M 3

a) Equipollent force system from M2

$$\underline{F} = \begin{pmatrix} -2.4 \\ -2.7 \\ 0 \end{pmatrix} N \qquad \underline{M} = \begin{pmatrix} 0 \\ 0 \\ -1.89 \end{pmatrix} Nm$$

∴ Need a force and a moment to provide equilibrium

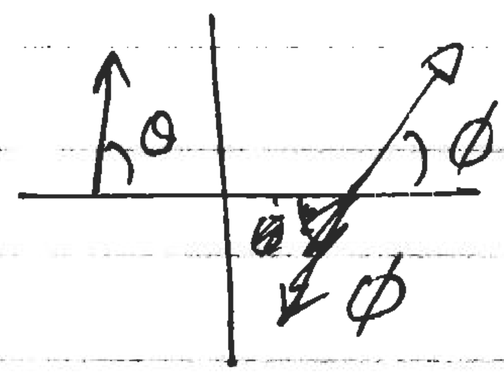
∴ a) No

b) No

c) Yes. $\underline{F} = \begin{pmatrix} +2.4 \\ +2.7 \\ 0 \end{pmatrix} N$, $\underline{M} = \begin{pmatrix} 0 \\ 0 \\ +1.89 \end{pmatrix} Nm$

d) Two forces, known magnitude, unknown direction express in terms of angle to x axis

$$\underline{F_1} = 20 \begin{pmatrix} \cos\theta \\ \sin\theta \\ 0 \end{pmatrix}$$



$$\underline{F_2} = 20 \begin{pmatrix} \cos\phi \\ \sin\phi \\ 0 \end{pmatrix}$$

$$\underline{F_1} + \underline{F_2} = \begin{pmatrix} +2.4 \\ +2.7 \\ 0 \end{pmatrix} = \begin{pmatrix} 20\cos\theta + 20\cos\phi \\ 20\sin\theta + 20\sin\phi \\ 0 \end{pmatrix} \begin{matrix} (1) \\ (2) \end{matrix}$$

$$\Sigma \underline{r} \times \underline{F}) = \begin{pmatrix} 0 \\ 0 \\ +1.89 \end{pmatrix}$$

$$20\begin{pmatrix} -1 \\ 0 \\ 0 \end{pmatrix} \times \begin{pmatrix} \cos\theta \\ \sin\theta \\ 0 \end{pmatrix} = 20\begin{pmatrix} 0 \\ 0 \\ -\sin\theta \end{pmatrix}$$

$$20\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \times \begin{pmatrix} \cos\phi \\ \sin\phi \\ 0 \end{pmatrix} = 20\begin{pmatrix} 0 \\ 0 \\ +\sin\phi \end{pmatrix}$$

$$\therefore \quad 20\,(-\sin\theta + \sin\phi) = +1.89 \quad (3)$$

add (2) + (3) $\Rightarrow$ $40\sin\phi = 4.59 \Rightarrow \sin\phi = 0.115$

substitute back into (2) $\Rightarrow$ $\sin\theta = \frac{-1.89}{20} + 0.115 = 0.020$

$\theta = 1.16^\circ$, $\phi = 6.6^\circ$ $\cos\phi = 0.99$, $\cos\theta = 1.0$

or $\theta = 1.16$ $\phi = 173.4$ $\cos\phi = -0.99$ $\cos\theta = 1.0$

~~$\therefore$ substitute back into (1)~~

or $\theta = 178.8$ $\phi = 1.16^\circ$ $\cos\phi = 0.99$ $\cos\theta = -1.00$

$\therefore$ by inspection $\theta = 1.16^\circ$, $\phi = 173.4^\circ \Rightarrow$ (1) = 0.2 N $\therefore$ NSF sufficient

Cannot ~~replace~~ achieve equilibrium with this pair of forces - problem is over constrained.