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Research Article

SOLVING MECHANICAL PROBLEMS

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ABSTRACT

This article addresses nine issues related to the Department of Mechanics of Physics.

KEYWORDS
Motion, time, distance, velocity, acceleration, coordinate, gravitational force, free fall acceleration, equation, vertical, horizontal.

INTRODUCTION

Issue 1. What is the duration of T per day for objects to be weightless at the equator? Assume that the radius of the earth is R = 6400 km.

Given: R = 6400 km.

Need to find: T =?

Solution. To solve the problem, P = mg is determined by Newton's second law of gravity $_{1}\frac{2}{}$ We use the condition that the force is equal to, where m is the mass of the body, v is the velocity of its density, R is the radius of the Earth, that is

$$\frac{2}{} = ; \frac{2}{} = ,$$

But

$$= \frac{2}{},$$

In that case

$$\frac{4^{22}}{2} = g,$$

From this

$$\frac{4\pi^2 R}{g},$$

or

$$T=2\pi\sqrt{\frac{R}{g}};\ T=\text{-1 hour 24 min.}$$

Answer: $T=2\pi\sqrt{\frac{R}{g}}$; T=-1 hour 24 min.

Issue 2. If bodies are weightless at the equator of a spherical planet with T = 10 per day, calculate the density p of the planet's matter.

Given: T=-1 hour $36*10^3$ c; γ=$6.67x\ 10^{-11}\ \frac{M^3}{kg*c^2}$

Need to find: p=?

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Solution. Since objects are weightless at the equator, the following equation can be written:

$$\gamma * \frac{Mm}{R^2} = \frac{mv^2}{R}$$

In this case, the expression on the left side of the equation is the force acting on the body according to the law of universal gravitation, and on the right according to Newton's law II. This is equal

$$v = \frac{2\,\pi R}{T},$$

and

$$M = \frac{4}{3}\,\pi R^3 p$$

Given that, it can be written as follows:

$$\gamma * \frac{4\pi R^3 p}{3R^2} = \frac{4\pi^2 R^2}{T^2 R},$$

or

$$\frac{\gamma p}{3} = \frac{}{2}$$

From this

$$p = \frac{3}{2\gamma} \cong 108{,}9\frac{kg}{M^3}.$$

Answer: $\rho \cong 108{,}9\,\frac{kg}{M^3}$

Issue 3. Two satellites are moving around the Earth in orbits at altitudes h1 and h2. Determine the ratio of the velocities of these satellites v1 / v2 and the ratio of the cycles T1 T2. The radius of the Earth is R.

Given: h_1; h_2; R.

Need to find: T_1/T_2=? v_1/v_2= ?

Solution. The following can be written for both satellites :

$$\gamma * \frac{m_1 M}{(h_1+R)^2}=\frac{m_1 v_1^2}{R+h_1}=m_1 g,$$

$$\gamma * \frac{m_2 M}{(h_2+R)^2}=\frac{m_1 v_2^2}{R+h_2}=m_2 g,$$

in this case $m_1\ va\ m_2$ – masses of satellites, h1 and h2- their height above the ground, respectively, v1 / v2- their velocities, γ- gravitational constant; g -free fall acceleration.

From this, $\frac{v_1^2}{R+h_1}$=g; $\frac{v_2^2}{R+h_2}$=g;

or $\frac{v_1^2}{R+h_1}=\frac{v_2^2}{R+h_2}$; $\frac{v_1^2}{v_2^2}=\frac{R+h_1}{R+h_2}$,

or $\frac{v_1}{v_2}=\sqrt{\frac{R+h_1}{R+h_2}}$.

If we consider the first pair of equations, then

$$\gamma * \frac{Mm_1}{(R+h_1)^2} = \frac{m_1}{R+h_1} * \frac{4\pi^2 (R+h_1)^2}{T_1^2},$$

$$\gamma * \frac{Mm_2}{(R+h_2)^2} = \frac{m_2}{R+h_2} * \frac{4\pi^2 (R+h_2)^2}{T_2^2},$$

or

$$\gamma * \frac{M}{(R+h_1)^2} = \frac{4\pi^2 (R+h_1)}{T_1^2},$$

$$\gamma * \frac{M}{(R+h_2)^2} = \frac{4\pi^2 (R+h_2)}{T_2^2}.$$

Dividing them one by one, we create the following:

$\frac{(R+h_2)^3}{(R+h_1)^3} = \frac{T_2^2}{T_1^2}$ yoki $\frac{T_1^2}{T_2^2}= \frac{(R+h_1)^3}{(R+h_2)^3}$

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From this $\frac{T_1}{T_2} = \sqrt{(\frac{R+h_1}{R+h_2})^3}$.

Answer: $\frac{v_1}{v_2} = \sqrt{\frac{R+h_1}{R+h_2}}; \frac{T_1}{T_2} = \sqrt{(\frac{R+h_1}{R+h_2})^3} == \sqrt{(\frac{R+h_1}{R+h_2})^{3|2}}$

Determine the first cosmic velocity v1 for a planet whose mass and radius are 3 times larger than Earth.

Given: R1 = 3R; M1 = 3M.

Need to find: v_1 1 =?

Solution: .You can write the following for any planet

$$\gamma * \frac{M_1 m}{R_1^2} = \frac{m v_1^2}{R_1} = m g_1,$$

where g_1 is the acceleration of free fall for this planet, v_1 is the first cosmic velocity, and *m* is the mass of the body.

In this case $v_1^2 = R_1 g_1$,

From this $v_{1=}\sqrt{R_1 g_1}$, $\gamma * \frac{M_1 m}{R_1^2} = m g_1$

That is $g_1 = \gamma * \frac{M_1}{R_1^2}$.

According to the condition $g_1 = \frac{3M}{(3R)^2}$

$$\upsilon_1 \sqrt{3R * \gamma * \frac{3M}{9R^2}} = \sqrt{\frac{\gamma M}{R}} = 7{,}9 \frac{km}{c},$$

where M is the mass of the Earth, it $M=6*10^{24}$ g.

Answer : υ_{1}=7,9 km/c.

Issue 5. and is directed vertically downwards. Calculate the work A done by the body over time τ =10s against the resistance forces. At the end of this time, it turns out that the body has a velocity υ=50m/s It turns out that Assume the resistance force is constant.

Given : m=3 kg ; υ_0 = 2m/c ; τ =10s ; υ =50m/s F_{qarsh}=const.

Need to find: A =?

Solution. To a freely falling body in a given state $\vec{P}$- weight $\vec{F}_{qarsh}$- resistance. The law of motion is written as follows :

$P-F_{qarsh}=ma.$

From this

$F_{qarsh}-P=ma.$

According to the expression for determining the velocity in a plane accelerating motion

$$\upsilon=\upsilon_0+at,$$

From this

$a=\frac{\upsilon-\upsilon_0}{t}.$

Now it is possible to determine the resistance force by knowing the acceleration:

$F_{qarsh}=mg-ma=m(g-a)$=15H.

Because the motion is smoothly accelerating

$$h=\upsilon_0 t+\frac{at^2}{2}.$$

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It can be used to determine the distance traveled in 10 s :

h=260 m.

Because the power is constant F_{qarsh} =const=15N, in that case

A= F_{qarsh} *h=3900 J.

Answer : A=3,9 kJ.

Issue 6. The body is first the angle of inclination a =30° from the inclined plane, then slides on a horizontal surface and passes the same distance in both planes (Fig. 1). Find the coefficient of friction k, which is the same in the horizontal and oblique planes.

Given : =$a = 30^0$

Need to find : k= ?

Solution : In a body standing on a sloping plane $\vec{P}$ – gravity , $\vec{N}$- reaction force and friction force.

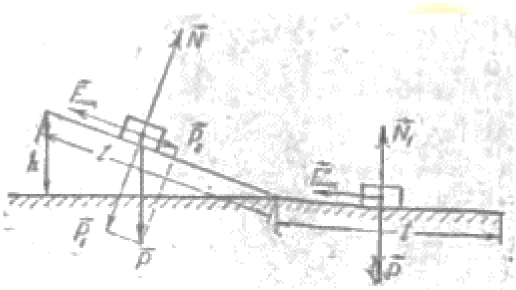

Figure 1

The initial energy reserve (potential) is used to overcome the frictional force in the inclined plane and to work against the frictional force on the horizontal surface.

Let the slope l be the length of the horizontal surface , $l\sin a = h -$ the height of the slope. In this case, the potential energy of an object standing at a height h in the inclined plane

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$$W_{pot} = mglsina$$

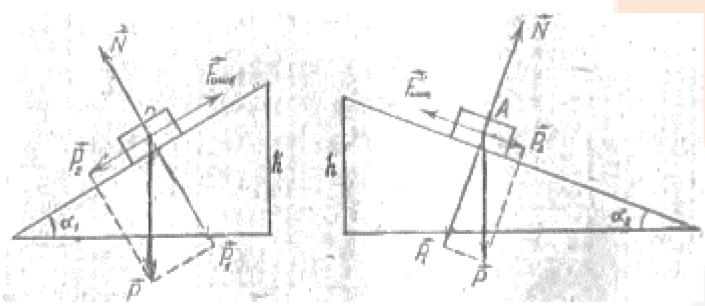
$P_1 = Pcosa = N$, N – the reaction force of the land

$F_{ishq} = kN = kmgcosa$ horizontal surface $N_1 = P$, so $F''_{ishq} = kmg$. From this $A_1 = lF''_{ishq} = klmg$ – work done in the horizontal plane . w_{pot}=A_1+A_2 or $mglsina = klmg(cosa + 1)$ or $sina = k(cosa + 1)$, from this,

$$k = \frac{sina}{cosa+1} = \frac{0,5}{0,866+1} = 0,27.$$

Answer : $k = 0.27$.

Issue 7 : From point A, the two bodies begin to slide in two different inclined planes without initial velocity. a) Excluding friction; b) the ratio of velocity based on inclined planes, taking into account friction $\frac{v_1}{v_2}$ should be found . In this case, k is the same for both planes (Figure 2).



(Figure 2).

Solution. a) Using the law of conservation of energy in the absence of friction, we can write that the potential energy at point A is equal to the kinetic energy at the base of the inclined plane:

$w_A = mgh$; $mgh = \frac{v^2 m}{2}$; hence $v_1 = \sqrt{2gh}$ va $v_2 = \sqrt{2gh}$, $\frac{v_1}{v_2} = 1$, that is, the velocity ratio is 1.

b) To find the base reaction force in the presence of friction, we divide the gravitational force into components. Slopea_1 for an inclined plane

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$$P_1 = N = Pcosa_1 = mgcosa_1.$$

In this case

$$F'_{ishq} = kmgcosa_1,$$

while the work done

$$A_1 = F'_{ishq} * l_1 = kmhctga_1.$$

Herein $\frac{h}{l_1} = sina_1$, So $l_1 = \frac{h}{sina_1}$.

In the same way, for an inclined plane with slope a_1 For an inclined plane, we write:

$$P_1 = N_1 = pcosa_2 = mgcosa_2.$$

In that case $F''_{ishq} = kmgcosa_2$ while the work done $A_2 = F''_{ishq} l_2 = kmghctga_2$.

Herein $\frac{h}{l_2} = sina_2$, so $l_2 = \frac{h}{sina_2}$

In the presence of friction, the potential energy is used to overcome the frictional force and the kinetic energy is expended.

For the first body: $mgh = kmgh\ ctga_1 + \frac{mv_1^2}{2}$;

For the second body: $mgh = kmgh\ ctga_2 + \frac{mv_2^2}{2}$;

$$gh(1 - kctga_1) = \frac{v_1^2}{2} ;$$

$$gh(1 - kctga_2) = \frac{v_2^2}{2} ;$$

or divide the first equation by the second and get the following:

$$\frac{v_1^2}{v_2^2}=\frac{1-kctga_1}{1-kctga_2}.$$

Henceforth

$$\frac{v_1}{v_2}=\sqrt{\frac{1-kctga_1}{1-kctga_2}}.$$

Answer : a) $\frac{v_1}{v_2}=1;$ b) $\left(\frac{v_1}{v_2}\right)_1=\sqrt{\frac{1-kctga_1}{1-kctga_2}}.$

Issue 8. The boy leaned against the barrier and threw the stone at a horizontal speed v_0=14 m/s If a child skates on the ice with the previous force, does the stone gain v speed relative to the ground? If the coefficient of friction of the skate on the ice is *k* = 0.02, how much distance did the child slip after throwing the stone and stop? The mass of the stone *m*=1 *kg*, the mass of the child *M*=36*kg*.

Given : v_0=14 m/s ; *m*=1 *kg* ; M=36*kg* ; *k*=0,02.

Need to find : υ= ? *l*= ?

Solution. According to the law of conservation of energy, the following can be written:

$$\frac{v_0^2}{2}=\frac{mv^2}{2}+\frac{v_1^2}{2},$$

Herein v_1- the speed of the child's movement, v- the speed of the stone. According to the law of conservation of momentum :

$$M\, v_1 mv, \text{ henceforth } v_1=\frac{m}{M}v$$

or

$$\frac{v_0^2}{2}=\frac{mv^2}{2}+\frac{Mm^2}{2M^2}v^2\,;\ \frac{v_0^2}{2}=v^2\left(\frac{1}{2}+\frac{m}{2m}\right);$$

$$v_0^2=v^2\left(\frac{M+m}{M}\right);\ v^2=v_0^2\frac{M+m}{M};\ v=v_0\sqrt{\frac{M}{M+m}}\cong 13.8\frac{M}{c}.$$

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In the first case when the child throws a stone A=$\frac{v_0^2}{5}$ did the job. In the second case, the child throws the stone with the same force, he does the same work, but this work is spent on giving the stone both kinetic energy and himself. Therefore, in this case it is possible to apply the law of conservation of energy. As the child gains speed, he also acquires kinetic energy, which is used to overcome the force of friction. This is the speed that the child gets

$$mv_1 = mv;\ v_1 = \frac{mv}{M}$$

We find from equality. Then we put the following equation in the expression of the law of conservation of energy:

$$\frac{Mv_1^2}{2} = F_{ishq}\, l, \text{ henceforth s } \frac{Mv_1^2}{2F_{ishq}} = l,$$

From this F_{ishq}=kMg. In this case

$$l = \frac{Mv_1^2}{2kMg} = \frac{v_1^2}{2kg} = \frac{m^2v^2}{2M^2kg} = \frac{m^2v_0^2M}{2Mkg(M+m)} = \frac{m^2v_0^2M}{2Mkg(M+m)} \cong 0{,}37 \text{ M.}$$

Answer : $v = 13{,}8\frac{M}{c}$, $l = 0{,}37$ M.

Issue 9. A balloon of mass m descends from a height *H* and sinks into the water to a depth *h* and rises. The volume of the bubble is *V* and its density is less than the density of water. Water resistance to bubbles F_{qarsh} (assume it is constant), as well as the height at which it rises from the water h_1 (Figure 3). Ignore air resistance.

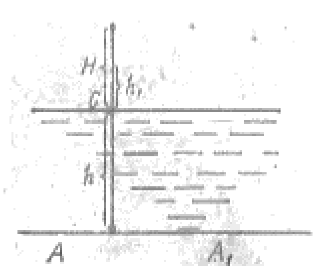

Figure 3

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Given : V ; H ; h.

Need to find : F_{qarsh} = ? h_1 = ?

Solution. Balloon AA_1 relative to the level W_p=mg (H+h) potential energy. This initial energy reserve is used to work against the Archimedean force, which acts on the water resistance against the energy and the collapsing bubble, that is

$$mg\,(H+h) = F_{qarsh}\, h + Vpgh,$$

$$mg\,(H+h) - Vpgh = F_{qarsh}\, h.$$

From this

$$F_{qarsh} = \frac{mg\,(H+h) - Vpgh}{h} = \frac{mg\,(H+h)}{h} - Vpg,$$

In this case, the density of p-water: The ball is at point C.

$$W_p' = F_A * h = Vpgh$$

has an initial potential energy reserve, which is the potential consumption relative to the work of overcoming the resistance force and the water surface, in which case

$$F_A h = hF_{qarsh} + mg(h_1 + h).$$

From this

$$h_1 = \frac{F_A h - hF_{qarsh} - mgh_1}{mg} = \frac{Vpgh - mg(H_1+h) + Vpgh - mgh}{mg} = \frac{2Vpgh - 2mgh - mgH}{mg} = \quad = 2h\left(\frac{Vp}{m} + 1\right) - H.$$

Answer: $F_{qarsh} mg\left(\frac{H}{h} + 1\right) - Vpg;$

$$h_1 = 2h\left(\frac{Vp}{m} - 1\right) - H.$$

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