Physics 2A Spring 2020
Discussion 6

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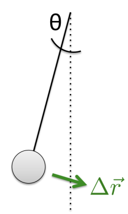
1. **Warm-ups**[1]



(a) In the motion of a swinging pendulum, which of the following forces does positive work?

A. Tension

B. Drag force

C. Weight

D. None of the above

Solution: C. The tension is perpendicular to the path so it does no work. The drag force is dissipative and does negative work. The weight has a component parallel to the path which does positive work.

(b) A person is jumping on a trampoline, what is true about the person's energy between the bottom of the jump (fully compressed trampoline) and top of the jump?

A. KE is lower and PE is higher at top of the jump

B. KE is lower and PE is higher at bottom of the jump

C. KE and PE are the same at top and bottom

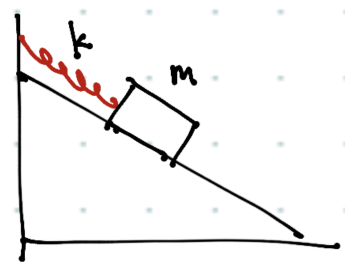
D. KE and PE are both higher at the top of the jump

E. KE and PE are both higher at the bottom of the jump

Solution: C. The kinetic energy is 0 at both the top and bottom since the person has zero velocity at both points. Since there is no external work, energy is conserved so the potential energy must be the same at both points.

[1] From Prof. Burgasser's TPS worksheet

2. **Calculating work**



A block is lying on an inclined plane angled at θ from the ground and connected to the wall by a spring, which has a rest length of L (unstretched length). We then release the block from rest when the spring is at its rest length.

(a) What is the length of the spring when it's fully stretched if the inclined plane has a kinetic friction coefficient of μ?

Solution: There are four forces acting on the block. As usual, the normal force $F_N = mg\cos\theta$ and it does no work. If the length of the spring increases by Δx when it's fully stretched, the total work done as the block slides down the ramp is

$$\begin{aligned} W &= \int \vec{F} \cdot d\vec{r} = \int_0^{\Delta x} (mg\sin\theta - \mu mg\cos\theta - kx)dx \\ &= mg\Delta x\sin\theta - \mu mg\Delta x\cos\theta - \frac{1}{2}k(\Delta x)^2 = \Delta KE = 0 \end{aligned} \tag{1}$$

since the block is at rest initially and will have zero velocity when fully stretched. Solving this equation gives

$$\Delta x = \frac{2mg}{k}(\sin\theta - \mu\cos\theta) \tag{2}$$

and the fully stretched length is $L + \Delta x$.

(b) Write down an equation with the initial KE and PE on the left hand side and final KE and PE on the right hand side. Also include other work involved in the process. Identify each term with the work done by specific forces we calculated in the last part.

Solution: We start by writing down

$$\frac{1}{2}mv_i^2 + mgh_i + \frac{1}{2}k(\Delta x_i)^2 + \Delta W_{dissipative} = \frac{1}{2}mv_f^2 + mgh_f + \frac{1}{2}k(\Delta x_f)^2 \tag{3}$$

where $\Delta W_{dissipative} < 0$. Both $v_i = v_f = 0$. Initially the spring is unstretched so $\Delta x_i = 0$. We recognize that $mg(h_i - h_f) = mg\Delta x\sin\theta$ is the work done by weight. This means $\Delta W_{dissipative} = -\mu mg\Delta x\cos\theta =$ work done by friction.

3. **Energy conservation**

If we wish to send a probe to distant planets, the rocket carrying the probe must achieve a sufficiently large velocity in order to escape the Earth's gravitational pull. Otherwise the rocket will remain in orbit around the Earth or fall back to the Earth. What is this escape velocity? What is the work done by Earth's gravity as the probe escapes?

Solution: An escaped object is not gravitationally bound by the Earth, which means its gravitational potential energy is zero ($r_f = \infty$). Assume there is no external work done on the object

$$\frac{1}{2}mv_i^2 - \frac{GM_Em}{r_i} = \frac{1}{2}mv_f^2 - \frac{GM_Em}{r_f} \tag{4}$$

Since we are looking for the minimum v_i, we set $v_f = 0$, so $V_{escape} = \sqrt{\frac{2GM_E}{R_E}}$. The work done by gravity is $-\frac{GM_Em}{r_i} + \frac{GM_Em}{r_f} = -\frac{GM_Em}{R_E}$.