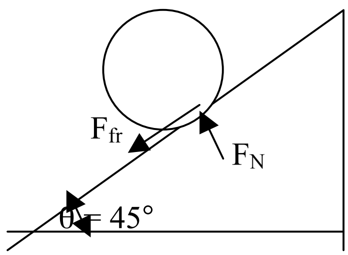
Appendix A: Free Body Diagram Analysis

Sum of forces in the horizontal direction:

$$\sum F_x = R_{x1} + R_{x2} + R_{x3} = 0$$
$$R_{x3} = -(R_{x1} + R_{x2})$$

We measured the coefficient of friction by inclining the slope of the beach until the Eggman started to slide, which was at 45 degrees.



$$F_{fr} = \mu \cdot F_N$$
$$mg \cdot \sin\theta = \mu \cdot mg \cdot \cos\theta$$
$$\mu = \tan(45)$$
$$\mu = 1$$

From this, we could calculate the horizontal reaction forces by assuming the worst-case (highest torque) situation of slipping.

$$R_{x1} = \mu \cdot N \qquad R_{x2} = \mu \cdot N$$
$$R_{x1} = 1 \cdot R_{y1} \qquad R_{x2} = 1 \cdot R_{y2}$$
$$R_{x1} = 3.24N \qquad R_{x1} = 2.155N$$

Sum of forces in the vertical direction:

$$\sum F_y = R_{y1} + R_{y2} + R_{y3} - mg = 0$$

Assume that sixty percent of the weight is on the front set of wheels and forty percent of the weight is on the back set of wheels. This allows us to calculate the vertical reaction forces R_{y1} and R_{y2}.

$$R_{y1} = 0.60 \cdot (total\_weight) \qquad R_{y2} = 0.40 \cdot (total\_weight)$$
$$R_{y1} = 0.60 \cdot 9.81 m/s^2 \cdot 0.55 kg \qquad R_{y2} = 0.40 \cdot 9.81 m/s^2 \cdot 0.55 kg$$
$$R_{y1} = 2.155N \qquad R_{y2} = 3.24N$$

Sum of moments about the gear shaft:

$$\sum M_{gear\_shaft} = -T + mg \cdot x_3 - R_{y1} \cdot x_1 + R_{y2} \cdot x_2 + R_{x1} y_1 + R_{x2} y_2 = 0$$

$$0 = -T + mg \cdot (1.905cm) - R_{y1}(10.6cm) + R_{y2}(9.7cm) + R_{x1}(8.3cm) + R_{x2}(8.3cm)$$

$$T = (9.81m/s^2)(.55kg)(.01905m) - 3.24N(.106m) + 2.155N(.097m) + 3.24N(.083m) + 2.155N(.083m)$$

$$T = 0.416N$$