Physics Club - Work, Energy and Power

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1 Introduction

What is energy? It is a tricky question. The official definition is "the ability to do work", but I, perhaps along with you, find this rather unsatisfactory. I haven't yet come across a good definition for energy, but if I do, I'll let you know. Until then, there are two broad kinds of energy - kinetic (energy of objects in motion), and potential (energy stored in an object that can be transferred to different stores). The symbol for kinetic energy is T, from the French verb "travailler" meaning "to work". The symbol for potential energy is U, because "U" have a lot of potential! Here is a quick reminder of the formulae for some common types of energy: $T = \frac{1}{2}mv^2$, $\Delta U_g = mg\Delta h$, $U_e = \frac{1}{2}kx^2$.

Question 1 (Physics Club Original) A bob is attached to a string of length L, with the opposite end fixed on the roof. The bob is initially held at an angle θ to the vertical, and then is released. Derive an expression in terms of L and θ for the kinetic energy of the bob at any given angle α.

Question 2 (Isaac Physics) A bungee jumper of mass m falls through a height h before his cord goes taut. If the spring constant of the cord is k, derive an expression for the height at which the jumper first comes to rest.

2 Work and Power

Work is the transfer of energy due to a force. Before we can use calculus in physics, we are often taught that $W = F \cdot d$ or, in the case that the force does not act in a parallel direction to the displacement, $W = Fd\cos(\theta)$, where θ is the angle between the force and the displacement. (After we are introduced to calculus and vectors, we will see that the more proper definition is $W = \int \vec{F} \cdot d\vec{s}$). Similarly, power is the rate of transfer of energy, hence $P = \frac{E}{t}$, (or, if we are alright with some calculus, $P = \frac{dE}{dt}$).

Question 3 (PAT 2006) This problem concerns the mathematical treatment of a simple model of an electric toy car of mass m, which is initially stationary. The batteries in the car can be considered as an electrical power source with constant power P. You may neglect air-resistance and other experimental imperfections in the calculations. Suppose that the car is placed on a level surface and that the motor can be treated as a device which converts electrical energy directly into kinetic energy. Calculate the kinetic energy of the car as a function of time, and hence its velocity as a function of time. Find the limiting value of the velocity at very large times and comment on whether your result seems reasonable. Instead of driving the car forward the motor could be used to lift the car up a vertical rope. Calculate the height which the car can reach as a function of time, and hence calculate the velocity at which it climbs the rope. The calculation above ignored the fact that as the car is moving then some of the motor's power must be used to give kinetic energy to the car. Assuming that the approach you used above is correct, calculate the ratio between the kinetic energy and the potential energy of the car climbing the rope as a function of time. Use your result to determine under what circumstances it is reasonable to ignore kinetic energy in this way.

3 Extension problems and resources

Question 4 (Physics Club Original) Derive the equation for kinetic energy by using SUVAT equations (use the work done by a force on an object in accelerating it from rest, this will be the kinetic energy of the object)

Question 5 (Physics Club Original) - requires some maths If a force acts on an object in the $+x$ direction, given by $F(x) = x^3 - 3x^2 + 5$, find the kinetic energy of the object as a function of x

If you are willing to learn some new and difficult mathematics, check out Lagrangian Mechanics. As always, the Isaac Science website and the BPhO is a great source of information and enrichment!

Thank you all for coming!