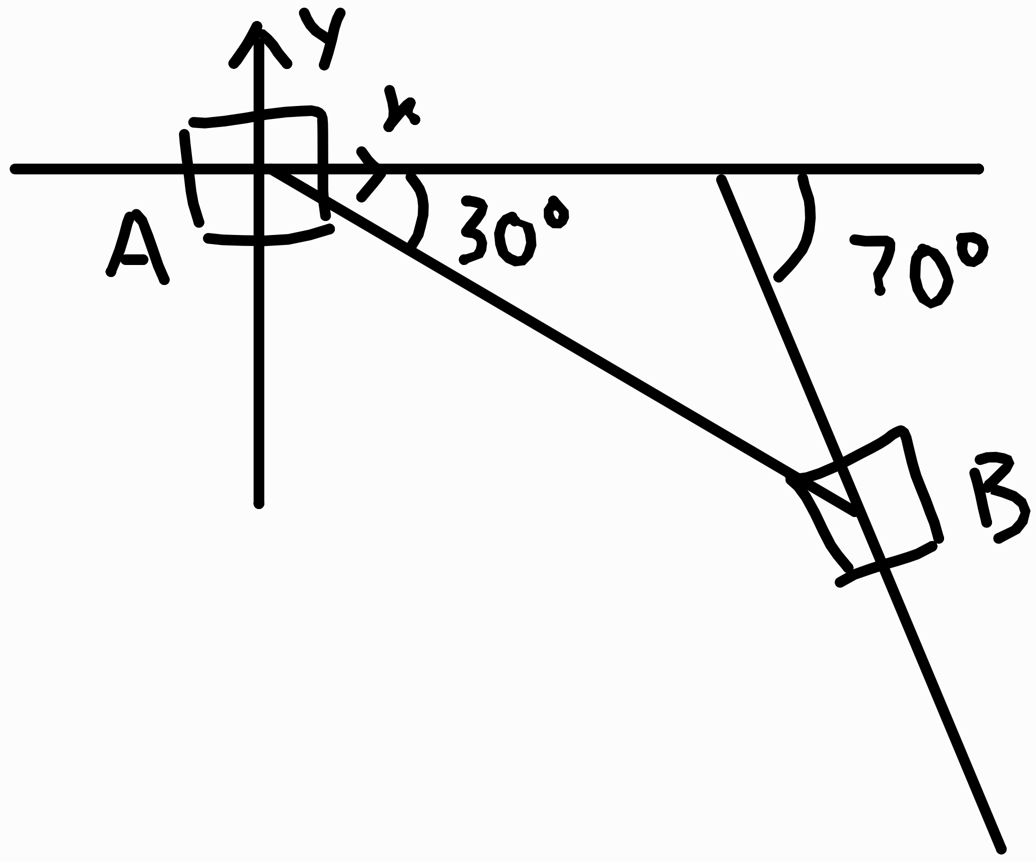
1)



Using a body attached frame on A called f,

$$\vec{v}_{B/f} = 0$$

$$\vec{v}_B = \vec{v}_{B/f} + \vec{v}_{B'}$$

$$\vec{v}_B = \vec{v}_{B/f} + \vec{v}_A + \vec{\omega}_f \times \vec{r}_{BA}$$

$$v_B \angle -70^\circ = 0 + 900\underset{\sim}{i} + \dot{\theta}\underset{\sim}{k} \times 300 \angle -30^\circ$$

$$v_B(0.342\underset{\sim}{i} - 0.939692\underset{\sim}{j}) = 900\underset{\sim}{i} + 300\dot{\theta}\underset{\sim}{k} \times \left(\frac{\sqrt{3}}{2}\underset{\sim}{i} - 0.5\underset{\sim}{j}\right)$$

$$v_B(0.342\underset{\sim}{i} - 0.939692\underset{\sim}{j}) = 900\underset{\sim}{i} + 300\dot{\theta}\left(\frac{\sqrt{3}}{2}\underset{\sim}{j} + 0.5\underset{\sim}{i}\right)$$

$$0.342 v_B\underset{\sim}{i} - 150\dot{\theta}\underset{\sim}{i} - 0.939692 v_B\underset{\sim}{j} - 150\sqrt{3}\underset{\sim}{j} = 900\underset{\sim}{i} + 0\underset{\sim}{j}$$

Solving,

$$v_B = 1017.464287 \text{ mms}^{-1}$$

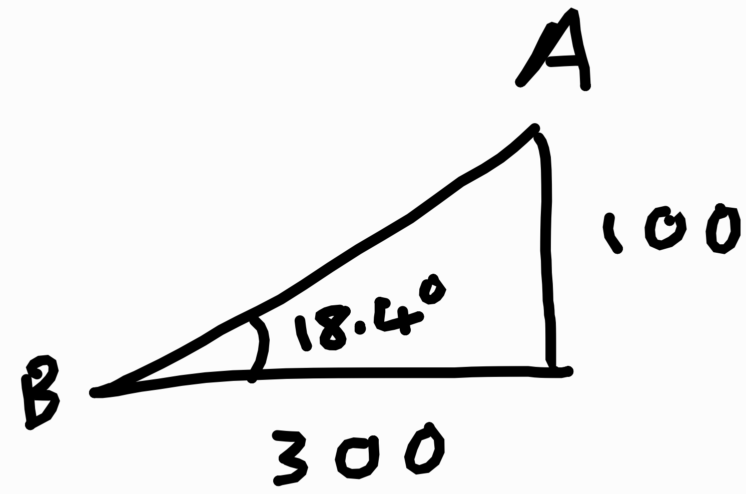
$$\dot{\theta} = -3.68004791 \text{ rads}^{-1}$$

$$\therefore \vec{v}_B \approx 1017 \angle -70^\circ$$

$$\vec{\omega} \approx -3.68\underset{\sim}{k}$$

2a) A and E are fixed points, so relative velocity and acceleration with respect to them are equal.

Length of AB is constant so B is circular motion about A

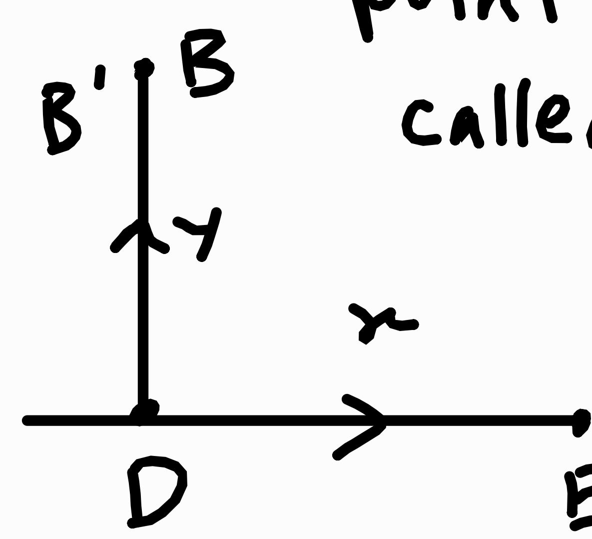


$$\vec{v}_B = \vec{\omega} \times \vec{r}_{BA}$$

$$= 3\underset{\sim}{k} \times (-300\underset{\sim}{i} - 100\underset{\sim}{j})$$

$$= 300\underset{\sim}{i} - 900\underset{\sim}{j}$$

Attach body-attached frame at point D called f



$$\vec{v}_B = \vec{v}_{B/f} + \vec{v}_{B'}$$

$$= 0 + \vec{v}_D + \underline{\vec{\omega}_{f_{BD}} \times \vec{r}_{B'D}} \rightarrow \boxed{\text{B is in circular motion about D}}$$

$$= \vec{v}_D + \omega_{f_{BD}}\underset{\sim}{k} \times (200\underset{\sim}{j})$$

$$= \vec{v}_D - 200\omega_{f_{BD}}\underset{\sim}{i}$$

$$= \underline{\vec{\omega}_{f_{DE}} \times \vec{r}_{DE}} - 200\omega_{f_{BD}}\underset{\sim}{i} \rightarrow \boxed{\text{D is in circular motion about E}}$$

$$= \omega_{f_{DE}}\underset{\sim}{k} \times (-225\underset{\sim}{i}) - 200\omega_{f_{BD}}\underset{\sim}{i} \qquad ijkij$$

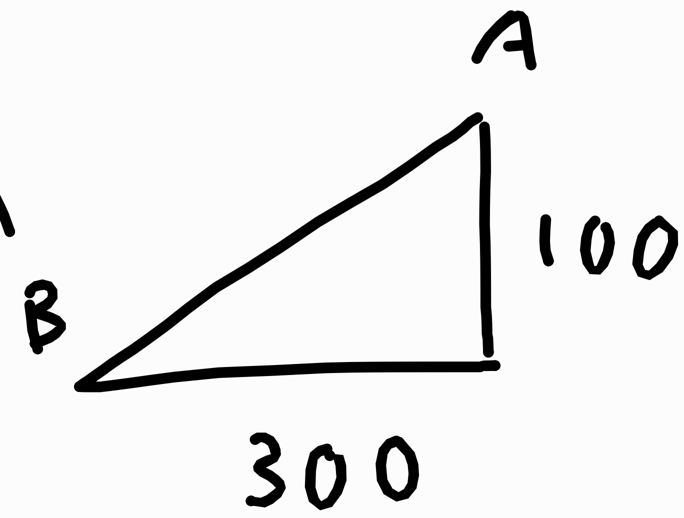
$$= -200\omega_{f_{BD}}\underset{\sim}{i} - 225\omega_{f_{DE}}\underset{\sim}{j}$$

2a) $300\underset{\sim}{i} - 900\underset{\sim}{j} = -200\,w_{f_{BD}}\underset{\sim}{i} - 225\,w_{f_{DE}}\underset{\sim}{j}$

Solving,

$w_{f_{BD}} = -1.5\,\text{rads}^{-1}$

$w_{f_{DE}} = 4\,\text{rads}^{-1}$



2b) $\vec{a}_B = \cancel{\vec{a}_A} + \cancel{\vec{\alpha} \times \vec{r}_{B/A}} - w^2 \vec{r}_{B/A}$

$= -w^2 \vec{r}_{B/A}$

$= -3^2(-300\underset{\sim}{i} - 100\underset{\sim}{j})$

$= 2700\underset{\sim}{i} + 900\underset{\sim}{j}$

$\vec{a}_B = \cancel{\vec{a}_{B/f}} + \vec{a}_{B'} + \cancel{2\vec{w}_f \times \vec{v}_{B/f}}$

$= \vec{a}_{B'}$

$= \cancel{\vec{a}_{BD}} + \vec{\alpha}_{BD} \times \vec{r}_{BD} - w^2_{BD}\vec{r}_{BD}$

$+ \cancel{\vec{a}_{DE}} + \vec{\alpha}_{DE} \times \vec{r}_{DE} - w^2_{DE}\vec{r}_{DE}$

i j k i

$= \alpha_{BD}\underset{\sim}{k} \times (200\underset{\sim}{j}) - (-1.5)^2(200\underset{\sim}{j}) + \alpha_{DE}\underset{\sim}{k} \times (-225\underset{\sim}{i})$

$- 4^2(-225\underset{\sim}{i})$

$= -200\alpha_{BD}\underset{\sim}{i} - 450\underset{\sim}{j} - 225\alpha_{DE}\underset{\sim}{j} + 3600\underset{\sim}{i}$

2b) $2700 = -200\alpha_{BD} + 3600$

$\alpha_{BD} = 4.5$

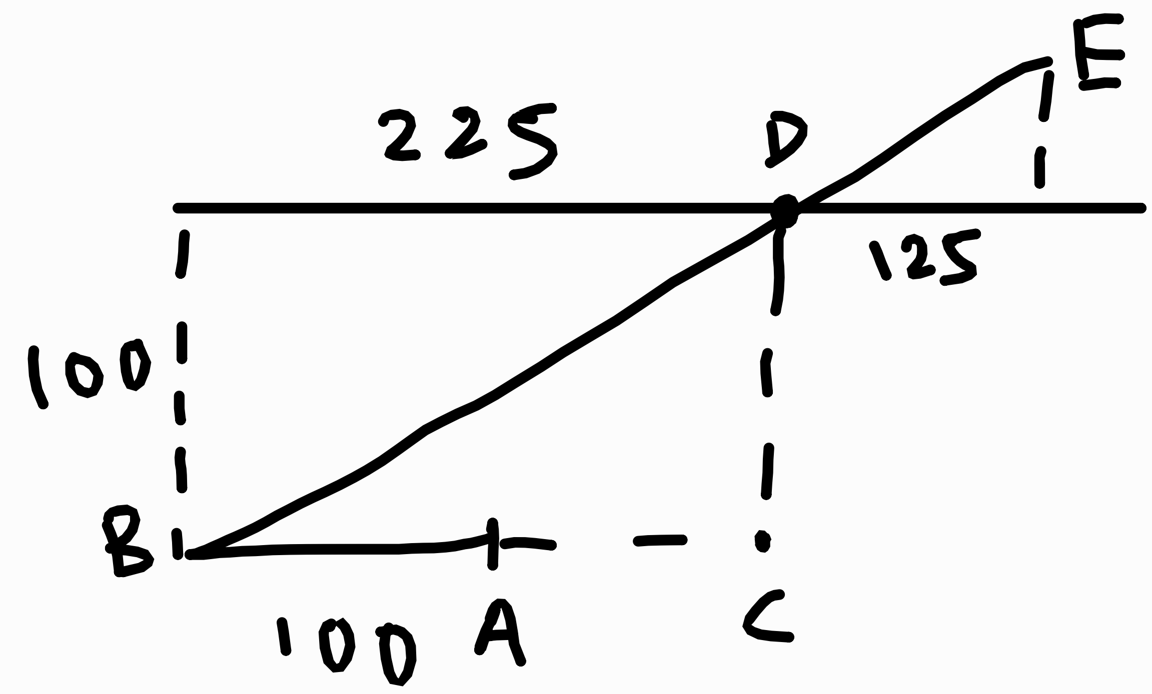
$\vec{\alpha}_{BD} = 4.5\underset{\sim}{k}\ \text{rads}^{-2}$

$900 = -225\alpha_{DE} - 450$

$\alpha_{DE} = 6$

$\vec{\alpha}_{DE} = 6\underset{\sim}{k}\ \text{rads}^{-2}$

3a) Let C be the instant centre.



b) $\vec{v}_D = -120\underset{\sim}{i}$

$\vec{v}_D = \vec{r}_{DC} \times \vec{w}$

$-120\underset{\sim}{i} = 100\underset{\sim}{j} \times w\underset{\sim}{k}$

$-120\underset{\sim}{i} = 100w(\underset{\sim}{i})$

$w = 1.2 \rightarrow \vec{w}_{BE} = 1.2\underset{\sim}{k}$ rads^{-1}

$\vec{v}_B = \vec{r}_{BC} \times \vec{w}$ $\quad$ i j k i

$= -225\underset{\sim}{i} \times 1.2\underset{\sim}{k}$

$= 270\underset{\sim}{j}$

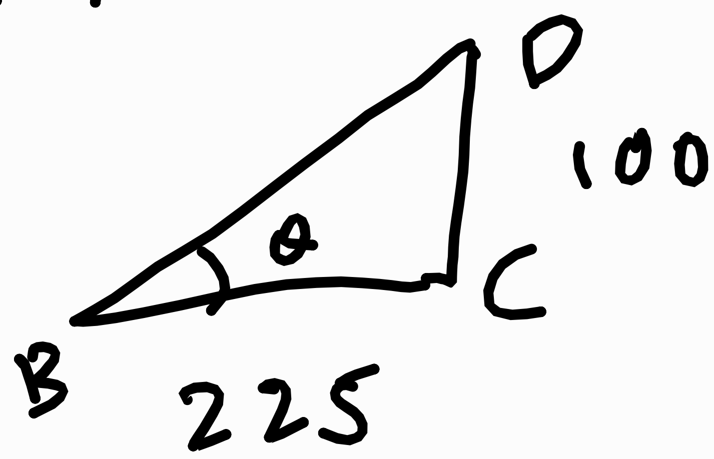
$\vec{v}_B = \vec{r}_{BA} \times \vec{w}_{BA}$

$270\underset{\sim}{j} = -100\underset{\sim}{i} \times w_{BA}\underset{\sim}{k}$

$270\underset{\sim}{j} = 100w_{BA}\underset{\sim}{j}$

$w_{BA} = 2.7 \rightarrow \vec{w}_{BA} = 2.7\underset{\sim}{k}$ rads^{-1}

3c) $\vec{v}_E = \vec{r}_{EC} \times \vec{w}$ $\quad$ i j k i

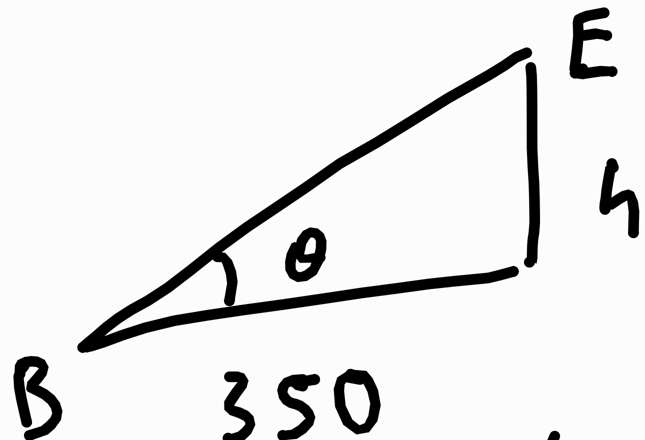


$= \left(125\underset{\sim}{i} + \frac{1400}{9}\underset{\sim}{j}\right) \times 1.2\underset{\sim}{k}$

$= -\frac{560}{3}\underset{\sim}{i} + 150\underset{\sim}{j}$

$\theta = \tan^{-1}\left(\frac{100}{225}\right)$

$\theta = 23.96^\circ$



$\tan\theta = \frac{h}{350}$

$\frac{100}{225} = \frac{h}{350}$

$h = \frac{1400}{9}$

4 a) $\vec{v}_A = \vec{w}_{AO} \times \vec{r}_{AO}$

i j k i j

$= w_{AO} \underset{\sim}{k} \times (4\underset{\sim}{i} + 3\underset{\sim}{j})$

$= 4w_{AO}\underset{\sim}{j} - 3w_{AO}\underset{\sim}{i}$

Attach a frame at E,

$\vec{v}_A = \cancel{\vec{v}_{A/f}} + \vec{v}_E + \vec{w}_f \times \vec{r}_{AE}$

$= 0.7\underset{\sim}{i} + w_f\underset{\sim}{k} \times (-8\underset{\sim}{i} + 8\underset{\sim}{j})$

$= 0.7\underset{\sim}{i} - 8w_f\underset{\sim}{i} - 8w_f\underset{\sim}{j}$

$-3w_{AO} = 0.7 - 8w_f$

$-3w_{AO} + 8w_f = 0.7 \quad -(1)$

$4w_{AO} = -8w_f$

$4w_{AO} + 8w_f = 0 \quad -(2)$

Solving,

$w_{AO} = -0.1 \text{ rads}^{-1}$

$w_f = 0.05 \text{ rads}^{-1}$

$\therefore w_f = w_{ABDE} = 0.05\underset{\sim}{k} \text{ rads}^{-1}$

4b) $\vec{v}_A = 4 w_{AO} \underset{\sim}{j} - 3 w_{AO} \underset{\sim}{i}$

$= 0.3 \underset{\sim}{i} - 0.4 \underset{\sim}{j}$ rads^{-1}

$\vec{v}_B = \vec{v}_{B/A} + \vec{v}_A$ $\qquad$ i j k i j

$= 0.3 \underset{\sim}{i} - 0.4 \underset{\sim}{j} + \vec{w}_f \times \vec{r}_{BA}$

$= 0.3 \underset{\sim}{i} - 0.4 \underset{\sim}{j} + 0.05 \underset{\sim}{k} \times (-8 \underset{\sim}{j})$

$= 0.7 \underset{\sim}{i} - 0.4 \underset{\sim}{j}$

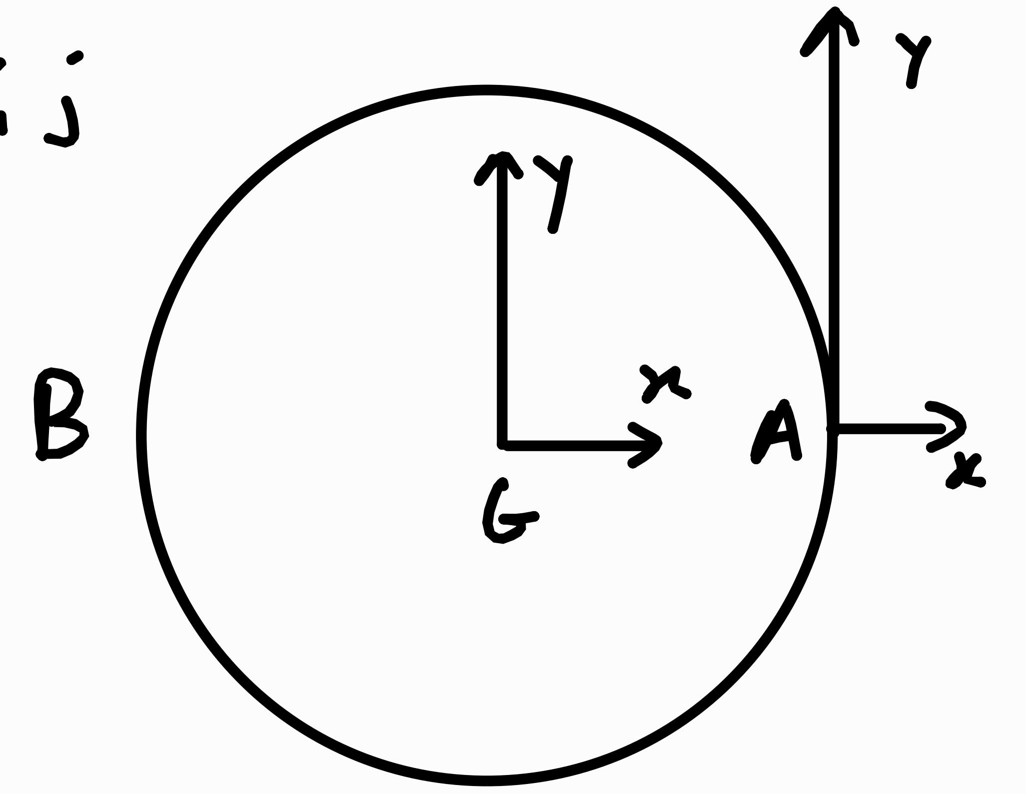
$\vec{v}_D = \vec{v}_A + \vec{v}_{D/A}$

$= 0.3 \underset{\sim}{i} - 0.4 \underset{\sim}{j} + \vec{w}_f \times \vec{r}_{DA}$

$= 0.3 \underset{\sim}{i} - 0.4 \underset{\sim}{j} + 0.05 \underset{\sim}{k} \times (8 \underset{\sim}{i})$

$= 0.3 \underset{\sim}{i}$

5a) $\vec{v}_B = \cancel{\vec{v}_{B/A}} + \vec{v}_{B'}$ $i\ j\ k\ i\ j$



$$= \vec{v}_A + \vec{\omega}_f \times \vec{r}_{BA}$$

$$= -1.8\underset{\sim}{j} + w_f \underset{\sim}{k} \times (-1.2\underset{\sim}{i})$$

$$= -1.8\underset{\sim}{j} - 1.2 w_f \underset{\sim}{j}$$

$$-1.5 = -1.8 - 1.2 w_f$$

$$w_f = -0.25$$

$$\vec{a}_B = \cancel{\vec{a}_{B/f}} + \vec{a}_{B'} + \cancel{2\vec{\omega}_f \times \vec{v}_{B/f}}$$

$i\ j\ k\ i\ j$

$$= \vec{a}_A + \vec{\alpha} \times \vec{r}_{BA} - w_f^2 \vec{r}_{BA}$$

$$= 0.6\underset{\sim}{j} + \alpha \underset{\sim}{k} \times (-1.2\underset{\sim}{i}) - (-0.25)^2(-1.2i) + \vec{a}_A^{\,n}$$

$$= 0.6\underset{\sim}{j} - 1.2\alpha \underset{\sim}{j} + 0.075\underset{\sim}{i} + a_B^n \underset{\sim}{i}$$

$$-0.45 = 0.6 - 1.2\alpha$$

$$\alpha = 0.875 \text{ rads}^{-1}$$

5) $\vec{v}_B = -1.8\underset{\sim}{j} - 1.2 w_f \underset{\sim}{j}$

$= -1.5\underset{\sim}{j}$

$\vec{a}_B = \cancel{\vec{a}_{B/f_2}} + \vec{a}_{B'} + \cancel{2\vec{w}_f \times \vec{v}_{B/f_2}}$

$= \vec{a}_G + \vec{\alpha} \times \vec{r}_{BG} - w_f^2 \vec{r}_{BG}$

$= a_G \underset{\sim}{j} + 0.875\underset{\sim}{k} \times (-0.6\underset{\sim}{i}) - (-0.25)^2 (-0.6\underset{\sim}{i})$

$= a_G \underset{\sim}{j} - 0.525\underset{\sim}{j} + \underline{0.0375\underset{\sim}{i}}$

$\therefore \vec{a}_B = 0.0375\underset{\sim}{i} - 0.45\underset{\sim}{j}$