

# Rotational inertia and Newton's second law

AP Physics 1 (algebra-based) · Lab answers

The model answers use the sample data in the table. Your own wheel will have a different rotational inertia, but the increase caused by the clamps should be close to  $2mr^2$ , and the discussion of friction and uncertainty should be similar.

**Level:** AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 5

## Question 1 Acceleration of the mass

$$a = 2d/t^2 = 2 \times 1.00 \div (4.06)^2 = 2.00 \div 16.48 = \mathbf{0.121 \text{ m/s}^2}.$$

## Question 2 Tension and angular acceleration

$$\alpha = a/r = 0.1213 \div 0.050 = \mathbf{2.43 \text{ rad/s}^2}. T = m(g - a) = 0.500 \times (9.81 - 0.121) = \mathbf{4.84 \text{ N}}.$$

This is slightly less than the weight  $mg = 4.905 \text{ N}$ , because the mass accelerates downward.

## Question 3 Rotational inertia of the wheel

$$\tau = Tr = 4.844 \times 0.050 = 0.2422 \text{ N m}. I = \tau/\alpha = 0.2422 \div 2.427 = \mathbf{0.100 \text{ kg m}^2}.$$

## Question 4 Rotational inertia with the clamps

$$a = 2.00 \div (4.37)^2 = 0.1047 \text{ m/s}^2; \alpha = 2.095 \text{ rad/s}^2; T = 0.500 \times (9.81 - 0.1047) = 4.853 \text{ N};$$
$$\tau = 0.2426 \text{ N m}. I = 0.2426 \div 2.095 = \mathbf{0.116 \text{ kg m}^2}.$$

## Question 5 Testing the prediction

Predicted increase =  $2mr^2 = 2 \times 0.200 \times (0.20)^2 = 0.016 \text{ kg m}^2$ . Measured increase =  $0.1158 - 0.0998 = \mathbf{0.016 \text{ kg m}^2}$ . The two agree to within the precision of the data, supporting  $I = \Sigma mr^2$ .

## Question 6 Size of the correction

$(4.905 - 4.844) \div 4.905 = 0.012$ , a difference of **1.2 %**. For a rough estimate this is small, but because it enters  $I$  directly in a subtraction, it is better to keep the correction and use  $T = m(g - a)$ .

### Question 7 Uncertainty

Range =  $4.10 - 4.03 = 0.07$  s, so uncertainty  $\approx 0.035$  s, which is  $0.035 \div 4.06 = 0.9$  %.  
Since  $a \propto 1/t^2$ , the uncertainty in  $a$  is about **1.7** %.

### Question 8 Improvements

Friction in the axle slows the wheel, so the calculated  $I$  is too large; use a ball-bearing axle or measure friction by finding the mass that makes the wheel turn at a steady rate and allow for it. The string stretching or slipping on the spool changes the effective  $r$ ; use a thin non-stretching thread and wind it neatly. **Each reduces systematic error.**