Applied Mathematics Exercises for 15. and 16. of February

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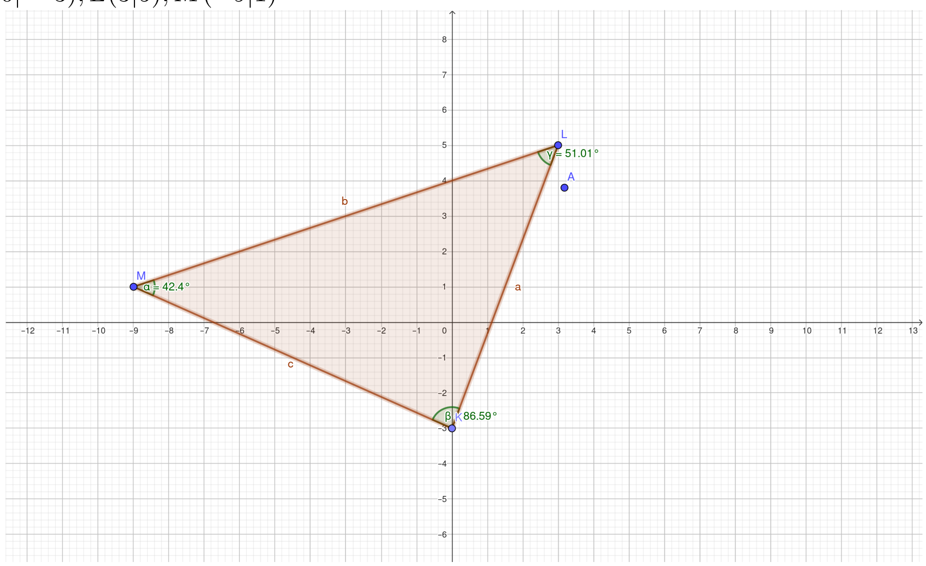
Contents

1 8.23

1.1 b)

Requirement: Calculate the size of the interior angles of the triangle with the given vertices.
$K(0|-3), L(3|5), M(-9|1)$



Definitions:

$$\vec{a} = \vec{KL} \tag{1}$$
$$\vec{b} = \vec{LM} \tag{2}$$
$$\vec{c} = \vec{MK} \tag{3}$$

Exercises:

$$\vec{a} = \begin{pmatrix} 3 \\ 5 \end{pmatrix} - \begin{pmatrix} 0 \\ -3 \end{pmatrix} \tag{4}$$

$$\vec{a} = \begin{pmatrix} 3 \\ 8 \end{pmatrix} \tag{5}$$

$$\vec{b} = \begin{pmatrix} -9 \\ 1 \end{pmatrix} - \begin{pmatrix} 3 \\ 5 \end{pmatrix} \tag{6}$$

$$\vec{b} = \begin{pmatrix} -12 \\ -4 \end{pmatrix} \tag{7}$$

$$\vec{c} = \begin{pmatrix} 0 \\ -3 \end{pmatrix} - \begin{pmatrix} -9 \\ 1 \end{pmatrix} \tag{8}$$

$$\vec{c} = \begin{pmatrix} 9 \\ -4 \end{pmatrix} \tag{9}$$

$$\cos(\alpha) = \frac{\vec{b} \cdot -\vec{c}}{|\vec{b}| * |\vec{c}|} \tag{10}$$

$$\cos(\alpha) = \frac{\begin{pmatrix} -12 \\ -4 \end{pmatrix} \cdot - \begin{pmatrix} 9 \\ -4 \end{pmatrix}}{\sqrt{12^2 + 4^2} * \sqrt{9^2 + 4^2}} \tag{11}$$

$$\cos(\alpha) = \frac{92}{124.579292019} \tag{12}$$

$$\alpha = \arccos(0.738485493929) \tag{13}$$

$$\alpha = 42.39744^\circ \tag{14}$$

$$\cos(\beta) = \frac{\vec{a} \cdot -\vec{c}}{|\vec{a}| * |\vec{c}|} \tag{15}$$

$$\cos(\beta) = \frac{\begin{pmatrix} 3 \\ 8 \end{pmatrix} \cdot - \begin{pmatrix} 9 \\ -4 \end{pmatrix}}{\sqrt{3^2 + 8^2} * \sqrt{9^2 + 4^2}} \tag{16}$$

$$\cos(\beta) = \frac{5}{84.1486779456} \tag{17}$$

$$\beta = \arccos(0.0594186399842) \tag{18}$$

$$\beta = 86.59356^\circ \tag{19}$$

$$\gamma = 180^\circ - (\alpha + \beta) \tag{20}$$

$$\gamma = 180^\circ - (42.39744^\circ + 86.59356^\circ) \tag{21}$$

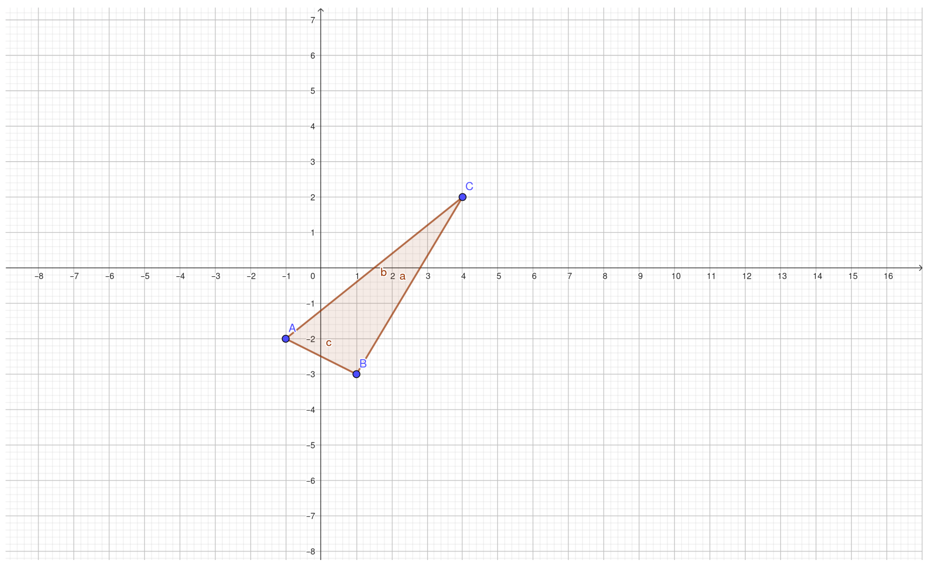
$$\gamma = 51.00901^\circ \tag{22}$$

2 8.26

2.1 b)

Specification: Check if these points form a right angled triangle:

$$A(-1|-2) \qquad B(1|-3) \qquad C(4|2)$$



Definitions:

$$\vec{a} = \vec{BC}$$
$$\vec{b} = \vec{CA}$$
$$\vec{c} = \vec{AB}$$

Exercises:

$$\vec{a} \cdot \vec{b} = a_x * b_x + a_y * b_y \tag{23}$$
$$\vec{a} \cdot \vec{b} = -1 * 1 + -2 * -3 \tag{24}$$
$$\vec{a} \cdot \vec{b} = -1 + 6 \tag{25}$$
$$\vec{a} \cdot \vec{b} = 5 \tag{26}$$

$$\vec{a} \cdot \vec{c} = a_x * c_x + a_y * c_y \tag{27}$$
$$\vec{a} \cdot \vec{c} = -1 * 4 + -2 * 2 \tag{28}$$
$$\vec{a} \cdot \vec{c} = -4 + -4 \tag{29}$$
$$\vec{a} \cdot \vec{c} = -8 \tag{30}$$

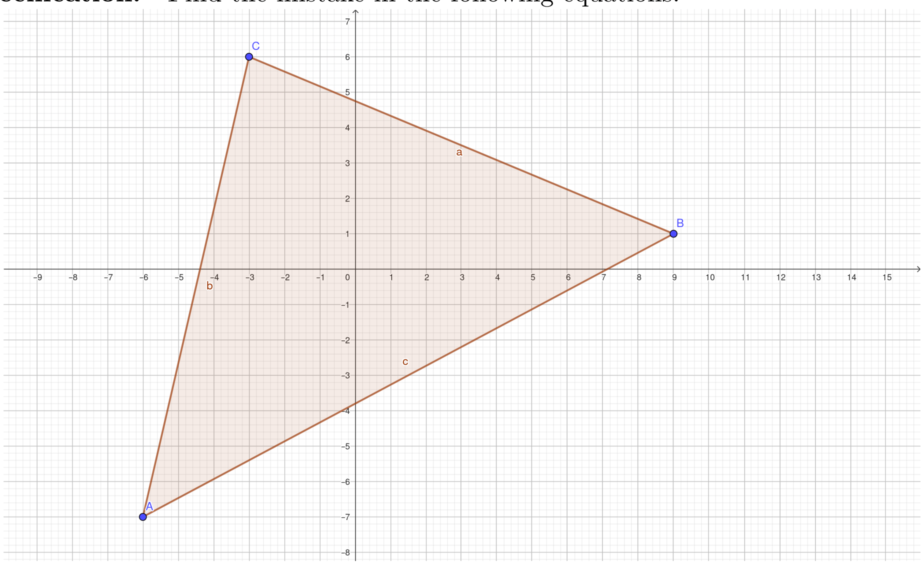
$$\vec{a} \cdot \vec{c} = b_x * c_x + b_y * c_y \tag{31}$$
$$\vec{a} \cdot \vec{c} = 1 * 4 + -3 * 2 \tag{32}$$
$$\vec{a} \cdot \vec{c} = 4 + -6 \tag{33}$$
$$\vec{a} \cdot \vec{c} = -2 \tag{34}$$

Answer: The triangle is not a right angle as none of the angles α, β, γ are $90°$. This is shown be the fact that none of the dot products of the triangles sides are 0.

3 8.29

3.1 1)

Specification: Find the mistake in the following equations:



$$\vec{c} = \vec{AB} \tag{35}$$
$$= \begin{pmatrix} 15 \\ 8 \end{pmatrix} \tag{36}$$
$$c = |\vec{c}| \tag{37}$$
$$= 17cm \tag{38}$$

$$\vec{a} = \vec{BC} \tag{39}$$
$$= \begin{pmatrix} -12 \\ 5 \end{pmatrix} \tag{40}$$
$$a = |\vec{a}| \tag{41}$$
$$= 13cm \tag{42}$$

$$\tag{43}$$

$$\cos(\beta) = \frac{\vec{a} \cdot \vec{c}}{|\vec{a}| * |\vec{b}|} \tag{44}$$

$$= \frac{\begin{pmatrix} 15 \\ 8 \end{pmatrix} * \begin{pmatrix} -12 \\ 5 \end{pmatrix}}{13 * 17} \tag{45}$$

$$= -\frac{140}{221} \tag{46}$$

$$= -0.633... \tag{47}$$

$$\beta = \arccos(-0.633...) \tag{48}$$

$$\approx 129.31^\circ \tag{49}$$

$$A = \frac{a * c * \sin(\beta)}{2} \tag{50}$$

$$= \frac{13 * 17 * \sin(129.31^\circ)}{2} \tag{51}$$

$$\approx 85.5cm^2 \tag{52}$$

Answer: The obtuse value of β (129.31°) was used instead of the acute value of β (50.69°). This didn't affect the result because $\sin(\beta)$ returns the same value for the obtuse and the acute value of β

$$\sin(\alpha) = \sin(180^\circ - \alpha) \tag{53}$$

$$\sin(129.31^\circ) = 0.77368 \tag{54}$$

$$\sin(50.69^\circ) = 0.77368 \tag{55}$$

4 8.31

Specification: An isosceles triangle ABC, which is named in the mathematically positive direction, has the base AB with $A(-2|-1)$, $B(4|7)$ and the height h = 10E. Calculate the missing point C, the angle ϕ which is enclosed by $\vec{AB}$ and $\vec{AC}$, and the area A_{rea} of the triangle.

Definitions:

$$h = 10E \tag{56}$$

$$A = \begin{pmatrix} -2 \\ -1 \end{pmatrix} \tag{57}$$

$$B = \begin{pmatrix} 4 \\ 7 \end{pmatrix} \tag{58}$$

$$\vec{c} = \vec{AB} \tag{59}$$

$$\vec{c_m} = \vec{OA} + \frac{1}{2}\vec{c} \tag{60}$$

Exercise:

Point C:

$$\vec{c} = \vec{OB} - \vec{OA} \tag{61}$$

$$\vec{c} = \begin{pmatrix} 4 \\ 7 \end{pmatrix} - \begin{pmatrix} -2 \\ -1 \end{pmatrix} \tag{62}$$

$$\vec{c} = \begin{pmatrix} 6 \\ 8 \end{pmatrix} \tag{63}$$

$$\vec{c_m} = \begin{pmatrix} -2 \\ -1 \end{pmatrix} + \frac{1}{2} \begin{pmatrix} 6 \\ 8 \end{pmatrix} \tag{64}$$

$$\vec{c_m} = \begin{pmatrix} -2 \\ -1 \end{pmatrix} + \begin{pmatrix} 3 \\ 4 \end{pmatrix} \tag{65}$$

$$\vec{c_m} = \begin{pmatrix} 1 \\ 3 \end{pmatrix} \tag{66}$$

$$\vec{c_n} = \begin{pmatrix} -8 \\ 6 \end{pmatrix} \tag{67}$$

$$\vec{c_{n0}} = \frac{1}{|\vec{c_n}|} \vec{c_n} \tag{68}$$

$$\vec{c_{n0}} = \frac{1}{\sqrt{(-8)^2 + 6^2}} \begin{pmatrix} -8 \\ 6 \end{pmatrix} \tag{69}$$

$$\vec{c_{n0}} = \frac{1}{10} \begin{pmatrix} -8 \\ 6 \end{pmatrix} \tag{70}$$

$$\vec{c_{n0}} = \begin{pmatrix} -0.8 \\ 0.6 \end{pmatrix} \tag{71}$$

$$\vec{OC} = \begin{pmatrix} 1 \\ 3 \end{pmatrix} + 10 \begin{pmatrix} -0.8 \\ 0.6 \end{pmatrix} \tag{72}$$

$$\vec{OC} = \begin{pmatrix} -7 \\ 9 \end{pmatrix} \tag{73}$$

Angle ϕ:

$$\vec{AC} = \vec{OC} - \vec{OA} \tag{74}$$
$$\vec{AC} = \begin{pmatrix} -7 \\ 9 \end{pmatrix} - \begin{pmatrix} -2 \\ -1 \end{pmatrix} \tag{75}$$
$$\vec{AC} = \begin{pmatrix} -5 \\ 10 \end{pmatrix} \tag{76}$$

$$\cos(\phi) = \frac{\vec{AB} \cdot \vec{AC}}{|\vec{AB}| * |\vec{AC}|} \tag{77}$$
$$\cos(\phi) = \frac{\begin{pmatrix} 6 \\ 8 \end{pmatrix} \cdot \begin{pmatrix} -5 \\ 10 \end{pmatrix}}{\sqrt{6^2 + 8^2} * \sqrt{(-5)^2 + 10^2}} \tag{78}$$
$$\cos(\phi) = \frac{50}{111.803398875} \tag{79}$$
$$\phi = \arccos(0.4472135955) \tag{80}$$
$$\phi = 63.43495° \tag{81}$$

Area:

$$A = \frac{1}{2} c h_c \tag{82}$$
$$A = 5c \tag{83}$$

$$c = |\vec{c}| \tag{84}$$
$$c = \sqrt{6^2 + 8^2} \tag{85}$$
$$c = 10 \tag{86}$$

$$A = 50E^2 \tag{87}$$

Answer: The point C is at the location $(-7|9)$, the angle between $\vec{AB}$ and $\vec{AC}$ is $63.43495°$, and the area of the triangle is $50E^2$.

5 8.33

5.1 1)

Specification: Given are the points $pA(120|10)$, $pB_1(150|140)$, and $pB_2(500|250)$. Calculate the angle β that encloses the horizontal and the vector $p\vec{ApB_1}$.

Definitions: Let $\vec{i}$ be the horizontal enclosing β.

Exercise:

$$\vec{AB} = \begin{pmatrix}150\\140\end{pmatrix} - \begin{pmatrix}120\\10\end{pmatrix} \tag{88}$$

$$\vec{AB} = \begin{pmatrix}30\\130\end{pmatrix} \tag{89}$$

$$\vec{H} = \vec{A} + \vec{i} \tag{90}$$

$$\vec{H} = \begin{pmatrix}120\\10\end{pmatrix} + \begin{pmatrix}1\\0\end{pmatrix} \tag{91}$$

$$\vec{H} = \begin{pmatrix}121\\10\end{pmatrix} \tag{92}$$

$$\cos(\beta) = \frac{\vec{AB} \cdot \vec{H}}{|\vec{AB}| * |\vec{H}|} \tag{93}$$

$$\beta = \arccos(\frac{\vec{AB} \cdot \vec{H}}{|\vec{AB}| * |\vec{H}|}) \tag{94}$$

$$\beta = \arccos(\frac{\begin{pmatrix}30\\130\end{pmatrix} \cdot \begin{pmatrix}121\\10\end{pmatrix}}{\sqrt{30^2 + 130^2} * \sqrt{121^2 + 10^2}}) \tag{95}$$

$$\beta = \arccos(\frac{30 * 121 + 130 * 10}{133.416640641 * 121.412519947}) \tag{96}$$

$$\beta = 72.2809315108° \tag{97}$$

Answer: The angle β that is enclosed by the horizontal and the vector $\vec{AB}$ has a value of 72.2809315108°.

5.2 2)

Specification: Calculate the angle between the vectors $\vec{B_1A}$ and $\vec{B_1B_2}$.

Exercise:

$$\vec{B_1A} = \begin{pmatrix} 120 \\ 10 \end{pmatrix} - \begin{pmatrix} 150 \\ 140 \end{pmatrix} \tag{98}$$

$$\vec{B_1A} = \begin{pmatrix} -30 \\ 110 \end{pmatrix} \tag{99}$$

$$\vec{B_1B_2} = -1.0 \tag{100}$$

$$\vec{B_1B_2} = \begin{pmatrix} 350 \\ 110 \end{pmatrix} \tag{101}$$

$$\cos(\alpha) = \frac{\vec{B_1A} \cdot \vec{B_1B_2}}{|\vec{B_1A}| * |\vec{B_1B_2}|} \tag{102}$$

$$\alpha = \arccos(\frac{\begin{pmatrix} -30 \\ 110 \end{pmatrix} \cdot \begin{pmatrix} 350 \\ 110 \end{pmatrix}}{|\begin{pmatrix} -30 \\ 110 \end{pmatrix}| * |\begin{pmatrix} 350 \\ 110 \end{pmatrix}|}) \tag{103}$$

$$\alpha = \arccos(\frac{1600}{41830.6108012}) \tag{104}$$

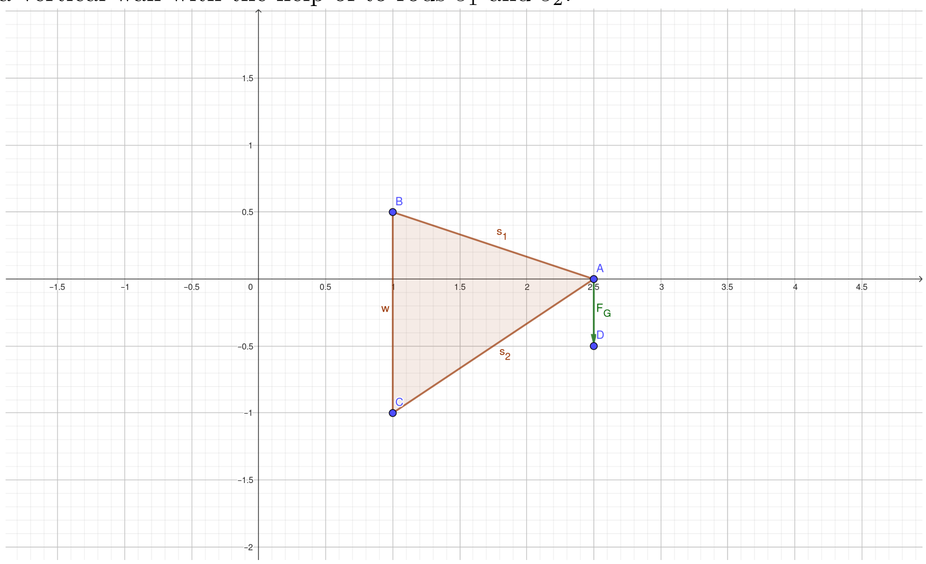
$$\alpha = 87.80793028° \tag{105}$$

TODO: Area, correction

Answer: The angle between the vectors $\vec{B_1A}$ and $\vec{B_1B_2}$ is 87.80793028°.

6 8.37

Specification A Lamp with the weight $F_G = |\vec{F_G}| = 45N$ should be mounted to a vertical wall with the help of to rods s_1 and s_2.



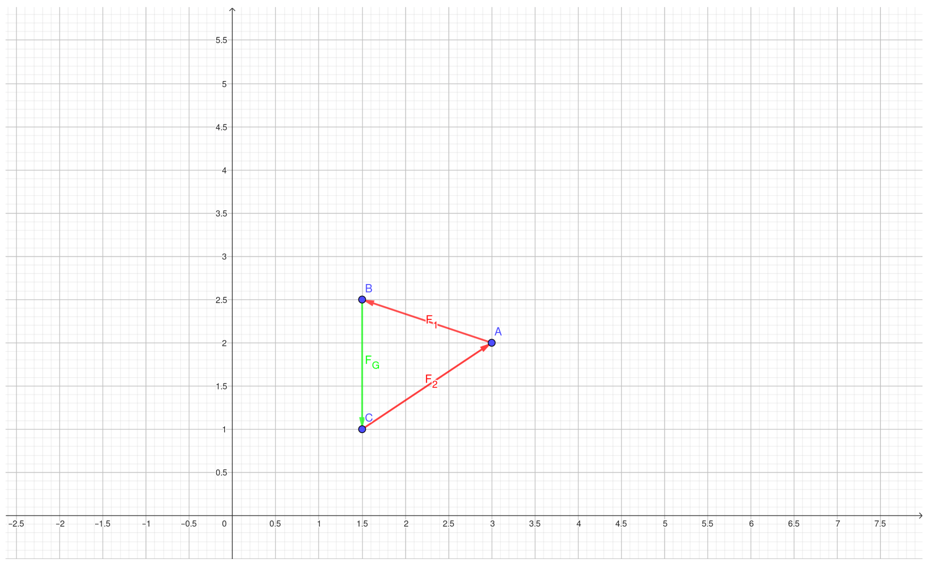
6.1 1)

Requirements: Sketch the force triangle of the forces acting on the point A where the lamp is mounted. Denote the directions of the forces.

Answer: The direction of the force $\vec{F_1}$ is taken from the direction of $s_1 = \begin{pmatrix} -1.5 \\ 0.5 \end{pmatrix}$.

The same goes for the force $\vec{F_2}$: $s_2 = \begin{pmatrix} 1.5 \\ 1 \end{pmatrix}$.

The weight force points vertically down with $45N$: $\vec{F_G} = \begin{pmatrix} 0 \\ -45 \end{pmatrix}$.



6.2 2)

Requirements: Calculate the magnitudes of the forces in the rods s_1 and s_2. Note: The sum of the forces acting on A has to be the zero vector.

$$\vec{F_G} + \vec{F_1} + \vec{F_2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \tag{106}$$

$$\vec{F_1} + \vec{F_2} = -\vec{F_G} \tag{107}$$

$$r * \begin{pmatrix} -1.5 \\ -.5 \end{pmatrix} + t * \begin{pmatrix} 1.5 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 45 \end{pmatrix} \tag{108}$$

I. $-1.5r + 1.5t = 0 \Rightarrow t = r$
II. $0.5r + t = 45$
I. in II. $1.5r = 45 \Rightarrow r = 30, t = 30$

$$\vec{F_1} = r + s_1 = \begin{pmatrix} -45 \\ 15 \end{pmatrix} \tag{109}$$

$$|\vec{F_1}| = 47.343...N \approx 47N \tag{110}$$

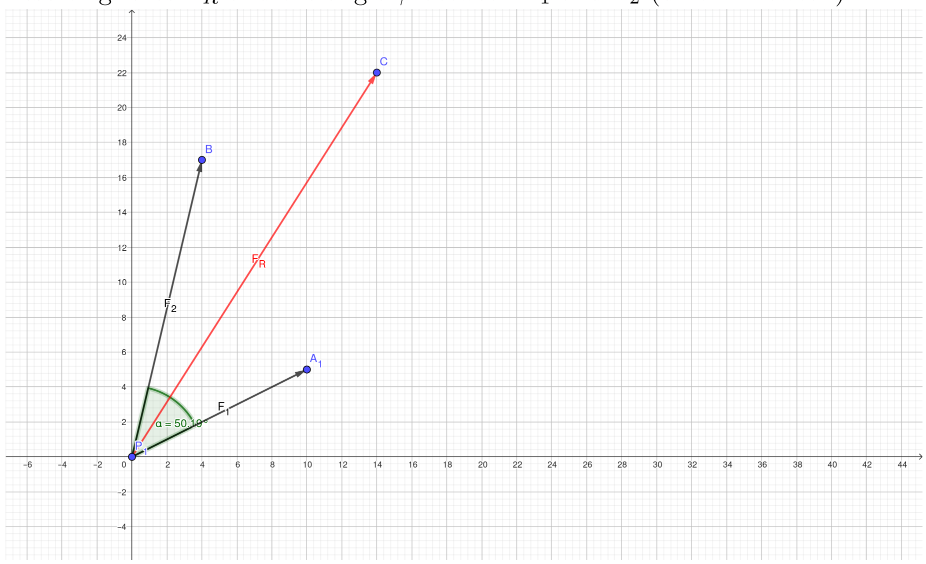
$$\vec{F_2} = r + s_2 = \begin{pmatrix} 45 \\ 30 \end{pmatrix} \tag{111}$$

$$|\vec{F_2}| = 54.083...N \approx 54N \tag{112}$$

7 8.38

7.1 a)

Specification: 2 forces $\vec{F_1}$ and $\vec{F_2}$ are effecting the same point P. Calculate the resulting force $\vec{F_R}$ and the angle ϕ between $\vec{F_1}$ and $\vec{F_2}$ (unit = Newton).



Definitions:

$$\vec{F_1} = \begin{pmatrix} 10 \\ 5 \end{pmatrix} \tag{113}$$

$$\vec{F_2} = \begin{pmatrix} 4 \\ 17 \end{pmatrix} \tag{114}$$

Exercises:

$$\vec{F_R} = \vec{F_1} + \vec{F_2} \tag{115}$$
$$\vec{F_R} = \begin{pmatrix} 10 \\ 5 \end{pmatrix} + \begin{pmatrix} 4 \\ 17 \end{pmatrix} \tag{116}$$
$$\vec{F_R} = \begin{pmatrix} 14 \\ 22 \end{pmatrix} \tag{117}$$
$$|\vec{F_R}| = \sqrt{14^2 + 22^2} \tag{118}$$
$$|\vec{F_R}| = 26.0768096208 \tag{119}$$

$$\cos(\phi) = \frac{\vec{F_1} \cdot \vec{F_2}}{|\vec{F_1}| * |\vec{F_2}|} \tag{120}$$
$$\cos(\phi) = \frac{\begin{pmatrix} 10 \\ 5 \end{pmatrix} \cdot \begin{pmatrix} 4 \\ 17 \end{pmatrix}}{\sqrt{125} * \sqrt{305}} \tag{121}$$
$$\cos(\phi) = \frac{125}{195.256241898} \tag{122}$$
$$\phi = \arccos(0.640184399663) \tag{123}$$
$$\phi = 50.19443^\circ \tag{124}$$

Answer: The resulting force F_R has a magnitude of 26.0768096208 Newton and the angle ϕ between the forces $\vec{F_1}$ and $\vec{F_2}$ is 50.19443°.

8 8.39

8.1 b)

Specification: The forces $\vec{F_1}$, $\vec{F_2}$, and $\vec{F_3}$ form a force triangle. Find the missing force graphically and through calculation, such that the force triangle is balanced. (units = kN)

Definitions:

$$\vec{F_1} = \begin{pmatrix} 20 \\ 30 \end{pmatrix} \tag{125}$$

$$\vec{F_2} = \begin{pmatrix} -10 \\ 15 \end{pmatrix} \tag{126}$$

$$\vec{F_3} = ? \tag{127}$$

Exercise:

$$\vec{F_1} + \vec{F_2} + \vec{F_3} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \tag{128}$$

$$\vec{F_1} + \vec{F_2} = \begin{pmatrix} 20 \\ 30 \end{pmatrix} + \begin{pmatrix} -10 \\ 15 \end{pmatrix} \tag{129}$$

$$\vec{F_1} + \vec{F_2} = \begin{pmatrix} 10 \\ 45 \end{pmatrix} \tag{130}$$

$$\begin{pmatrix} 10 \\ 45 \end{pmatrix} + \vec{F_3} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \tag{131}$$

$$\vec{F_3} = \begin{pmatrix} -10 \\ -45 \end{pmatrix} \tag{132}$$

Answer: The force F_3 has the value $\begin{pmatrix} -10 \\ -45 \end{pmatrix}$.