Answers to Homework II

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1 Question 3

1.1 Q1

I downloaded the data from `http://hepdata.cedar.ac.uk/pdf/pdf3.html`. I used group CTEQ45 and set cteq5m. I used $Q^2 = 100\text{GeV}^2$. I chose particle type all to get PDFs for $u, \bar{u}, d, \bar{d}, s, c, b, g$. The site did not have information on $\bar{s}, \bar{c}, \bar{b}$ so I assume they have the same PDFs as their antiparticles. Virtual particles are created in particle-antiparticle pairs. The PDFs, $f(x, Q^2)$, were given as $g(x, Q^2) = xf(x, Q^2)$. Integrating these functions gives the mean energy fraction for that particle type.

$$\frac{E_i}{E_{proton}} = \int_0^1 x f_i(x, Q^2) \mathrm{d}x = \int_0^1 g_i(x, Q^2) \mathrm{d}x \tag{1}$$

This has been calculated numerically and the result is seen in Table 1.
Integrating $f_i(x, Q^2)$ gives the number of particle i present in the proton. But this diverges in the low energy limit. What can be calculated instead is the asymetry in number between particle and antiparticle.

$$n_i = \int_0^1 x(g_i(x, Q^2) - g_{\bar{i}}(x, Q^2)) \mathrm{d}x \tag{2}$$

This is 0 by assumption for s, c, b but not for u, d. This has been calculated numerically and the result is seen in Table 1. The total charge and energy has been calculated using this and the result is seen in Table 1.

1.2 Q2

I varied the value of Q^2 and the results are seen in Table 2, 3, 1, 4. The results are the same but the precision of the numerical integral goes down as the PDFs become more peaked at lower energy for the high Q^2-values.

1.3 Q3

The antiproton is the antiparticle to the proton. The PDFs are the same but for the antiparticles of the partons. So the u PDF is that of $\bar{u}$ and so on.

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Table 1: Results for $Q^2 = 100\text{GeV}^2$

Parton	t asymmetry	Charge contribution	Energy contribution
u	1.9993	1.3329	0.2601
d	1.0059	-0.3353	0.1308
$\bar{u}$	-	-	0.0323
$\bar{d}$	-	-	0.0392
$s, \bar{s}$	-	-	0.0249
$c, \bar{c}$	-	-	0.0147
$b, \bar{b}$	-	-	0.0049
g	-	-	0.4615
Total	3.0052	0.9976	1.0129

Table 2: Results for $Q^2 = 0.001\text{GeV}^2$

Parton	t asymmetry	Charge contribution	Energy contribution
u	1.9999	1.3332	0.3791
d	1.0004	-0.3335	0.1769
$\bar{u}$	-	-	0.0229
$\bar{d}$	-	-	0.0337
$s, \bar{s}$	-	-	0.0113
$c, \bar{c}$	-	-	0.0000
$b, \bar{b}$	-	-	0.0000
g	-	-	0.3654
Total	3.0003	0.9998	1.0006

The u and d-quarks have similar masses and the electromagnetic interaction is weak compared to the strong interaction which is isospin invariant. $u, \bar{u}$ and $d, \bar{d}$ can then be interchanged assuming isospin invariance and the neutron PDFs are obtained.

2 Question 4

The integral in the handwritten notes has been calculated numerically for different invariant masses and proton-proton center of mass energy. The result is seen in Figure 1.

Table 3: Results for $Q^2 = 1\text{GeV}^2$

Parton	t asymmetry	Charge contribution	Energy contribution
u	1.9999	1.3332	0.3791
d	1.0004	-0.3335	0.1769
$\bar{u}$	-	-	0.0229
$\bar{d}$	-	-	0.0337
$s, \bar{s}$	-	-	0.0113
$c, \bar{c}$	-	-	0.0000
$b, \bar{b}$	-	-	0.0000
g	-	-	0.3654
Total	3.0003	0.9998	1.0006

Table 4: Results for $Q^2 = 10000\text{GeV}^2$

Parton	t asymmetry	Charge contribution	Energy contribution
u	1.9991	1.3327	0.2210
d	0.9997	-0.3332	0.1151
$\bar{u}$	-	-	0.0356
$\bar{d}$	-	-	0.0412
$s, \bar{s}$	-	-	0.0295
$c, \bar{c}$	-	-	0.0213
$b, \bar{b}$	-	-	0.0132
g	-	-	0.4763
Total	2.9988	0.9995	1.0173

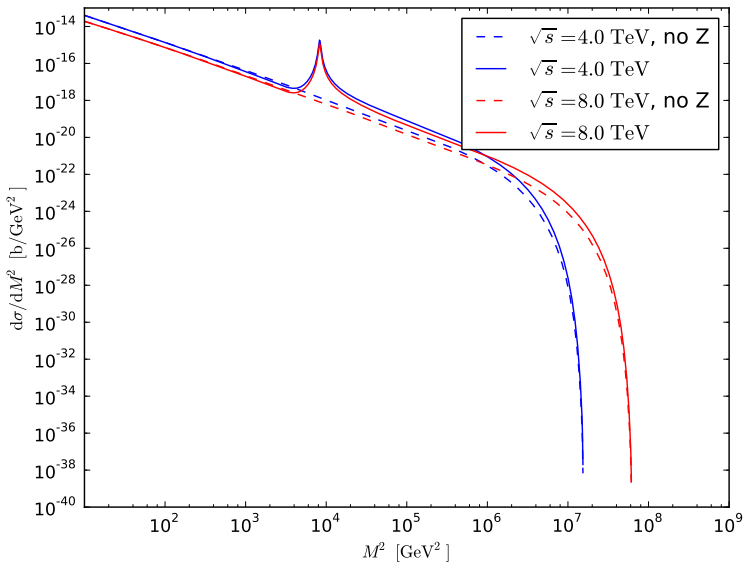

Figure 1: Differential cross-section calculated by numerical integration.