STUDENT >    # g = gap length (function of theta)
STUDENT >    # h = axial height
STUDENT >    # R = radius
STUDENT >
STUDENT > # energy W = (1/2)  B^2 / mu0
STUDENT > #  Radial Force F = dW/dg with B held constant
STUDENT > #   F and g are functions of theta
STUDENT >
STUDENT > # Energy contained in differential volume element
STUDENT > dW := (1/2) * B^2/mu0 * dV;
```

$$dW := \frac{1}{2}\,\frac{B^2\,R\,g\,h\,dtheta}{\mu 0}$$

```
STUDENT >
STUDENT > # Radial attractive force associated with dV
STUDENT > dF:=diff(dW,g);
```

$$dF := \frac{1}{2}\,\frac{B^2\,R\,h\,dtheta}{\mu 0}$$

```
STUDENT > # dF varies with theta always radial outward direction.
          Magitude depends on B^2 (a function a theta)
STUDENT >
STUDENT > B_nominal:=Bmax*cos(w*t-theta*p/2);
STUDENT >
```

$$B\_nominal := Bmax \cos\left(w\,t - \frac{1}{2}\theta\,p\right)$$

```
STUDENT > g:=g0*(1-e*cos(theta));
```

$$g := g0\,(1 - e\cos(\theta))$$

```
STUDENT > B_actual:=B_nominal* (g0/g);
```

$$B\_actual := \frac{Bmax \cos\left(w\,t - \frac{1}{2}\theta\,p\right)}{1 - e\cos(\theta)}$$

```
STUDENT >
STUDENT > dF:=subs(B=B_actual,dF);
```

$$dF := \frac{1}{2}\frac{Bmax^2 \cos\left(w\,t - \frac{1}{2}\theta\,p\right)^2 R\,h\,dtheta}{(1 - e\cos(\theta))^2\,\mu 0}$$

```
STUDENT > subs_basic:={Bmax=59000*lpis,mu0=4*Pi*1E-7*Newton/(Amp^2)}
          ;
```

$$subs\_basic := \{Bmax = 59000\,lpis,\ \mu 0 = .4\;10^{-6}\frac{\pi\,Newton}{Amp^2}\}$$

```
STUDENT > dF_1:=(subs(subs_basic,dF));
```

$$dF\_1 := .4351250000\;10^{16}\frac{lpis^2 \cos\left(w\,t - \frac{1}{2}\theta\,p\right)^2 Amp^2\,R\,h\,dtheta}{(1 - e\cos(\theta))^2\,\pi\,Newton}$$

```
STUDENT > dF_1:=dF_1*(Gauss/(6.54*lpis))^2;
```

$$dF\_1 := .1017322242\;10^{15}\frac{\cos\left(w\,t - \frac{1}{2}\theta\,p\right)^2 Amp^2\,R\,h\,dtheta\,Gauss^2}{(1 - e\cos(\theta))^2\,\pi\,Newton}$$

```
STUDENT > dF_1:=dF_1*(Tesla/(1E4*Gauss))^2;
```

$$dF\_1 := .1017322242\;10^{7}\frac{\cos\left(w\,t - \frac{1}{2}\theta\,p\right)^2 Amp^2\,R\,h\,dtheta\,Tesla^2}{(1 - e\cos(\theta))^2\,\pi\,Newton}$$

```
STUDENT > dF_1:=dF_1*((Newton/Amp/meter) / Tesla)^2;
```

$$dF\_1 := .1017322242\;10^{7}\frac{\cos\left(w\,t - \frac{1}{2}\theta\,p\right)^2 Newton\,R\,h\,dtheta}{(1 - e\cos(\theta))^2\,\pi\,meter^2}$$

```
STUDENT >
STUDENT > # take the component in the x direcion
STUDENT > dF_x1:=dF_1*cos(theta);
```

$$dF\_x1 := .1017322242\ 10^{7}\,\frac{\cos\left(w\,t-\frac{1}{2}\,\theta\,p\right)^{2}\,Newton\,R\,h\,dtheta\,\cos(\theta)}{(1-e\,\cos(\theta))^{2}\,\pi\,meter^{2}}$$

```
STUDENT >
STUDENT > subs_dimension:={R=12/40*meter,h=12/40*meter};
```

$$subs\_dimension := \left\{R=\frac{3}{10}\,meter,\ h=\frac{3}{10}\,meter\right\}$$

```
STUDENT > dF_x1:=subs(subs_dimension,dF_x1);
```

$$dF\_x1 := 91559.00178\,\frac{\cos\left(w\,t-\frac{1}{2}\,\theta\,p\right)^{2}\,Newton\,dtheta\,\cos(\theta)}{(1-e\,\cos(\theta))^{2}\,\pi}$$

```
STUDENT > dF_x1:=dF_x1/Newton;
```

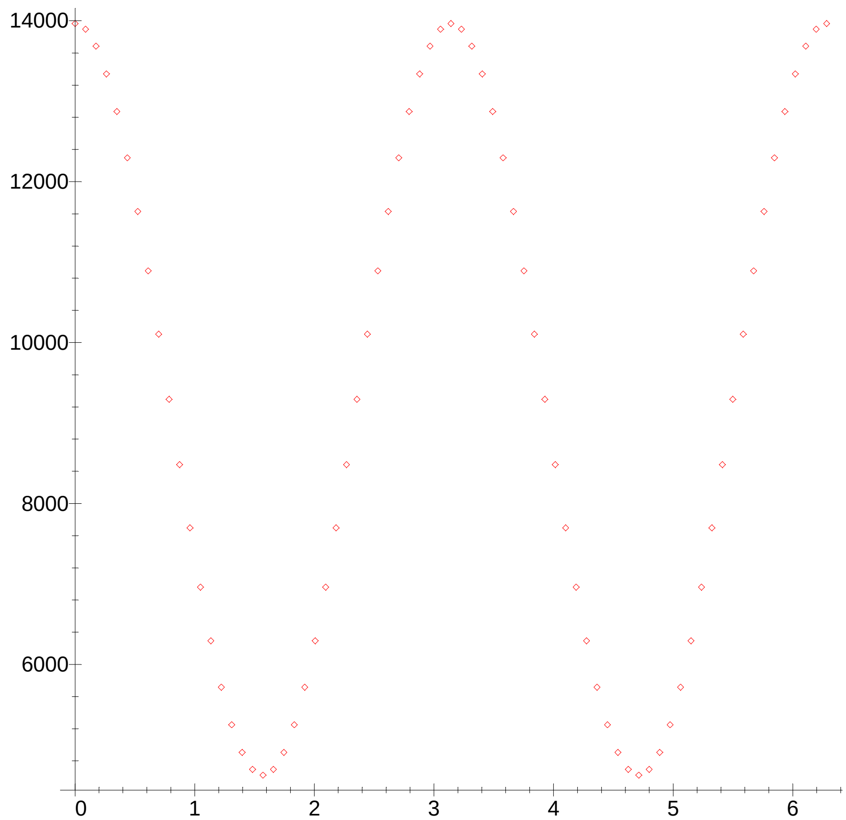
$$dF\_x1 := 91559.00178\,\frac{\cos\left(w\,t-\frac{1}{2}\,\theta\,p\right)^{2}\,dtheta\,\cos(\theta)}{(1-e\,\cos(\theta))^{2}\,\pi}$$

```
STUDENT > # *** now Force will be in Newtons ***
STUDENT >
STUDENT > # Set up parameters of plot
STUDENT > with(plots):
STUDENT > N:=72:  # Number of points in plot
STUDENT > dwt:=2*Pi/N: # delta-wt for plotting
STUDENT > dF_x1n:=subs(w*t=n*dwt,dF_x1); # function of discrete n
```

$$dF\_x1n := 91559.00178\,\frac{\cos\left(\frac{1}{36}\,n\,\pi-\frac{1}{2}\,\theta\,p\right)^{2}\,dtheta\,\cos(\theta)}{(1-e\,\cos(\theta))^{2}\,\pi}$$

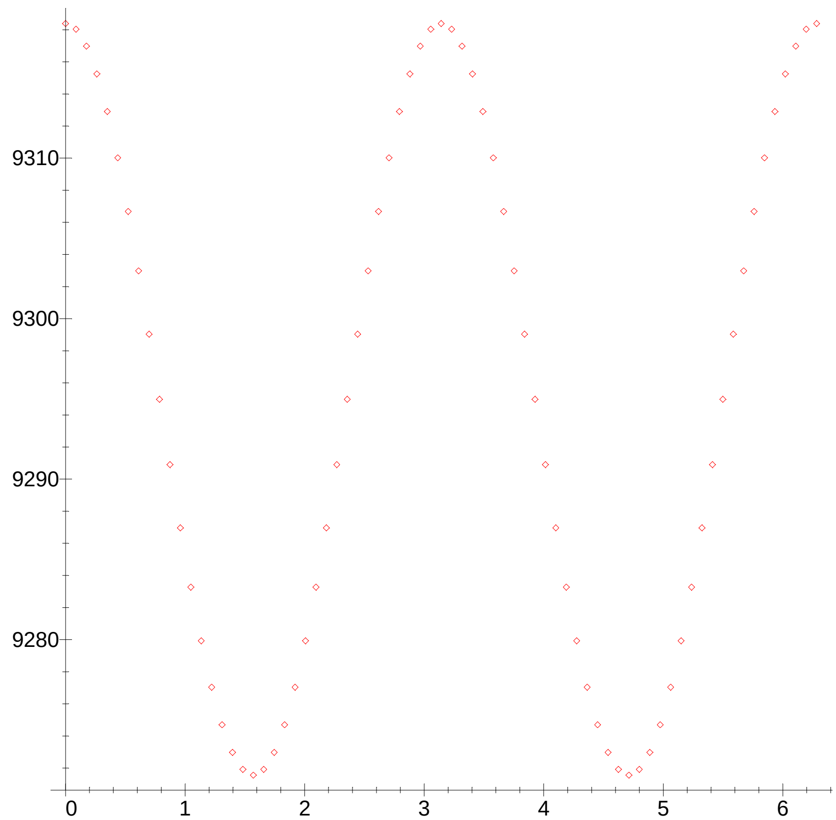
```
STUDENT >
STUDENT > # look at 2-pole machine
STUDENT > pointplot({seq([n*dwt,evalf(Int(subs({p=2,e=0.1},dF_x1n/dt
          heta),theta=0..2*pi))],n=0..N)},title='TwoPole_Net_Force_i
          n_X_direction_vs_wt',color=red);
```

TwoPole_Net_Force_in_X_direction_vs_wt

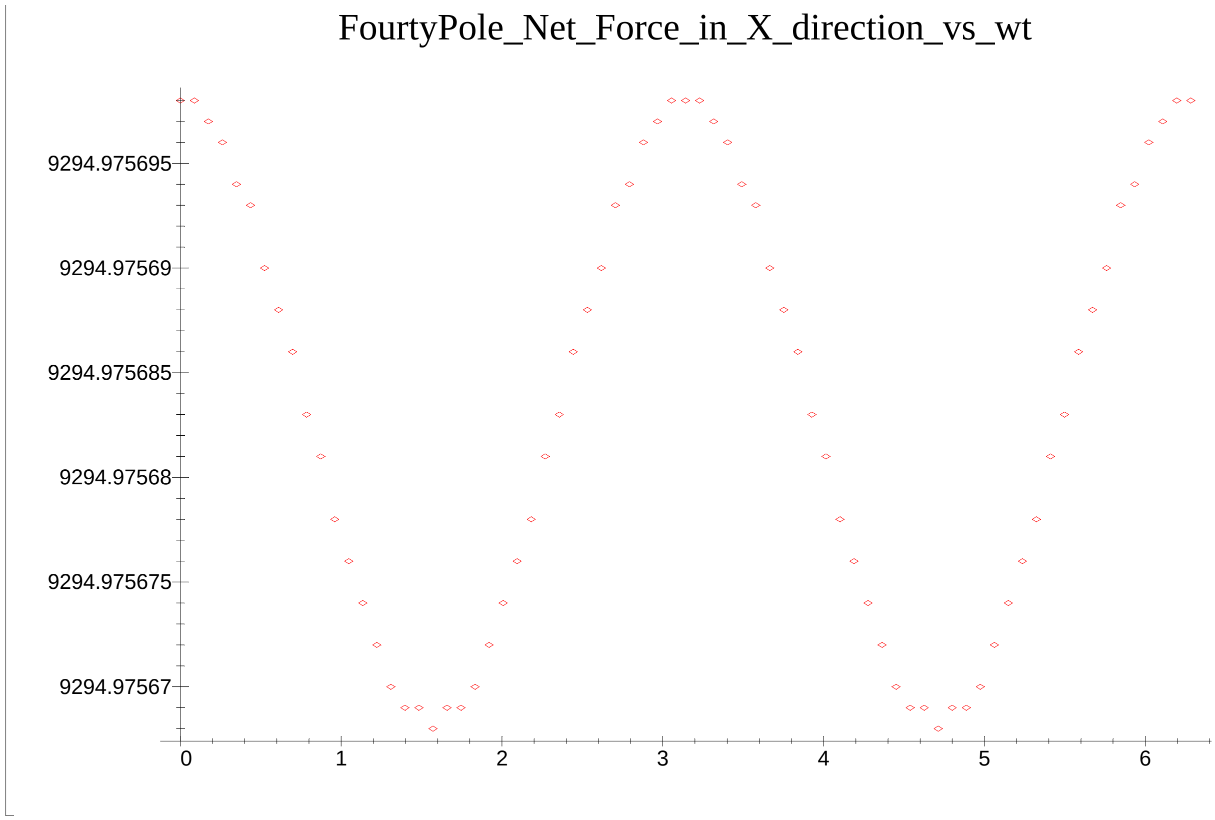



```
STUDENT > # Look at 4-pole machine
STUDENT >
STUDENT > pointplot({seq([n*dwt,evalf(Int(subs({e=0.1,p=4},dF_x1n/dt
          heta),theta=0..2*pi))],n=0..N)},title='FourPole_Net_Force_
          in_X_direction_vs_wt',color=red);
```

FourPole_Net_Force_in_X_direction_vs_wt




```
STUDENT >
STUDENT >
STUDENT > # look at 40 pole machine
STUDENT >
STUDENT > pointplot({seq([n*dwt,evalf(Int(subs({e=0.1,p=40},dF_x1n/d
          theta),theta=0..2*pi))],n=0..N)},title='FourtyPole_Net_For
          ce_in_X_direction_vs_wt',color=red);
```



STUDENT >
STUDENT >
STUDENT >