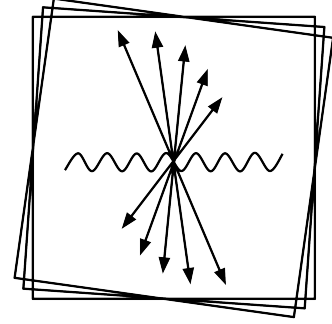


International Physics Competition

The Education Program & Talent Search in Physics

Edition of 2025

Solution: Qualification Round



Solution to Problem A

To determine where the human (H) and the turtle (T) meet, we write their positions as functions of time t , where x_0 is the turtle's head start:

$$x_H(t) = v_H t, \quad x_T(t) = v_T t + x_0.$$

They meet at the time $\tilde{t}$ when both positions are equal:

$$x_H(\tilde{t}) = x_T(\tilde{t}) \implies v_H \tilde{t} = v_T \tilde{t} + x_0 \implies \tilde{t} = \frac{x_0}{v_H - v_T}.$$

The position at which they meet is then

$$\tilde{x} = x_H(\tilde{t}) = v_H \tilde{t} = \frac{v_H}{v_H - v_T} x_0 = \frac{x_0}{1 - \frac{v_T}{v_H}}.$$

Given that $v_H = n \cdot v_T$, we obtain

$$\tilde{x} = \frac{x_0}{1 - \frac{1}{n}}.$$

For $n = 100$ and $x_0 = 980$ m, this gives

$$\tilde{x} = 990 \text{ m}.$$

Since this distance is less than the total race length of 1 km, the human catches the turtle before the finish line and therefore wins the race.

Solution to Problem B

The tension in the vertical string is mg . Since the mass m is at rest, this downward force must be balanced by the sum of the vertical components of the forces in the two upper strings. Because both strings make the same angle α with the vertical, their tensions are equal:

$$mg = F_{\perp,1} + F_{\perp,2} = 2F_{\perp}.$$

Each vertical component is

$$F_{\perp} = F \cos \alpha,$$

so the tension in each upper string is

$$F = \frac{F_{\perp}}{\cos \alpha} = \frac{mg}{2 \cos \alpha}.$$

Because the pulleys are ideal, the tension in the string attached to mass M equals the weight of M :

$$Mg = F = \frac{mg}{2 \cos \alpha} \quad \Rightarrow \quad M = \frac{m}{2 \cos \alpha}.$$

With $m = 2 \text{ kg}$ and $\alpha = 80^\circ$, we obtain

$$M = 5.76 \text{ kg}.$$

Solution to Problem C

(a) For an ideal gas,

$$pV = Nk_B T.$$

At ground level, this gives (with volume $V = \pi R^2 L$)

$$N = \frac{p_1 V}{k_B T_1} = \frac{p_1 \pi R^2 L}{k_B T_1}.$$

Inserting the values we obtain

$$N = 1.4 \cdot 10^{22}.$$

b) The bottle is sealed and rigid, so N and V remain constant. From

$$pV = Nk_B T$$

it follows that

$$\frac{p}{T} = \frac{Nk_B}{V} = \text{const.}$$

Thus,

$$\frac{p_1}{T_1} = \frac{p_2}{T_2} \quad \Longrightarrow \quad p_2 = p_1 \frac{T_2}{T_1}.$$

Inserting the values we obtain

$$p_2 = 98.6 \text{ kPa.}$$

Solution to Problem D

The ball slides without friction, so along each straight slope it has constant acceleration given by the component of gravity along the slope. Since the slopes are inclined at angles θ_i to the *vertical*, the component of g along the slope is

$$a_i = g \cos \theta_i.$$

On the first slope, the distance along the slope is x_1 and the initial speed is 0:

$$x_1 = \frac{1}{2}a_1t_1^2 = \frac{1}{2}g \cos \theta_1 t_1^2.$$

Hence

$$t_1 = \sqrt{\frac{2x_1}{a_1}}.$$

The speed at the bottom of the first slope is then

$$v_1 = a_1t_1 = \sqrt{2x_1a_1}.$$

On the second slope, the ball starts with speed v_1 and travels a distance x_2 along the slope. Using

$$x_2 = \frac{1}{2}a_2t_2^2 + v_1t_2,$$

we get a quadratic equation in t_2 :

$$0 = \frac{1}{2}a_2t_2^2 + v_1t_2 - x_2 \Rightarrow 0 = t_2^2 + \frac{2v_1}{a_2}t_2 - \frac{2x_2}{a_2}.$$

Solving for t_2 (and taking the positive root):

$$t_2 = -\frac{v_1}{a_2} + \sqrt{\frac{v_1^2}{a_2^2} + \frac{2x_2}{a_2}}.$$

The total time is therefore

$$T = t_1 + t_2 = \sqrt{\frac{2x_1}{a_1}} - \frac{v_1}{a_2} + \sqrt{\frac{v_1^2}{a_2^2} + \frac{2x_2}{a_2}}.$$

Substituting a_i and v_1 , and rearranging, we get for the total time

$$T = \sqrt{\frac{2x_1}{g \cos \theta_1}} \cdot \left(1 + \frac{\cos \theta_1}{\cos \theta_2} \left[\sqrt{1 + \frac{x_2 \cos \theta_2}{x_1 \cos \theta_1}} - 1 \right] \right).$$

Solution to Problem E

- Sunlight contains all visible wavelengths and therefore appears white.
- When sunlight enters the atmosphere, it interacts with air molecules that are much smaller than the wavelength of visible light.
- Such small particles scatter light according to Rayleigh scattering.
- In Rayleigh scattering, the scattering intensity is proportional to

$$I \propto \frac{1}{\lambda^4},$$

so shorter wavelengths are scattered much more strongly.

- Blue and violet light, having smaller wavelengths, scatter far more than red light.
- Our eyes are less sensitive to violet light, and some violet is absorbed in the upper atmosphere.
- The strongly scattered blue light is redirected in all directions, including down toward the observer.
- Thus, blue light reaches us from all parts of the sky.
- As a result, when we look upward during the day, the sky appears blue.