Laboratory Manual: Work and Energy

Physics Department

1 Theoretical Background

The relationship between work and energy stands as one of physics' most elegant principles. When work is done on an object, that energy must go somewhere - typically manifesting as changes in the object's motion (kinetic energy) or position (potential energy).

> **Work-Energy Theorem**: The net work done on an object equals its change in kinetic energy

$$W_{net} = \Delta KE = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$

This experiment investigates this fundamental relationship using a cart-and-track system where we can precisely measure both the work done and the resulting change in kinetic energy.

2 Equipment

- Multi-purpose mechanical track system with leveling adjustment
- Two photogate sensors
- Cart with light blocking sheet (width = 0.002 m)
- Calibrated mass set and pulley system
- Digital timer (integrated with photogates)
- Level indicator

3 Experimental Setup

3.1 Key Parameters

- Fixed distance between photogates: 0.30 m
- Cart mass (including attachments): 0.225 kg
- Light blocking sheet width: 0.002 m

3.2 Setup Procedure

1. Level the track using the adjustment screws and level indicator 2. Mount photogates securely at 0.30 m separation 3. Attach pulley system to track end 4. Verify light blocking sheet triggers both photogates cleanly

4 Data Collection

For each trial:

1. Record the pulling force (F) from the hanging mass
2. Release the cart from rest
3. Record timing data (t_1, t_2) from both photogates
4. Repeat with different pulling forces (minimum 3 trials)

5 Analysis

5.1 Calculations

For each trial, calculate:

1. **Work Done**:
$$W = F \cdot d = F \cdot 0.30\,\text{m}$$
2. **Change in Kinetic Energy**:
$$\Delta KE = \frac{m}{2}\left(\left(\frac{0.002}{t_2}\right)^2 - \left(\frac{0.002}{t_1}\right)^2\right)$$

5.2 Data Analysis Table

Below is a sample data table showing the measurements and calculations:

t_1 (s)	t_2 (s)	M (kg)	s (m)	$F = 9.8m_1$ (N)	$W = Fs$ (J)	ΔKE (J)
0.07207	0.04399	0.225	0.30	0.0490	0.0147	0.0146
0.04964	0.03095	0.225	0.30	0.0980	0.0294	0.0287
0.04083	0.02542	0.225	0.30	0.1470	0.0441	0.0426
0.03259	0.02140	0.225	0.30	0.1960	0.0588	0.0559
0.03040	0.01965	0.225	0.30	0.2450	0.0735	0.0679

Table 1: Experimental measurements and calculated values

Where:

- t_1, t_2 are photogate timing measurements
- M is cart mass
- m_1 is hanging mass
- s is distance between photogates
- F is pulling force
- W is work done
- KE is change in kinetic energy

6 Discussion Points

Consider these questions while conducting your analysis:

1. List potential sources of discrepancy between work (W) and change in kinetic energy (ΔKE):
    - Rolling friction effects
    - Pulley system friction
    - Air resistance

- Mechanical vibrations
- String elasticity

2. Consider how friction would affect:
   - The measured ΔKE versus calculated work
   - Results at different velocities
   - Measurements over varying distances
3. Explain the advantages of photogate timing over direct velocity measurements:
   - Precision considerations
   - Measurement errors
   - Practical limitations
   - Data reliability

7 Common Sources of Error

- Track leveling imperfections
- Friction in the pulley system
- Air resistance
- Timing uncertainties in photogate measurements
- Cart wobble or vibration

8 Extensions

For advanced investigation:

- Plot W vs ΔKE and analyze the slope
- Investigate the effect of track angle on results
- Model the impact of friction quantitatively