Date of Lab 10/10/2018 Date of Submission 10/17/2018

Laboratory Report

Title Forces in Equilibrium

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Summary

In this experiment, I examined the forces in Equilibrium by using a force table. First, I put different weights in 3 or 4 hangers and balanced them by letting the ring be at the center. Also, I put different weights in 4 hangers and did not balance them. Then, I put the results of the 3 experiment into the graph and state Net Force by using the parallelogram method and head-to-tail method, and math-method. I learned that the net force made from several forces in equilibrium is zero, although there were some errors. I understand the equation($\vec{A} + \vec{B} + \vec{C} + \vec{D} = 0$)

· Meet a deadline · Write logically · Write clearly · Write with your own words

Teacher's Comments

Good drawings and analysis. Scales in graphs and the summary tables are also good. A wrong expression of the angle in the math method.

1	2	3	4	5	6	7	8	9
Due	Summary	Intro.	Method.	Results	Table/Fig.	Discussion	Clearness	General

* Use this form as a cover sheet.

* Submit your reports by the seventh day after your lab.

<Results>

Test 1 : 3 forces are balanced

Length of an arrow 1N=4cm

Table 1	Mass of Weight (kg)	Force (N)	Arrow (cm)	Angle (°)
A	0.2	1.96	7.84	0°
B	0.1	0.98	3.92	126°
C	0.15	1.47	5.88	219°

Newton's Second Law: Force=Mass × gravitational acceleration

=Mass × 9.80m/s^2

Test 2 : 4 forces are balanced

Length of an arrow 1N=4cm

Table 2	Mass of Weight (kg)	Force (N)	Arrow (cm)	Angle (°)
A	0.25	2.45	9.80	0°
B	0.1	0.98	3.92	102°
C	0.2	1.96	7.84	168°
D	0.15	1.47	5.88	254°

Newton's Second Law: Force=Mass × gravitational acceleration

=Mass × 9.80m/s^2

Test 3 : 4 forces are not balanced

Length of an arrow   1N=4cm

Table 3	Mass of Weight (kg)	Force (N)	Arrow (cm)	Angle (°)
A	0.25	2.45	9.80	0°
B	0.1	0.98	3.92	45°
C	0.2	1.96	7.84	182°
D	0.15	1.47	5.88	254°

Newton's Second Law: Force=Mass × gravitational acceleration

=Mass × $9.80 m/s^2$

Table 4 : Math Method of Experiment 1

Ex 1	Force	θ	Fx= Fcosθ	Fy= Fsinθ
Unit	[N]	[°]	[N]	[N]
A	1.96	0°	1.960	0.000
B	0.98	129°	-0.617	0.762
C	1.47	219°	-1.142	-0.925
		ΣFx, ΣFy	0.201	-0.163

$F=\sqrt{(\Sigma Fx)^2+(\Sigma Fy)^2}=\sqrt{(0.201)^2+(-0.163)^2}=0.259$ <u>F=0.259N</u>

OK

$\theta=\tan^{-1}(\Sigma Fy/\Sigma Fx)=\tan^{-1}(-0.613)/(0.201)=-39°$ <u>θ=-39°</u>

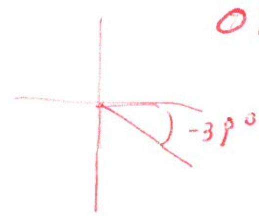


Table 5 : Math Method of Experiment 2

Ex 1	Force	θ	$F_x = F\cos\theta$	$F_y = F\sin\theta$
Unit	[N]	[°]	[N]	[N]
A	2.45	0°	2.45	0.000
B	0.98	102°	-0.204	0.959
C	1.96	168°	-1.917	0.408
D	1.47	254°	-0.405	-1.413
		ΣF_x, ΣF_y	-0.076	-0.100

$F=\sqrt{(\Sigma F_x)^2+(\Sigma F_y)^2}=\sqrt{(-0.076)^2+(-0.100)^2}=0.126$ <u>F=0.126N</u>

$\theta=\tan^{-1}(\Sigma F_y/\Sigma F_x)=\tan^{-1}(-0.076)/(0.100)=-37.2°$ <u>θ=-37.2°</u>

37.2°

180°+37.2°=217.2°

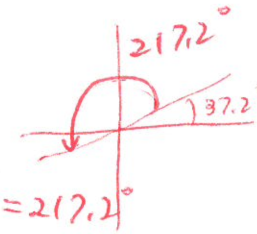


Table 6 : Math Method of Experiment 3

Ex 1	Force	θ	$F_x = F\cos\theta$	$F_y = F\sin\theta$
Unit	[N]	[°]	[N]	[N]
A	2.45	0°	2.45	0.000
B	0.98	45°	0.693	0.693
C	1.96	182°	-1.959	-0.068
D	1.47	254°	-0.405	-1.413
		ΣF_x, ΣF_y	0.779	-0.788

$F=\sqrt{(\Sigma F_x)^2+(\Sigma F_y)^2}=\sqrt{(0.779)^2+(-0.788)^2}=1.108$ <u>F=1.108N</u>

$\theta=\tan^{-1}(\Sigma F_y/\Sigma F_x)=\tan^{-1}(-0.779)/(-0.788)=-44.7$ <u>θ=-44.7°</u>

OK

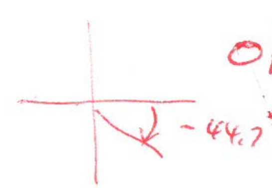


Fig.1 Parallelogram method of Experiment 1

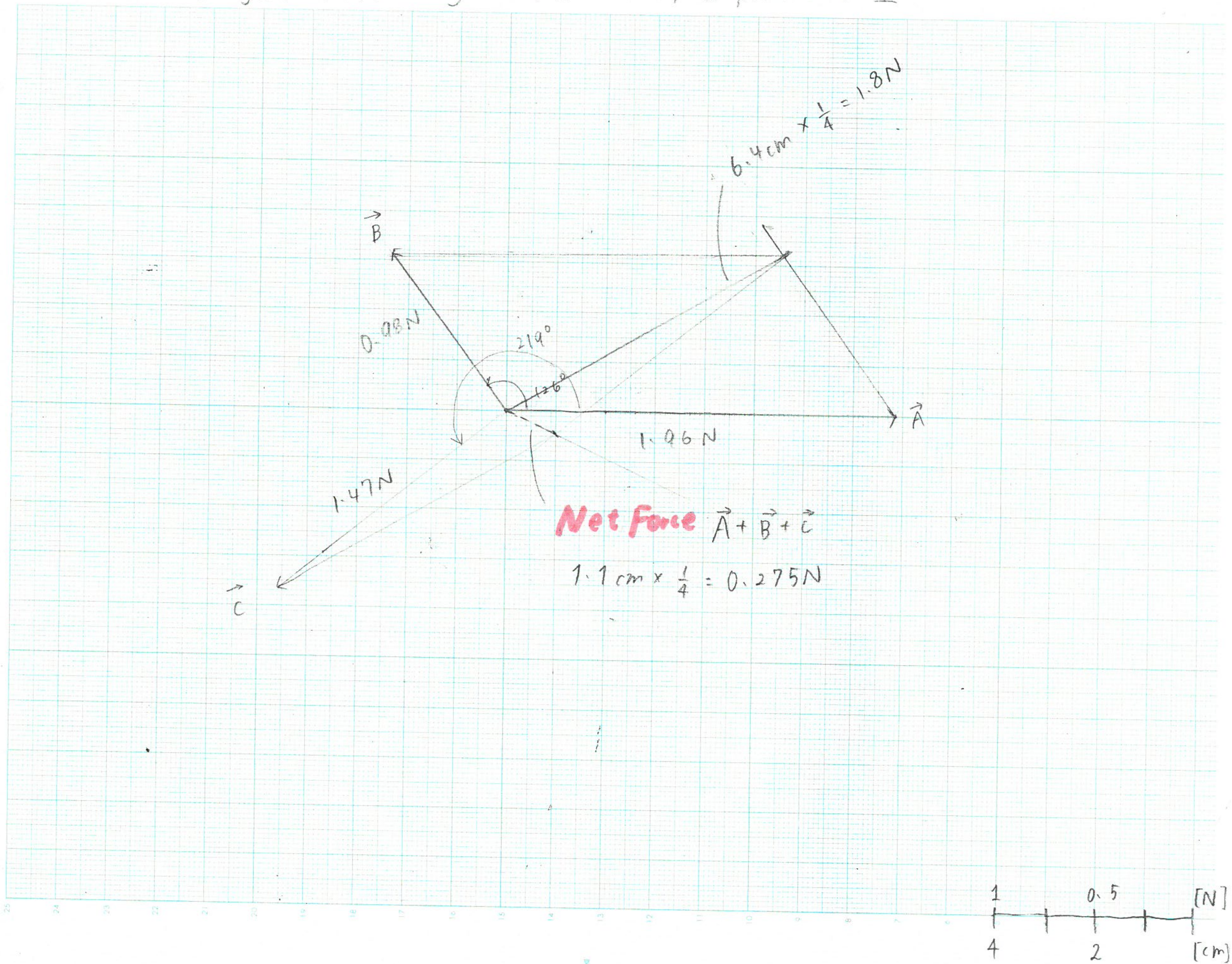


Fig. 2 Head-to-tail method of Ex. 1

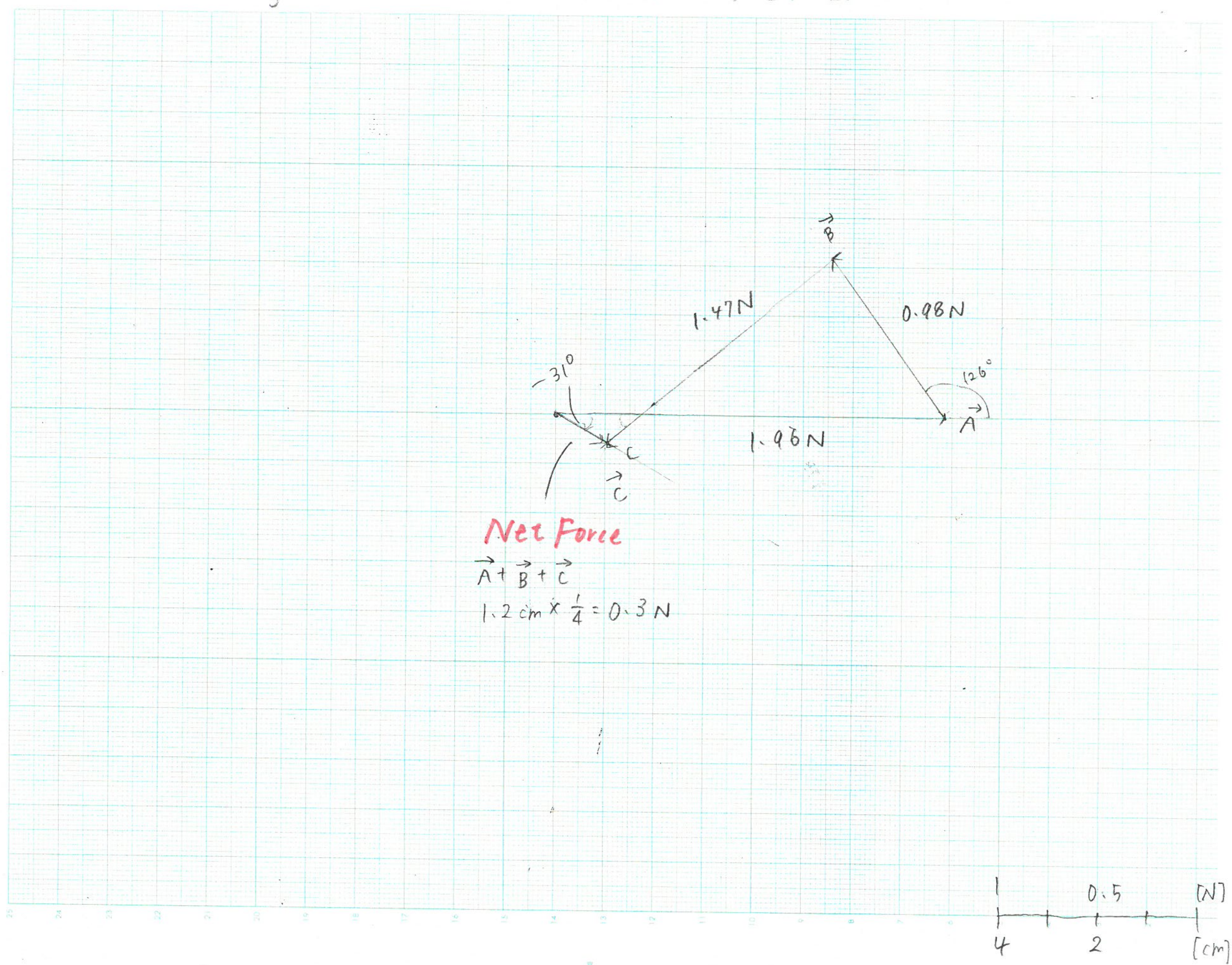


Fig. 3 Parallelogram method of Experiment 2

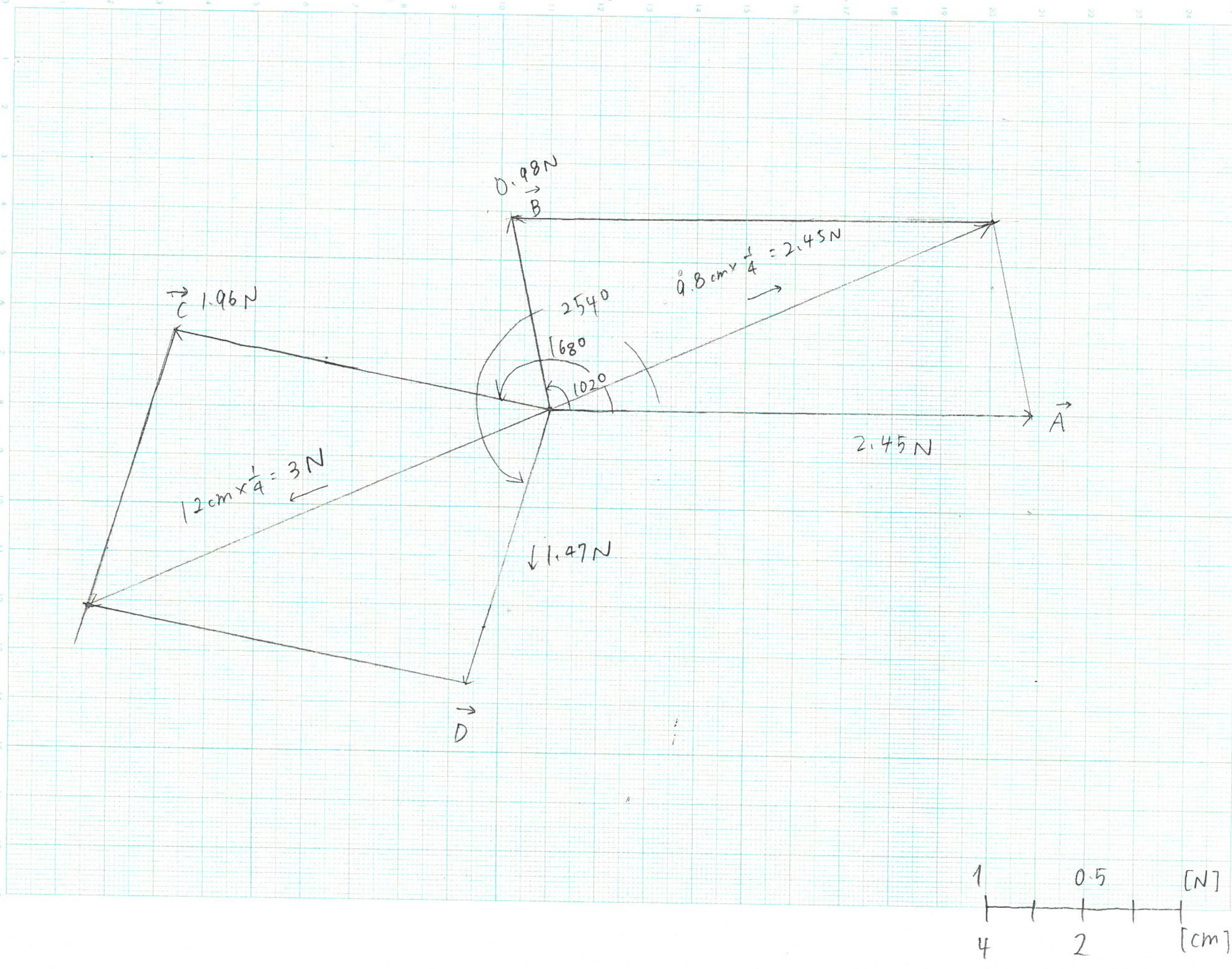


Fig. 4 Head-to-tail method of Experiment 2

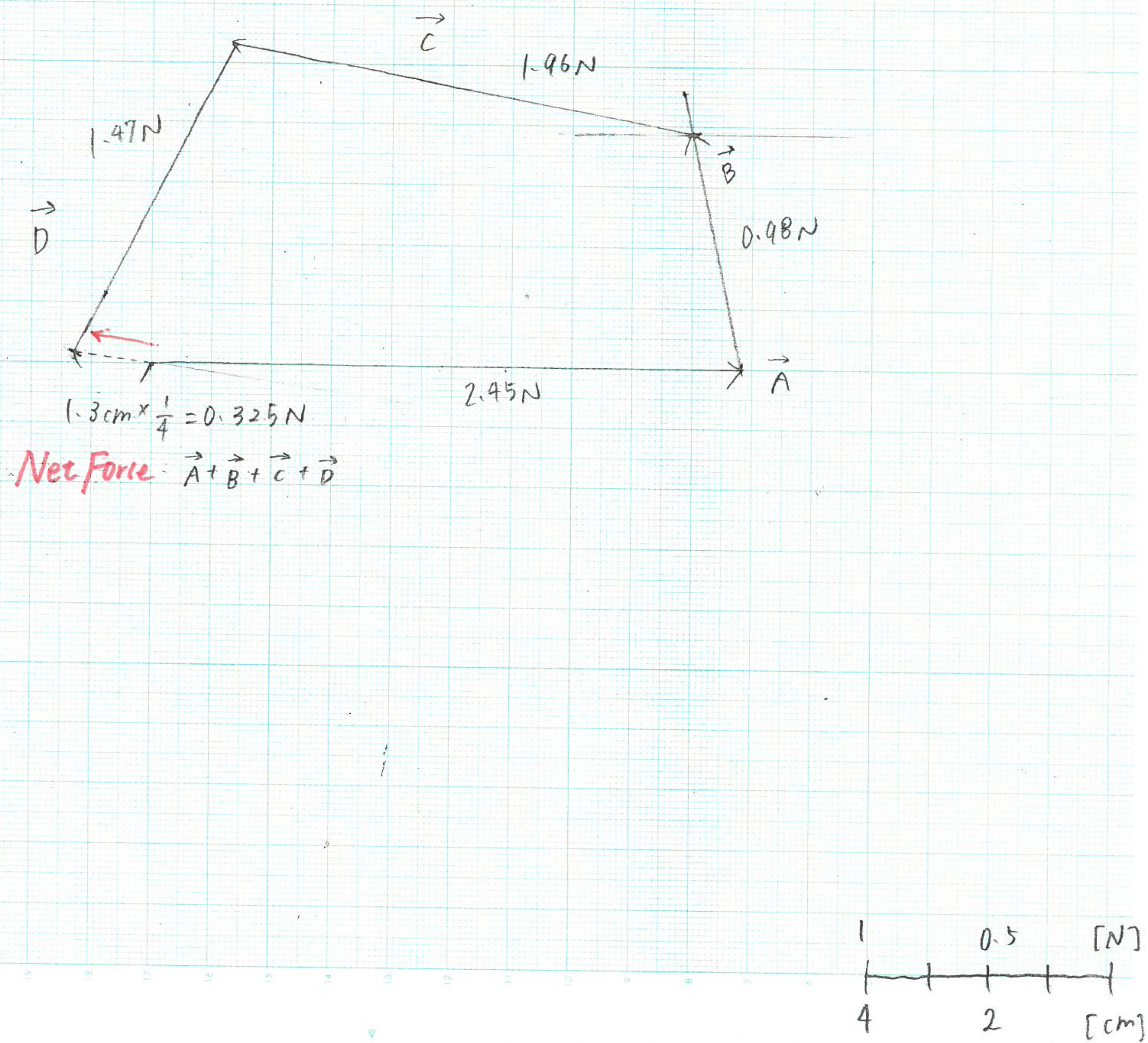


Fig. 5 Parallelogram Method of Experiment 3

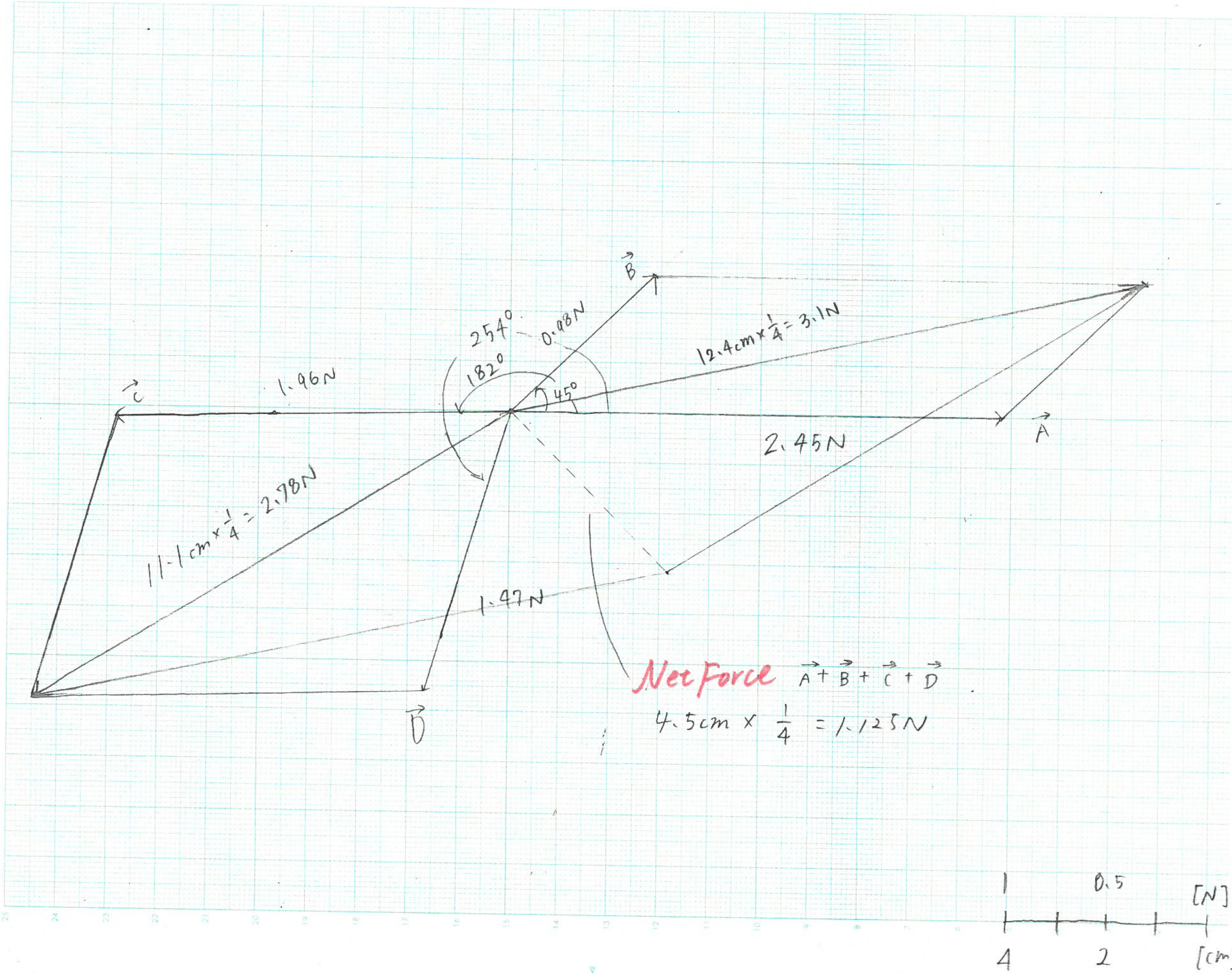
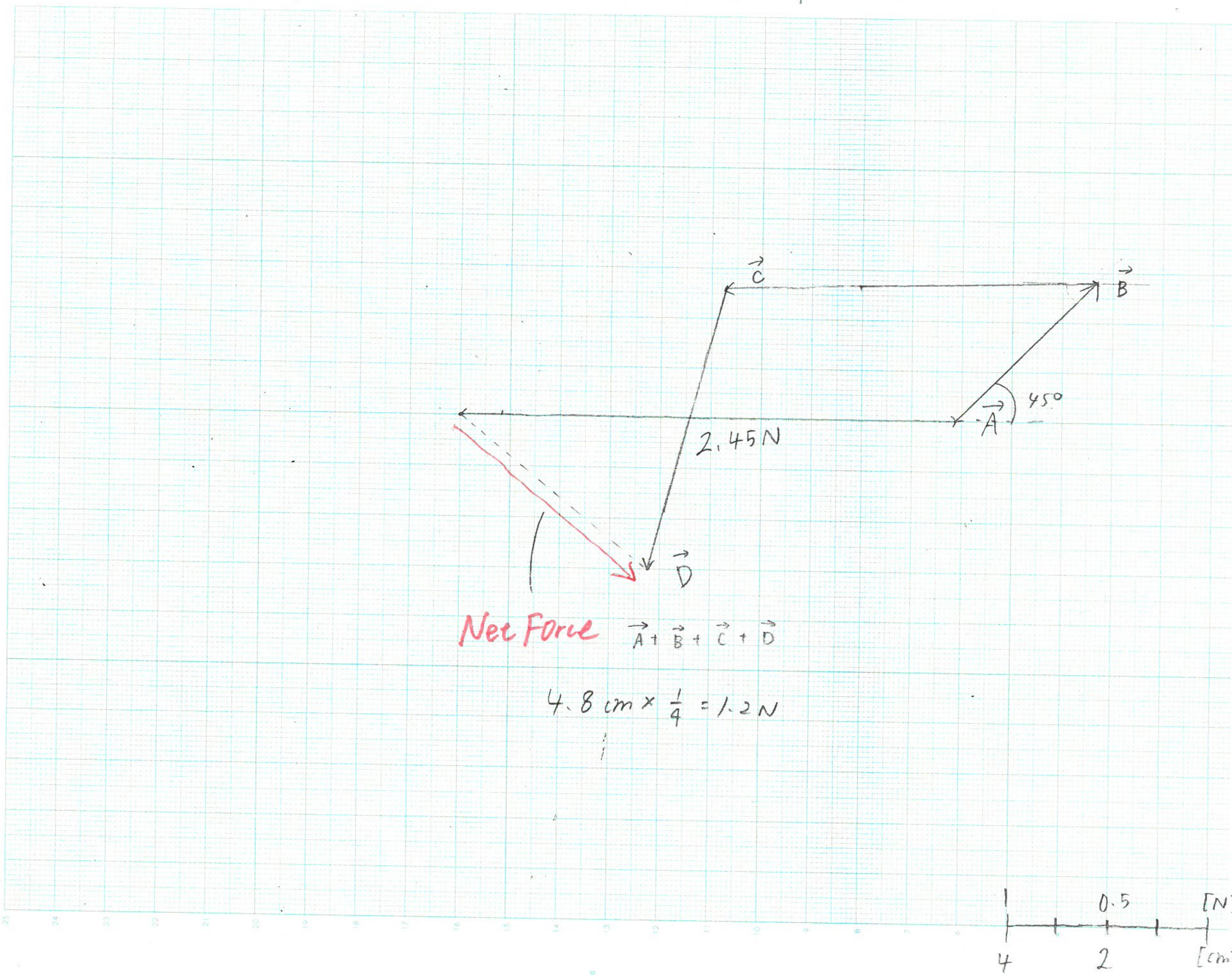


Fig. 6 Head - to - tail Method of Experiment 3



<Discussion>

(1) Experiment 1

○As you can see from Fig.1, the length of A is almost **same length** with B+C and the two lines are almost on **opposite side** of A. There is a little difference between the force of line C and the diagonal of parallelogram, so you can make a parallelogram by using the 2 lines and state the **Net Force**.(=0.275N)

○As you can see from Fig.2, the tail point of C almost reach the origin point of A. However, It doesn't completely reach the tail point C, so you can state **Net force.**(=0.3N)

○From table 4, the value of net force is almost 0. (0.259N)

○As you can see from Fig 1, Fig 2 and Table 5, the 3 value of net force that you state in 3 different ways are almost same number and close to zero.

Because of these reasons, the 3 forces are **balanced** and the equation is made.

$$* \vec{A} = -(\vec{B}+\vec{C})$$

$$* \vec{A} + \vec{B} + \vec{C} = 0$$

(2)Experiment 2

○As you can see from Fig.3, the length of $\vec{A}$ is almost **same length** with $\vec{B}+\vec{C}+\vec{D}$ and the two lines are almost on **opposite side** of $\vec{A}$. Although there is a difference between force of $\vec{A}$ (2.45N)and B+C+D(3N), the two diagonals of parallelogram are too straight and the net force doesn't appear.

○As you can see from Fig.4, the tail point of $\vec{D}$ almost reach the origin point of $\vec{A}$. However, line $\vec{D}$ doesn't completely reach the point $\vec{A}$, so you can state **Net force.** (=0.325N)

○From table 5, the value of net force is almost 0. (0.126N)

○As you can see from Fig 4 and Table 5, the 2 value of net force that you state in 2 different ways are almost same number and close to zero.

Because of these reasons, the 3 forces are **balanced** and the equation is made.

$$* \vec{A} = -(\vec{B}+\vec{C}+\vec{D})$$

$$* \vec{A} + \vec{B} + \vec{C} + \vec{D} = 0$$

(3) Experiment 3

○As you can see from Fig.5, the length of $\vec{A}$ is not same as length of $\vec{B}+\vec{C}+\vec{D}$. Also $\vec{A}$ is not on opposite side with B. Also there is difference between two diagonals of the parallelograms so you can state Net Force by making a parallelogram.(F=1.125N)

○As you can see from Fig.6, the tail point of $\vec{D}$ doesn't reach the origin point of $\vec{A}$, so you can state Net Force by drawing a line from the tail point $\vec{D}$ to the origin point $\vec{A}$.(F=1.2)

○According to table 6, the value of net force is not close to zero.(1.108N)

○From Fig 5, Fig 6 and Table 6, the four forces are not balanced and the equations does not hold.

$$* \vec{A} = -(\vec{B}+\vec{C}+\vec{D})$$

$$* \vec{A} + \vec{B} + \vec{C} + \vec{D} = 0$$

(4) Comparison

<Experiment 1>

Ex.1	F	θ
Parallelogram method	0.275N	-26°
Head-to-tail method	0.3N	-31°
Math method	0.259N	-39°

This results agree well.

Ex.2	F	θ
Parallelogram method	couldn't state	×
Head-to-tail method	0.325N	-9°
Math method	0.126N	-37.2°

※The net force of Parallelogram method was not stated because the two diagonals of parallelogram are too straight and the net force doesn't appear.

This result doesn't agree well.

Ex.3	F	θ
Parallelogram method	1.125N	-43°
Head-to-tail method	1.2N	-40°
Math method	1.108N	-44.7°

This result agree well.

There are differences of measured net forces, because ...
* I considered that there was a frictional force.
* I considered that the difference occured when I rounded off the values.

<Conclusion>

The net force made from several forces (In this lab, 3 or 4 forces) at equilibrium is zero. This show the equation below.

$$\vec{A}+\vec{B}+\vec{C}+\vec{D}=0$$

<Opinion>

Through this experiment, I learned how to state net force by drawing parallelogram method and head-to-tail method and using math method. Also I was able to understand the state of $\vec{A}+\vec{B}+\vec{C}+\vec{D}=0$ although I didn't understand well before this lab. This experiment helped me to learn forces in equilibrium.