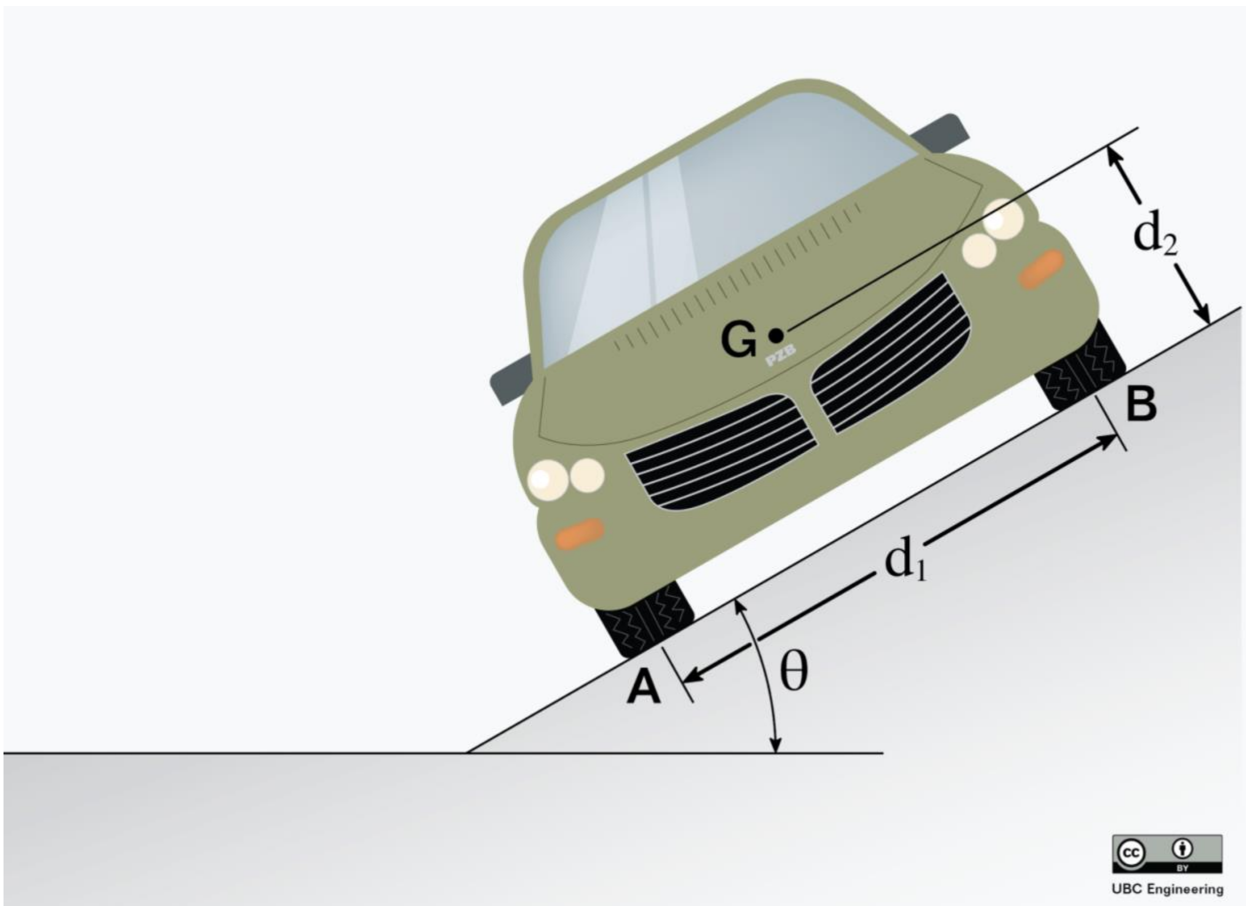
~~PHYS 1170~~ ~~Your Name:~~
~~Your final answer must have 3 sig. figs.~~ ~~Your mark: /10~~

What is the greatest slope the shoulder of the road can have without the car slipping down sideways or tilting over?
It is travelling at a constant velocity towards “you” or horizontally forward.
You will have to calculate these two things separately.
Will it tip or slip first?

Hint – as it tips the normal force at B would be zero
The car has a mass of 1.6 Mg and centre of mass at G as shown right in the centre.
The distance d1 between the tires is 5 feet.
The distance d2 above the road is 2.5 ft
The coefficient of static friction between the tires and the road is 0.400.



Solve for tipping first
As it tips, NB = 0 N
All we need to use is NA and W=mg

Easiest to resolve W into components and then use moment arms
They have chosen the size of the car so both moment arms are 2.5 ft. Annoying.
W into the slope = W cos θ
W down the slope, downhill = W sin θ

For it not to tip, the ,moment about A is zero. CCW is positive, as normal.

$(W \sin\theta) (2.5 \text{ ft}) + (- W \cos\theta) (2.5 \text{ ft}) = 0$
$W \sin\theta \; (2.5 \text{ ft}) = W \cos\theta \; (2.5 \text{ ft})$

$$\frac{\sin\theta}{\cos\theta} = \frac{2.5\text{ft}}{2.5 \text{ ft}} = 1$$

so $\theta_{\text{tipping}} = \tan^{-1}(1.2) = 45.0$ degrees

Slipping
Take uphill to be positive. Friction force FA is up hill to stop it from slipping.
Friction force F = 0.4 (normal force N) by definition

$0.4 N – W \sin\theta = 0$ (1)

Take out of the slope to be positive

$N – W \cos\theta = 0$ (2)

Solving (dividing) gives $0.4 = \sin\theta / \cos\theta = \tan\theta$

Tan $\theta = 0.4$ so $\theta = 21.8$ degrees

This shows the usual $\tan\theta = \mu$ static relationship
It will slip before it tips.

$\tan^{-1}(0.3) = 16.7^{\circ}$
$\tan^{-1}(0.4) = 21.8^{\circ}$
$\tan^{-1}(0.5) = 26.6^{\circ}$
$\tan^{-1}(0.6) = 31.0^{\circ}$

$\tan^{-1}(0.7) = 35.0^{o}$
$\tan^{-1}(0.8) = 38.7^{o}$
$\tan^{-1}(0.9) = 42.0^{o}$

If the car is 6 feet wide as opposed to 5 feet then
$(W \sin\theta)(\text{height}) - (W \cos\theta)(1/2 \text{ width}) = 0$
$(W \sin\theta)(2.5 \text{ ft}) - (W \cos\theta)(3.0 \text{ ft}) = 0$

So $W \sin\theta \ (2.5 \text{ ft}) = W \cos\theta \ (3.0 \text{ ft})$

$\sin\theta \ (2.5 \text{ ft}) = \cos\theta \ (3.0 \text{ ft})$

$$\frac{\sin\theta}{\cos\theta} = \frac{3.0 \text{ ft}}{2.5 \text{ ft}} = 1.2 = \tan\theta$$

so $\theta_{\text{tipping}} = \tan^{-1}(1.2) = 50.2$ degrees

It will slip down before it tips.