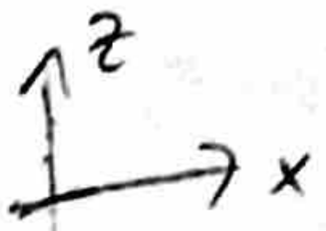
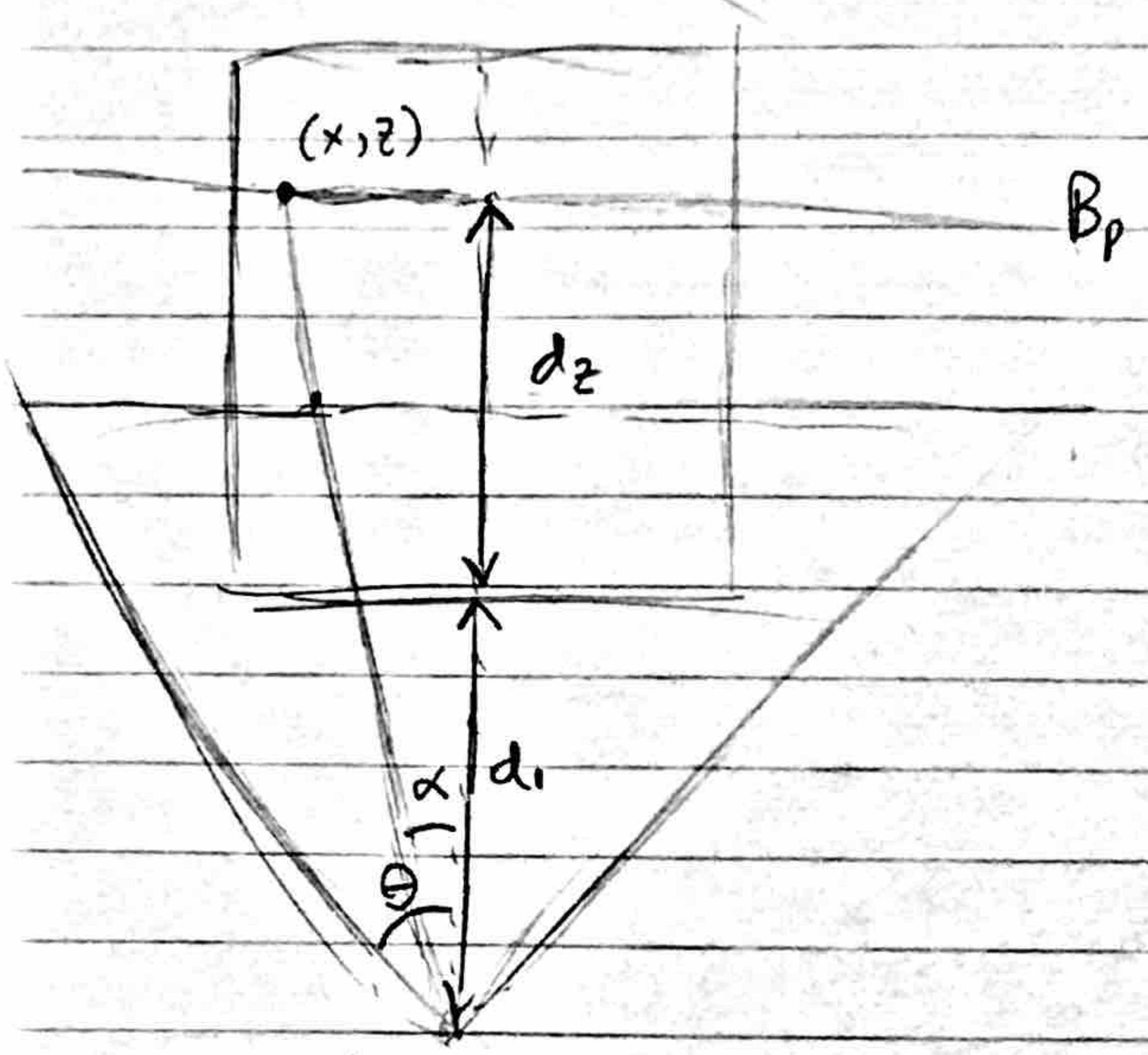
Set center line so $x=0$, so it does not change with Z

Unknown α



B_p ~ The YZ plane of the ball



$$W_{Imagep} = 2(\tan\theta)(d_1+d_z) \quad (m)$$

$\rightarrow$ $P_{xBall} = (\tan\alpha)(d_1+d_z)$ alpha left of center is negative

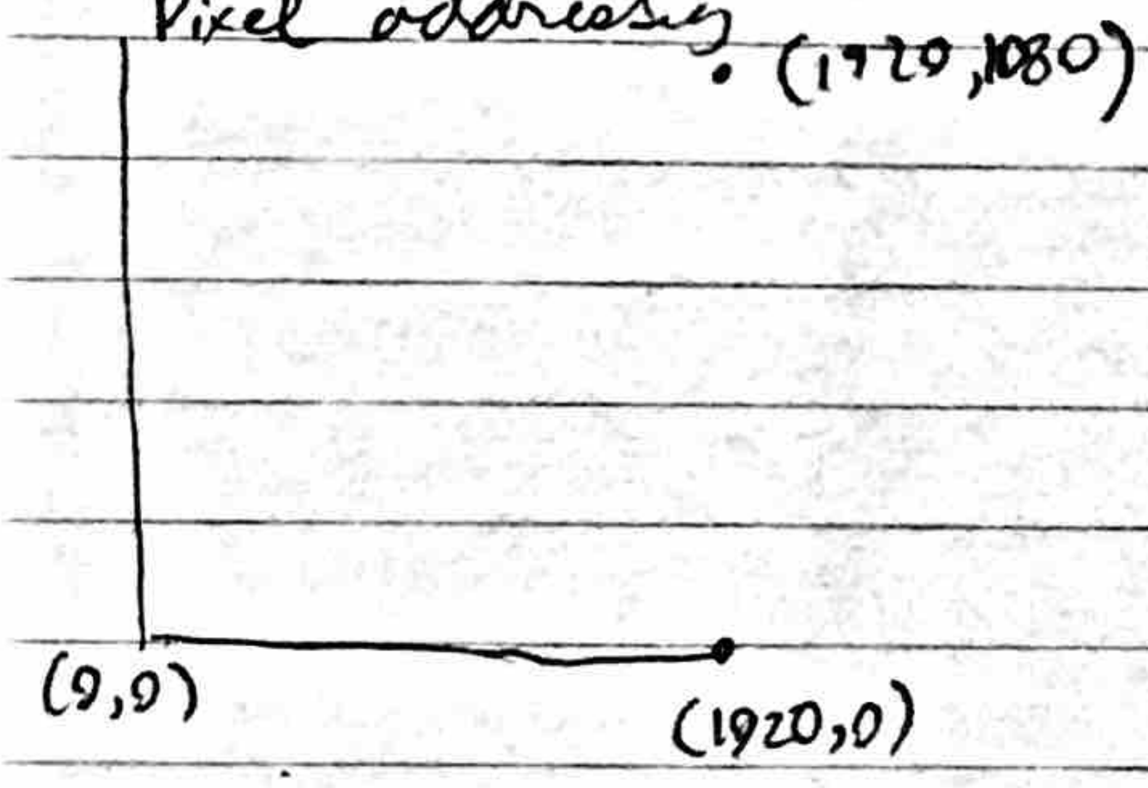
$$P_{pixBall} = P_{wBall}\cdot\left(\frac{1920}{W_{Imagep}}\right)$$

Need α, d_z

$$P_{zBall} = (\tan\beta)(d_1+d_x)$$
$$d_z = (\tan\beta)(d_1+d_x)$$

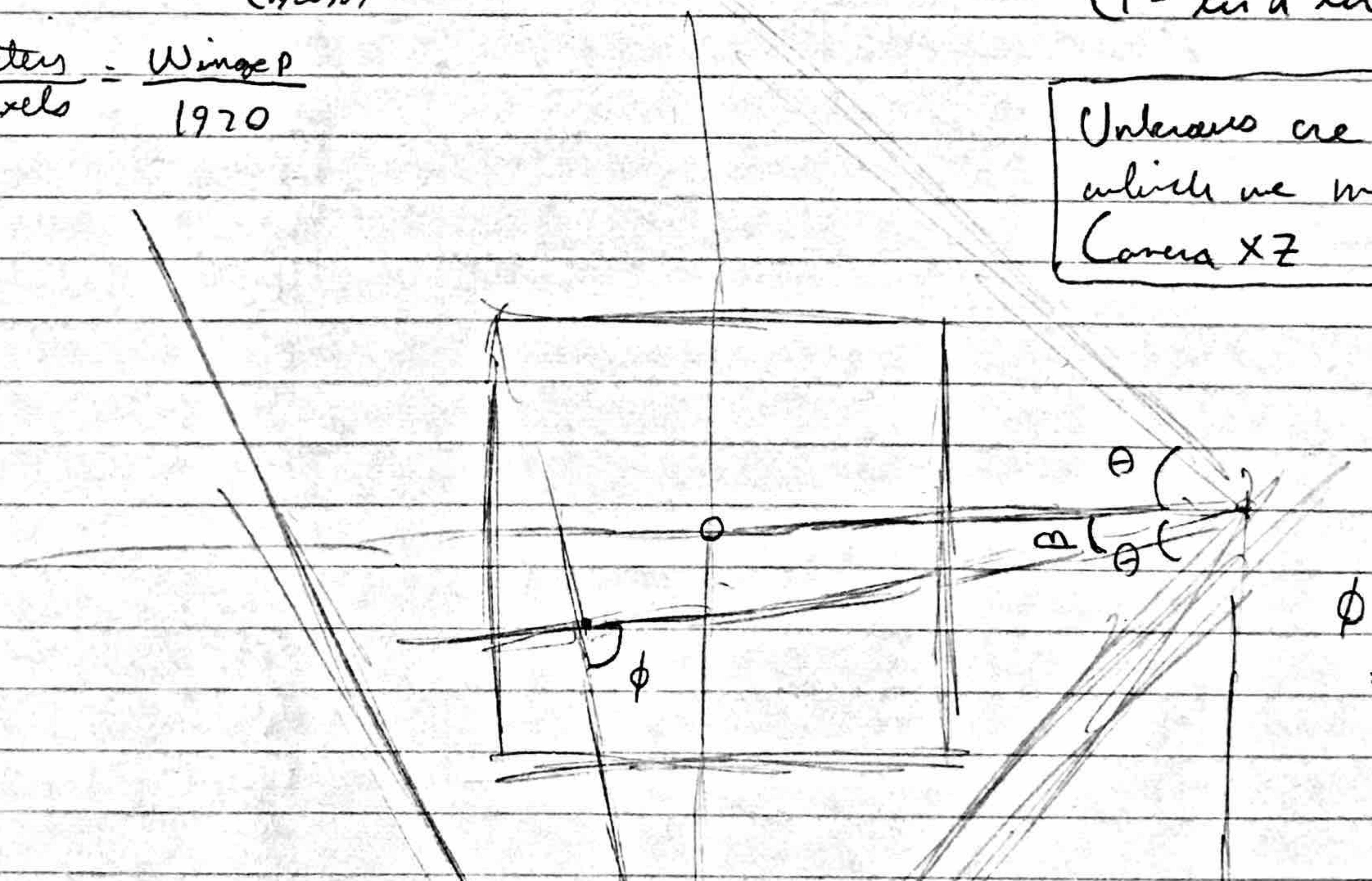
$$d_x = (\tan\alpha)(d_1 + (\tan\beta)(d_1+d_x))$$
$$d_x = (\tan\alpha)d_1 + \tan\alpha\tan\beta\, d_1 + \tan\alpha\tan\beta\, d_x$$
$$d_x(1-\tan\alpha\tan\beta) = (\tan\alpha)d_1 + (\tan\alpha\tan\beta)d_1$$
$$d_x = \frac{(\tan\alpha)d_1 + (\tan\alpha\tan\beta)d_1}{(1-\tan\alpha\tan\beta)}$$
$$= \frac{d_1(\tan\alpha+\tan\alpha\tan\beta)}{(1-\tan\alpha\tan\beta)}$$

Pixel addressing



$$\frac{\text{meters}}{\text{pixels}} = \frac{W_{imagep}}{1920}$$

$\boxed{\text{Unknowns are now } \alpha \text{ and } \beta\text{, which we may obtain from Camera XZ}}$



$$\phi = 180-(\alpha+\theta)-(\theta-\beta)$$
$$= 180-\alpha-2\theta+\beta$$

Assumptions ~ Camera perpendicular to ground

Correct for skew

$$dx = \text{proj}_{\overrightarrow{P_1P_2}} \vec{u}$$

$$d_y = \text{proj}_{\overrightarrow{P_1P_3}} \vec{u}$$