

Question 4: Qualitative Quantitative Translation (QQT)**8 points**

A	For indicating $f_D < f_R$	Point A1
	For a justification that compares one of the following:	Point A2
	- The motions of the disk and the ring using translational kinematics - The motions of the disk and the ring using rotational kinematics - The rotational inertias of the disk and the ring	
B	For a justification that includes one of the following:	Point A3
	- Reasoning that attempts Newton's second law in translational form - Reasoning that attempts Newton's second law in rotational form - Reasoning that attempts conservation of energy	
	Example Response <i>The ring has a greater rotational inertia because it has more mass distributed towards the edge. So the ring travels farther and has less acceleration down the ramp. Because the ring and the disk have the same mass, the gravitational forces exerted on the shapes are the same. From Newton's second law, the ring must have less net force down the ramp and more friction up the ramp.</i>	
B	For a multistep derivation that includes Newton's second law in both translational and rotational forms	Point B1
	For indicating opposite signs for the gravitational force and frictional force in an expression for Newton's second law	Point B2
	For using the relationship $a = r\alpha$ in an attempt to solve a system of equations	Point B3
Scoring Note: Responses that include conservation of energy may earn full credit.		

Example Response

$$\alpha_{\text{sys}} = \frac{\sum \tau}{I_{\text{sys}}}$$

$$\left(\frac{a}{R}\right) = \frac{fR}{I}$$

$$a = \frac{fR^2}{I}$$

$$\vec{a}_{\text{sys}} = \frac{\sum \vec{F}}{m_{\text{sys}}}$$

$$f - Mg \sin \theta = -Ma$$

$$f - Mg \sin \theta = -M \frac{fR^2}{I}$$

$$f + M \frac{fR^2}{I} = Mg \sin \theta$$

$$f \left(1 + \frac{MR^2}{I}\right) = Mg \sin \theta$$

$$f = \frac{Mg \sin \theta}{1 + \frac{MR^2}{I}}$$

C	For indicating "Equal to"	Point C1
	For a justification that includes that kinetic friction is only dependent on the surfaces (or equivalently, the coefficient of kinetic friction between those surfaces) and normal force	Point C2
Example Response <i>The forces of kinetic friction are equal. If slipping, the friction is kinetic, and the force of kinetic friction on the hoop and the disk are the same because the coefficient of kinetic friction is only dependent on the surfaces, and the normal forces on both are the same.</i>		