

## Conjugate Gradient method

```
 $k = 0 ; u^0 = 0 ; r^0 = f$   
for  $k = 1, 2, \dots$ do  
  if  $k = 1$  do  
     $p^1 = r^0$   
  else  
     $\beta_k = \frac{(r^{k-1})^T r^{k-1}}{(r^{k-2})^T r^{k-2}}$   
     $p^k = r^{k-1} + \beta_k p^{k-1}$   
  end if  
   $\alpha_k = \frac{(r^{k-1})^T r^{k-1}}{(p^k)^T A p^k}$   
   $u^k = u^{k-1} + \alpha_k p^k$   
   $r^k = r^{k-1} - \alpha_k A p^k$   
end for
```

## Preconditioned Conjugate Gradient method

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```
 $k = 0 ; u^0 = 0 ; r^0 = f$   
for  $k = 1, 2, \dots$  do  
   $z^{k-1} = M^{-1}r^{k-1}$   
  if  $k = 1$  do  
     $p^1 = z^0$   
  else  
     $\beta_k = \frac{(r^{k-1})^T z^{k-1}}{(r^{k-2})^T z^{k-2}}$   
     $p^k = z^{k-1} + \beta_k p^{k-1}$   
  end if  
   $\alpha_k = \frac{(r^{k-1})^T z^{k-1}}{(p^k)^T A p^k}$   
   $u^k = u^{k-1} + \alpha_k p^k$   
   $r^k = r^{k-1} - \alpha_k A p^k$   
end for
```







