2018-2019 Term 2

PHYS1001 Essential Physics

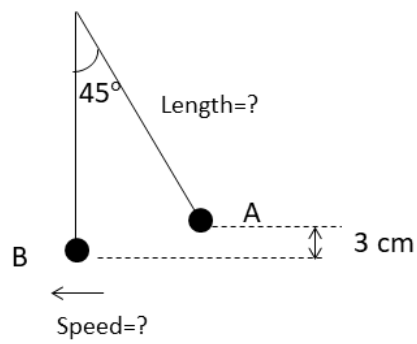
Assignment 3

Due date: 19th Feb, 2019 by 6:00 pm

(Please leave your homework in the box with the label "PHYS 1001" outside room 213 in Science Centre North Block)

Please answer **all** six questions

1. A pendulum is released from rest and undergoes swinging motion from A to B. The string makes an angle of 45° with the vertical axis initially. The change in the height of the ball is 3 cm from A to B. Ignore the effect of air resistance.



(a) At which point does the pendulum has (i) a higher K.E. and (ii) a higher P.E.??
(b) Calculate the speed of the pendulum at point B.
(c) Calculate length of the string.

Answer:

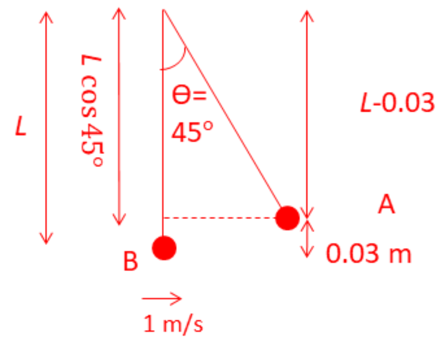
(a) Point B has a higher K.E. while point A has a higher P.E.. Potential energy is converted to kinetic energy when the pendulum moves from point A to point B.
(b) By conservation of energy,

$$K.E._A + P.E._A = K.E._B + P.E._B$$
$$K.E._A - K.E._B = P.E._B - P.E._A$$

At the highest point, *v*=0. Kinetic energy at point B is zero.

$$K.E._B - K.E._A = P.E._A - P.E._B$$
$$\frac{1}{2}m{v_B}^2 - \frac{1}{2}m{v_A}^2 = mgh$$
$$\frac{1}{2}{v_B}^2 - \frac{1}{2}{v_A}^2 = gh$$
$${v_B}^2 - 0^2 = 2(9.8)(0.03)$$
$$v_B = 0.77\ \text{m/s}$$

(c)

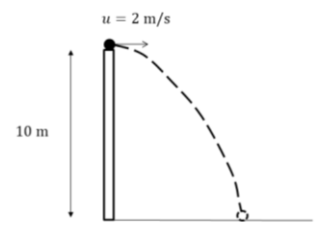


Consequently,

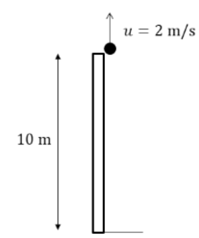
$$L\cos 45^\circ = L - 0.03$$

$$L = 0.10\ \mathrm{m}$$

2. (a) A ball with mass 0.5 kg is projected horizontally at the height of 10 m with an initial speed of 2 m/s as shown in the figure on the right. Using the conservation of energy, calculate the speed of the ball when reach the ground. Ignore the effect of air resistance.



(b) The same ball is thrown vertically upward from a height of 10 m as shown in the figure on the right. The initial speed of the ball is 2 m/s. Using the conservation of energy, calculate the speed of the ball when reach the ground. Ignore the effect of air resistance.



Answer:

(a) Suppose the start point is A and the finish point is B.
By conservation of energy from A to B,

$$K.E._A + P.E._A = K.E._B + P.E._B$$

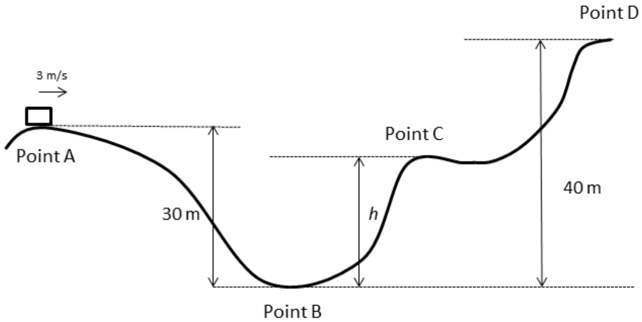
Suppose at the highest point, P.E.=0. Then the P.E. at point B should be *-mgh*.
Kinetic energy at point A is $\frac{1}{2}mv_0^2$.
We have:

$$\frac{1}{2}(0.5)(2)^2 + (0.5)(9.81)(10) = \frac{1}{2}(0.5)v^2$$

$$v = 14.1 \text{ m/s}$$

(b) The initial K.E. of the ball is the same as before. The change in P.E. is also the same as before. The speed of the ball is the same as before. The final speed of the ball is also 14.1 m/s

3. A roller coaster with a mass 600 kg travels on a track from point A to point C as shown below. The initial velocity of the roller coaster is 3 m/s at point A. Ignore friction and air resistance in the following question.



(a) Calculate the initial kinetic energy at point A.
(b) Calculate the velocity of the roller coaster at B.
(c) Calculate the difference in height *h* between point B and C if the velocity at point C is 10 m/s.
(d) Will the roller coast reach point D? Explain your answer.

Answer:

(a) $\text{K.E.}_A = \frac{1}{2}mv_A{}^2 = \frac{1}{2}(600)(3)^2 = 2700$ J

(b) By conservation of energy,

$$\text{K.E.}_A + \text{P.E.}_A = \text{K.E.}_B + \text{P.E.}_B$$
$$\text{K.E.}_B - \text{K.E.}_A = \text{P.E.}_A - \text{P.E.}_B$$
$$\frac{1}{2}mv_B{}^2 - \frac{1}{2}mv_A{}^2 = mg\Delta y$$
$$\frac{1}{2}v_B{}^2 - \frac{1}{2}v_A{}^2 = g\Delta y$$
$$\frac{1}{2}v_B{}^2 - \frac{1}{2}(3)^2 = g(30)$$
$$v_B = 24.4 \text{ m/s}$$

(c)
$$\text{K.E.}_A + \text{P.E.}_A = \text{K.E.}_C + \text{P.E.}_C$$
$$\frac{1}{2}mv_C{}^2 - \frac{1}{2}mv_A{}^2 = mg\Delta y$$
$$\frac{1}{2}v_C{}^2 - \frac{1}{2}v_A{}^2 = g(30 - h)$$
$$\frac{1}{2}(10)^2 - \frac{1}{2}(3)^2 = g(30 - h)$$
$$h = 25.4 \text{ m}$$

(d) Let point E be the highest point reached by the roller coaster

$$\text{K.E.}_A - \text{K.E.}_E = \text{P.E.}_E - \text{P.E.}_A$$

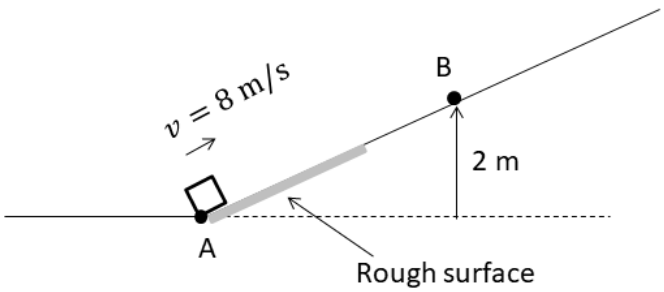
$$\frac{1}{2}m{v_A}^2 - \frac{1}{2}m{v_E}^2 = mg\Delta y$$

$$\frac{1}{2}(3)^2 - 0 = (9.8)\Delta y$$

$$\Delta y = 0.46 \text{ m}$$

Since point D is 10 m above point A, the roller coaster does not have enough energy to reach point A.

4. A 2 kg block which is initially at point A moves up an incline plane at 8 m/s. Point B is at a height of 2 m above the horizontal ground. It is known that the energy loss when the block moves on the rough surface is 30 J. Can the block reach B? Explain your answer.



Answer:

To reach point B, the block at least needs the following amount of energy:

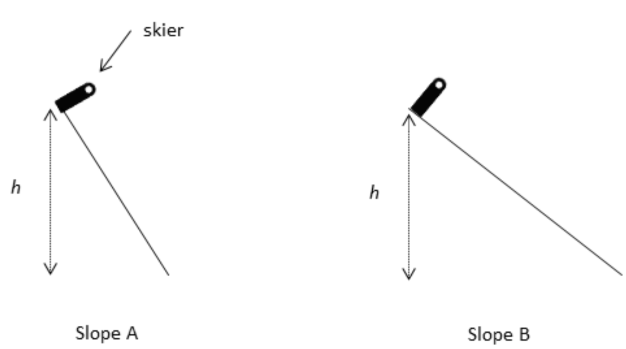
$$\Delta \text{P.E.} + \text{Energy loss} = mgh + \text{Energy loss} = (2)(9.81)(2) + 30 = 69.24 \text{ J}$$

The initial energy of the block is:

$\text{K.E.}_{initial} = \frac{1}{2}(2)(8)^2 = 64 \text{ J}$

Since the initial total energy of the block is smaller than the energy required to move up the incline plane, the block does not have enough energy to reach point B.

5. Discuss which skier has a higher speed at the bottom of the slope (a) by neglecting the effect of friction (b) in the presence of friction, assuming the skier starts from rest and the frictional force is the same in both cases.



Answer:

(a) By conservation of energy, the kinetic energy is equal to the drop in potential energy. Since the potential energy is equal to $mg\Delta y$ and Δy are the same in the two cases, the kinetic energies at the bottom of the hill in both cases are the same. Hence the velocity of the skier is the same in the two cases.

(b) If friction exists between the skier and the slope, the kinetic energy is equal to the drop in potential energy minus the work done against friction. The work done against friction is equal to $F_{friction} \times d$. In the question, it is stated that $F_{friction}$ is the same for both cases. However, the length of the incline d is longer in B so work done against friction is larger for slope B. Thus the kinetic energy at the bottom of slope B is smaller than that at the bottom of slope A. The skier has a higher velocity at the bottom of slope A.

Note that the analysis in part (b) is closer to reality. The higher speed at the bottom of slope A is due to less work done against friction but not to a steeper slope.

6. A block of mass 1 kg is released from rest at point A. It travels down a rough curve surface AB and a rough surface BC and finally stops at point C. The curve AB is a quarter of a circle with a radius of $R = 0.8$ m. The length of BC is 3 m. The friction acting on the block while it moves on the horizontal track is 0.65 N. Calculate the work done by friction on the block when it moves along the track AB.

Answer:

According to energy conservation from A to C:

$$\mathrm{K.E.}_A + \mathrm{P.E.}_A = \mathrm{K.E.}_C + \mathrm{P.E.}_C + \text{energy loss}$$

Suppose $\mathrm{P.E.}_C = 0$. Then $\mathrm{P.E.}_A = mgh = (1)(9.81)(0.8)$. energy loss $= \mathrm{W}_{BC} + \mathrm{W}_{AB}$

$$0 + (1)(9.81)(0.8) = 0 + 0 + (0.65)(3) + \mathrm{W}_{AB}$$

$$\mathrm{W}_{AB} = 5.9\ \mathrm{J}$$

The work done by friction is -5.9 J