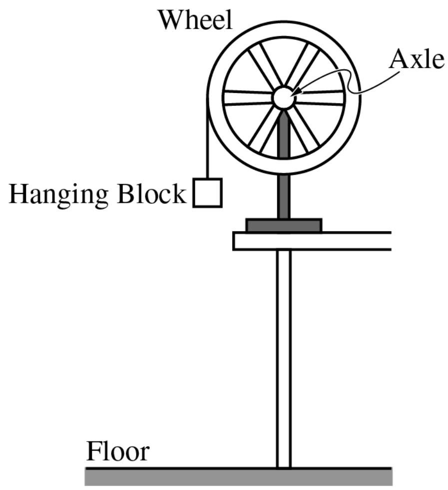
Begin your response to **QUESTION 3** on this page.



3. (12 points, suggested time 25 minutes)

A wheel is mounted on a horizontal axle. A light string is attached to the wheel's rim and wrapped around it several times, and a small block is attached to the free end of the string, as shown in the figure. When the block is released from rest and begins to fall, the wheel begins to rotate with negligible friction.

Two students are discussing how different forms of energy change as the block falls. One student says that the kinetic energy of the block increases as it falls. The second student says that this is because gravitational potential energy is converted to kinetic energy. The students decide to test whether the decrease in gravitational potential energy is equal to the increase in the block's kinetic energy from when the block starts moving to immediately before it reaches the floor.

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Continue your response to **QUESTION 3** on this page.

(a) Design an experimental procedure that the students could use to compare the increase in the block's translational kinetic energy with the decrease in the gravitational potential energy of the block-Earth system as the block falls.

In the table, list the quantities that would be measured in your experiment. Define a symbol to represent each quantity and list the equipment that would be used to measure each quantity. You do not need to fill in every row. If you need additional rows, you may add them to the space just below the table.

In the space to the right of the table, describe the overall procedure. Provide enough detail so that another student could replicate the experiment, including any steps necessary to reduce experimental uncertainty. As needed, use the symbols defined in the table.

If needed, you may include a simple diagram of the setup with your procedure.

Quantity to Be Measured	Symbol for Quantity	Equipment for Measurement	Procedure (and diagram, if needed)

(b) Explain how the students could determine the kinetic energy of the block immediately before it reaches the floor using the quantities you indicated in the table in part (a).

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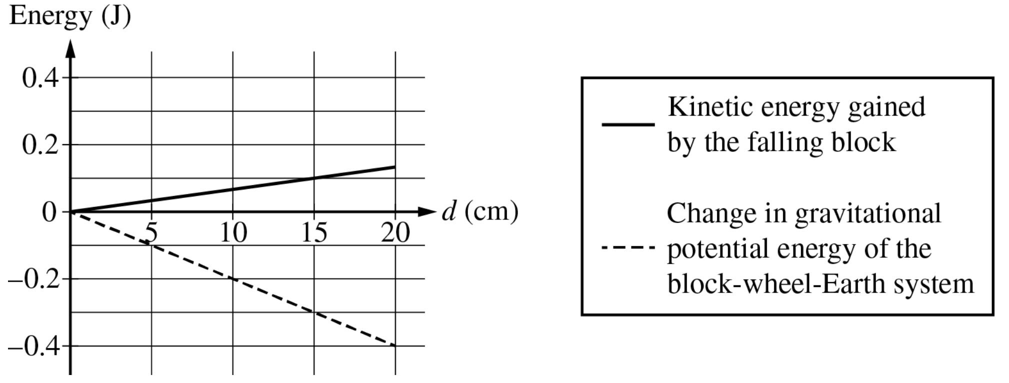
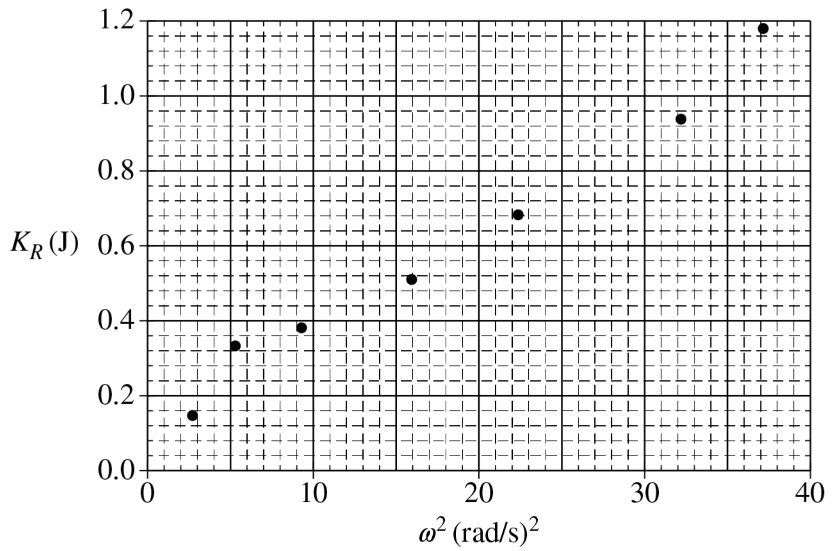
Continue your response to **QUESTION 3** on this page.



(c) The graph above represents both the change in the gravitational potential energy of the block-wheel-Earth system and the translational kinetic energy gained by the block as functions of the block's falling distance d. On the graph, draw a line or curve to represent the rotational kinetic energy of the wheel as a function of the block's falling distance d.

(d) The students also measure the angular velocity ω of the wheel as the block falls and determine the rotational kinetic energy K_R of the wheel. The students then make a graph of K_R as a function of ω^2, as shown.



i. On the above graph, draw a straight line that best represents the data.

ii. Using the line you drew for part (d)(i), calculate an experimental value for the rotational inertia of the wheel.

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Question 3: Experimental Design — 12 points

(a)	For listing relevant equipment that matches the measured quantities	**1 point**
	For listing measurements of quantities sufficient to determine the kinetic energy of the block	**1 point**
	For listing measurements of quantities sufficient to determine the gravitational potential energy of the block-Earth system	**1 point**
	For a plausible procedure (i.e., can be done in a typical school physics lab)	**1 point**
	For attempting to reduce uncertainty	**1 point**

Example Response

Quantity to Be Measured	Symbol for Quantity	Equipment for Measurement
Mass of block	m_B	Mass balance
Distance that block falls (initial height above floor)	d	Meterstick
Time for block to fall	t_B	Stopwatch

1. *Measure the mass of the block with the mass balance.*
2. *Hold the block in place with the string taut and measure the distance d with the meterstick.*
3. *Release the block and start the stopwatch.*
4. *Stop the stopwatch when the block hits the floor.*
5. *Record* d *and* t_B.
6. *Repeat steps* 3-5 *to get three separate trials at the same starting distance* d.
7. *Repeat steps* 2-6 *for several different starting distances* d.

Total for part (a) — 5 points

(b)	For indicating that mass and velocity are needed **Scoring Note:** This need not be the final velocity.	**1 point**
	For a valid explanation of how the final kinetic energy could be determined **Scoring Note:** This needs to be the FINAL kinetic energy.	**1 point**

Example Response

You can calculate the block's average speed by dividing $\frac{d}{t_B}$. *The block's final speed* v_F *is twice the average,* $\frac{2d}{t_B}$. *The kinetic energy* K *can then be calculated from*

$$K = \frac{1}{2}m_B\left(v_F\right)^2.$$

Total for part (b) — 2 points

(d)(ii) For correctly calculating a value for the slope using points on the line drawn, or a statement that a calculator was used to do a linear regression **1 point**

For **both** of the following: **1 point**

- correctly relating the slope of the graph to the rotational inertia
- a value of the rotational inertia I consistent with the calculated slope with correct units

Example Response

$$\text{slope} = \frac{1.04 - 0.20}{35 - 2.5} = 0.0258\ \text{kg} \cdot \text{m}^2$$

From $K = \frac{1}{2}I\omega^2$, *we have* $\text{slope} = \frac{1}{2}I$

The rotational inertia is $I = 2 \times \text{slope} = 0.0517\ \text{kg} \cdot \text{m}^2$

Total for part (d) 3 points

Total for question 3 12 points