Please state clearly all assumptions made in order for full credit to be given.

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Problem #1 (25 %)

Consider the following points in a 3D Cartesian coordinate system:

\( P_1(5,-8,-11), P_2(20,-68,-8), P_3(1,12,4), \) and \( P_4(2,0,4) \)

\( a. \) Find the vector \( \mathbf{A} \), which has initial point \( P_1 \) and terminal point \( P_2 \). Please write it in terms of Cartesian unit vectors \(( \mathbf{i}, \mathbf{j}, \mathbf{k} )\). (2)

\( b. \) Find the vector \( \mathbf{B} \), which has initial point \( P_3 \) and terminal point \( P_4 \). Please write it in terms of Cartesian unit vectors \(( \mathbf{i}, \mathbf{j}, \mathbf{k} )\). (2)

\( c. \) Find the norm of vector \( (\mathbf{A} - 3\mathbf{B}) \). (3)

\( d. \) Find the unit vector showing the direction of vector \( (\mathbf{A} - 3\mathbf{B}) \). (3)

\( e. \) Find the dot product of \( \mathbf{A} \) and \( 3\mathbf{B} \) (or \( \mathbf{A} \cdot 3\mathbf{B} \)). Then find the dot product of \( \mathbf{A} \) and \( \mathbf{B} \) (or \( \mathbf{A} \cdot \mathbf{B} \)). (3)

\( f. \) Find the angle between the vectors \( \mathbf{A} \) and \( 3\mathbf{B} \) in degrees. (3)

\( g. \) Find the orthogonal projection of \( \mathbf{A} \) on \( 3\mathbf{B} \) (or \( \text{proj}_{3\mathbf{B}} \mathbf{A} \)). (3)

\( h. \) Find the component of \( \mathbf{A} \) which is orthogonal to \( 3\mathbf{B} \). (3)

\( i. \) Explain how your answer could change if you had to repeat parts \( f \) through \( h \) for vector \( \mathbf{B} \) instead of vector \( 3\mathbf{B} \). (3)

Note: You need to show all the work to receive full credit.
Problem #2 (25%)

Two concurrent forces $\mathbf{F}_1$ and $\mathbf{F}_2$ intersect at the origin as shown. $p(-3, 4, 5)$ is a point on the line of action of $\mathbf{F}_1$. The elevation angle for $\mathbf{F}_2$ is $\phi = -30^\circ$ from the x-y plane. The azimuth angle of $\mathbf{F}_2$ is $\theta = 300^\circ$. $F_1$ is 500 N and $F_2$ is 300 N.

a) Obtain unit vectors for forces $\mathbf{F}_1$ and $\mathbf{F}_2$. (4)

b) Express both forces in N and Cartesian vector form (4)

c) Determine the resultant $\mathbf{R}$ of the two forces in N and express the resultant in vector form (6)

d) Calculate the magnitude of the resultant (5)

e) Determine the direction angles of the resultant $\theta_x$, $\theta_y$, and $\theta_z$ in degrees (6)

Note: You need to show all work to receive full credit.
Problem #3 (25 %)

The system shown in the figure is at equilibrium. Both pulleys are frictionless and the diameter of the pulley attached to mass A can be neglected.

a) Draw complete free body diagrams of objects A and B. (6)

b) Find the tension (force) in both cables. (16)

c) Find the mass of object B in kg if the mass of A is 30 kg. (3)

Note: You have to draw any required FBD and show all work to receive full credit
Problem #4 (25%) 

Solve the following system of linear equations using the Gauss-Jordan Elimination method:

\[ \begin{align*} 
4x_2 + x_3 &= 2 \\
2x_1 + 6x_2 - 2x_3 &= 3 \\
4x_1 + 8x_2 - 5x_3 &= 4 
\end{align*} \]

a) Show the augmented matrix \( \quad \) (5)

b) Use elementary row operations to obtain the reduced row echelon form \( \quad \) (12)

c) Show the equations for the solutions of this system \( \quad \) (5)

d) Determine the solution to that system if \( x_3 = 4 \) \( \quad \) (3)

Note: Show all intermediate steps (no credit will be given for unsupported answers).