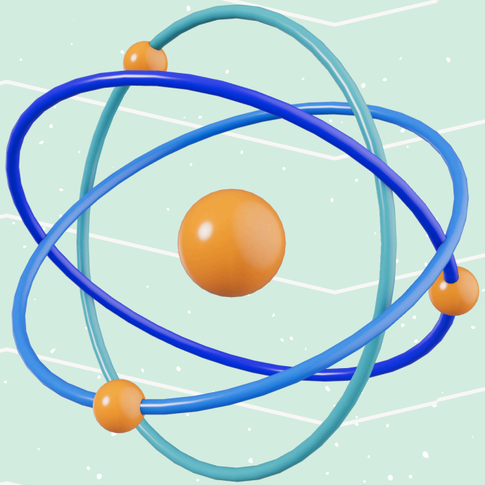
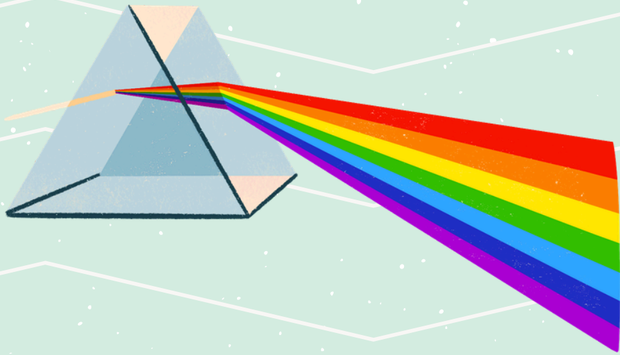
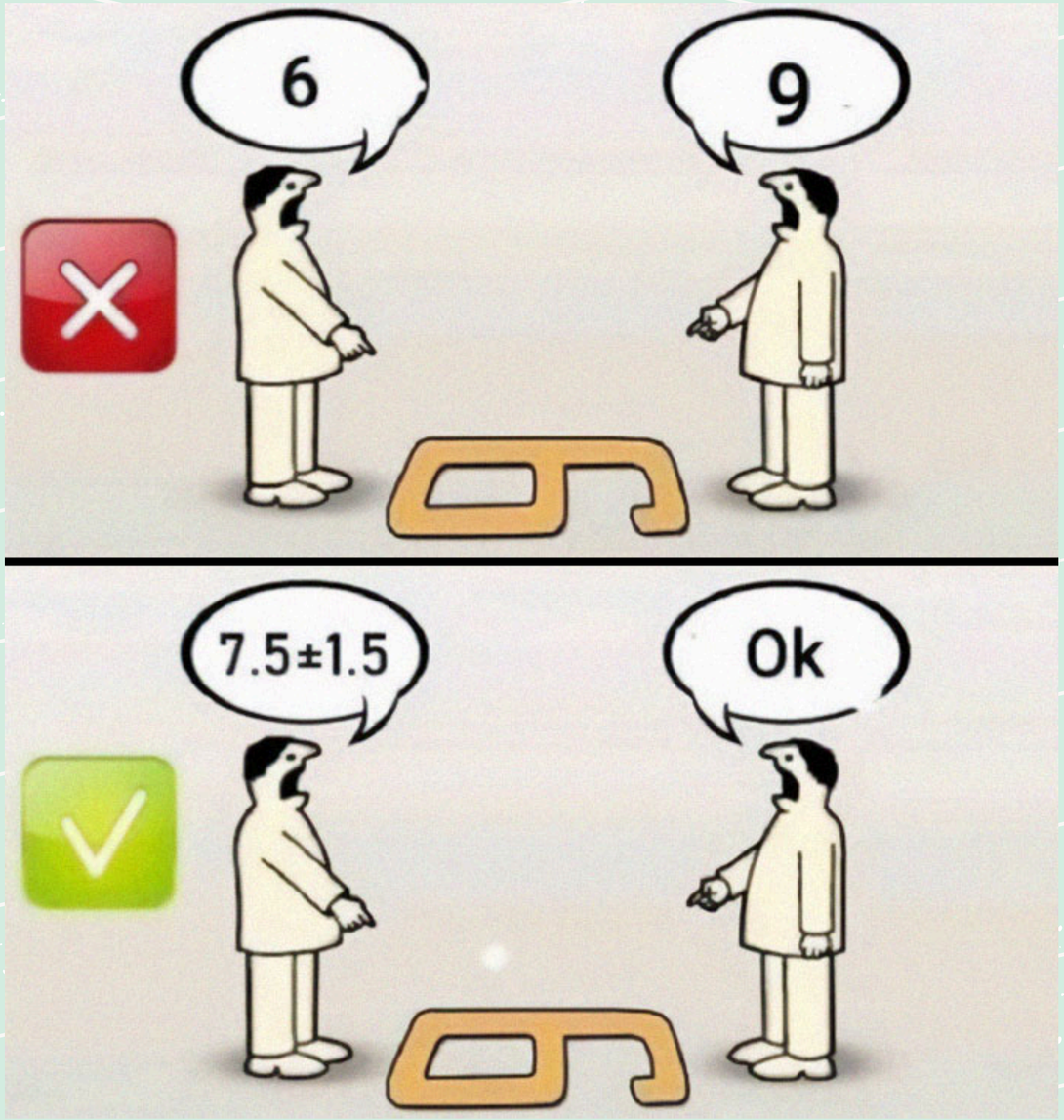


BOUNCE & POUNCE



SAFETY SLIDE !!

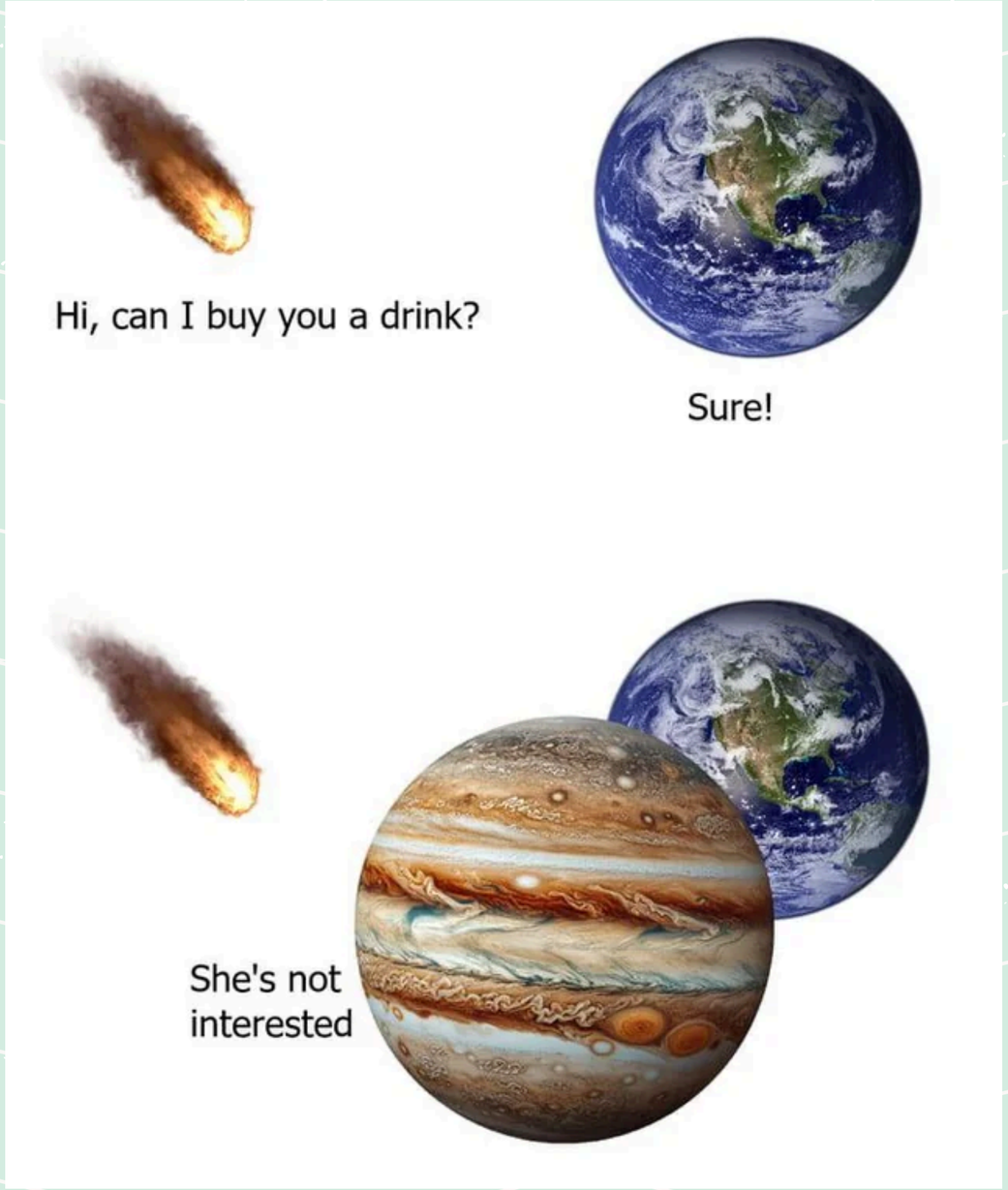


HOUSE RULES

POUNCE= A team (who the Q is not directed to) decides to answer it, in under a time of min (Bounce, Pounce Period).
BOUNCE= The team (who the Q is directed to) answers the Q
If answered correctly: The Q is thrown.
If answered wrongly: The Q is bounced to the next team which hasn't pounced or is thrown once one cycle is completed.
Pounce Period= 90 seconds after the Q is released
After the pounce period, 60 additional seconds are given to the team

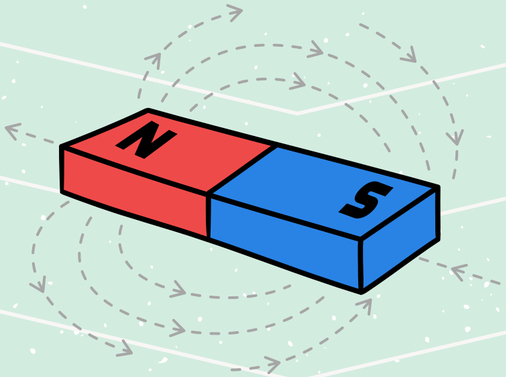
POINTS:
100 FOR BOUNCE
120 FOR POUNCE
-60 FOR WRONG POUNCE

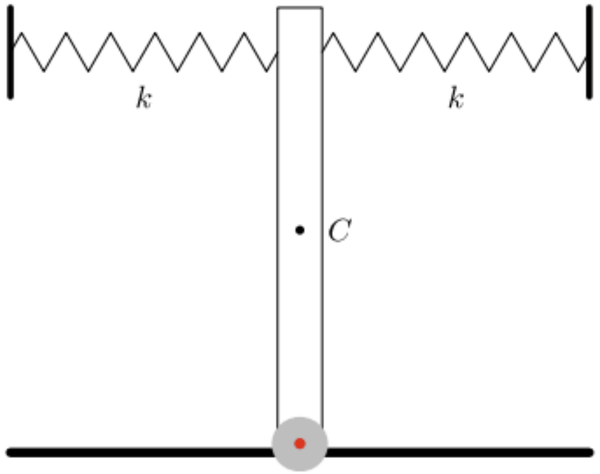
SAFETY SLIDE !!





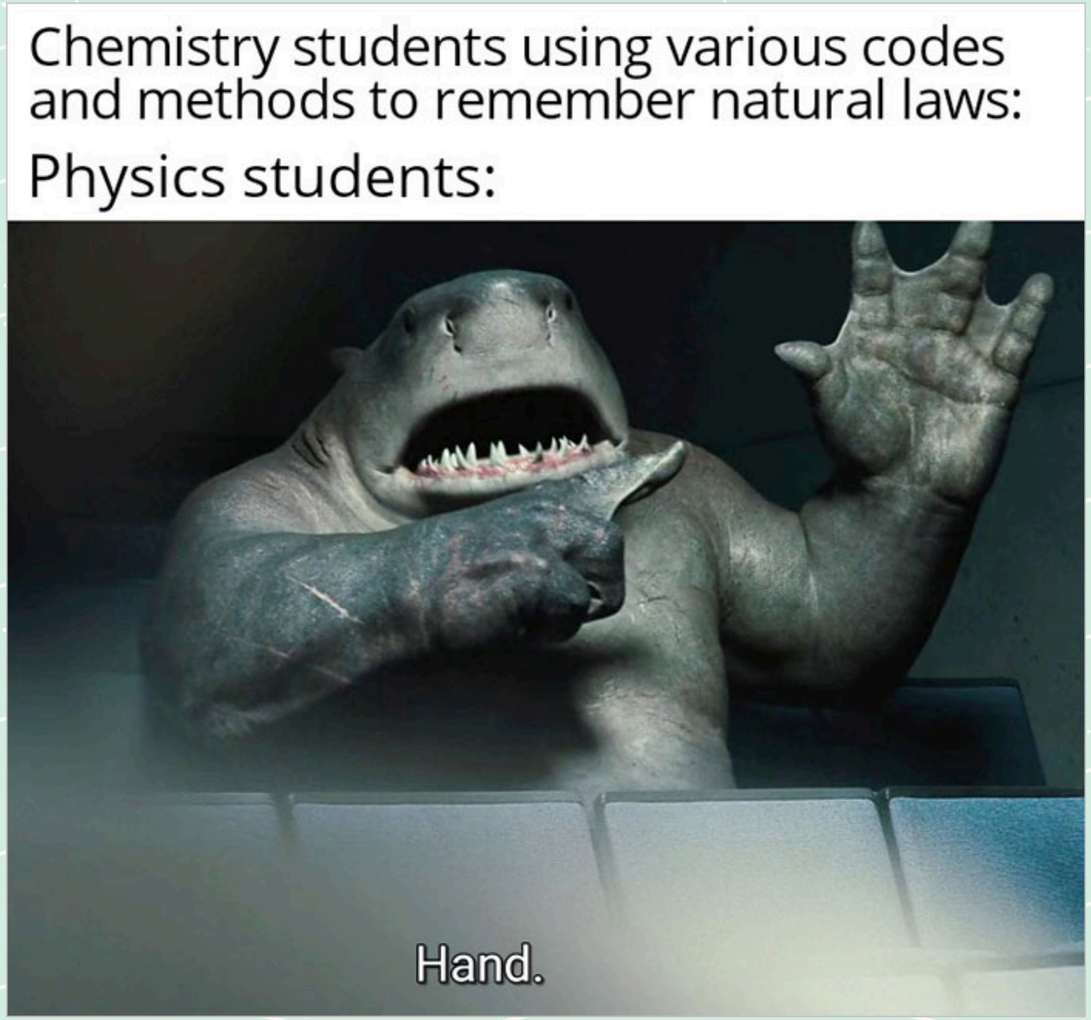
Question 1.1

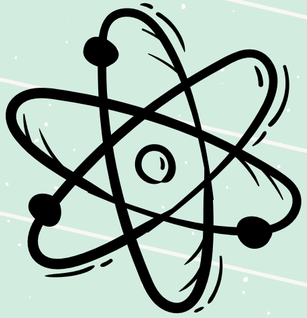




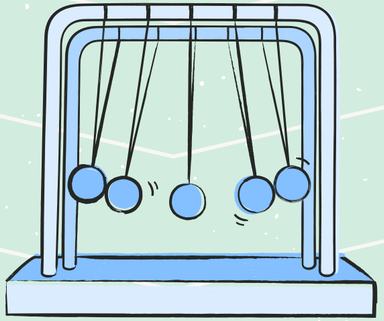
A uniform rod of mass M and length L is hinged on a horizontal surface at the bottom. Its top end is connected to two springs, both with spring constant k. What relation must M, k, and L satisfy such that the position shown in the figure is a stable equilibrium?

SAFETY SLIDE !!





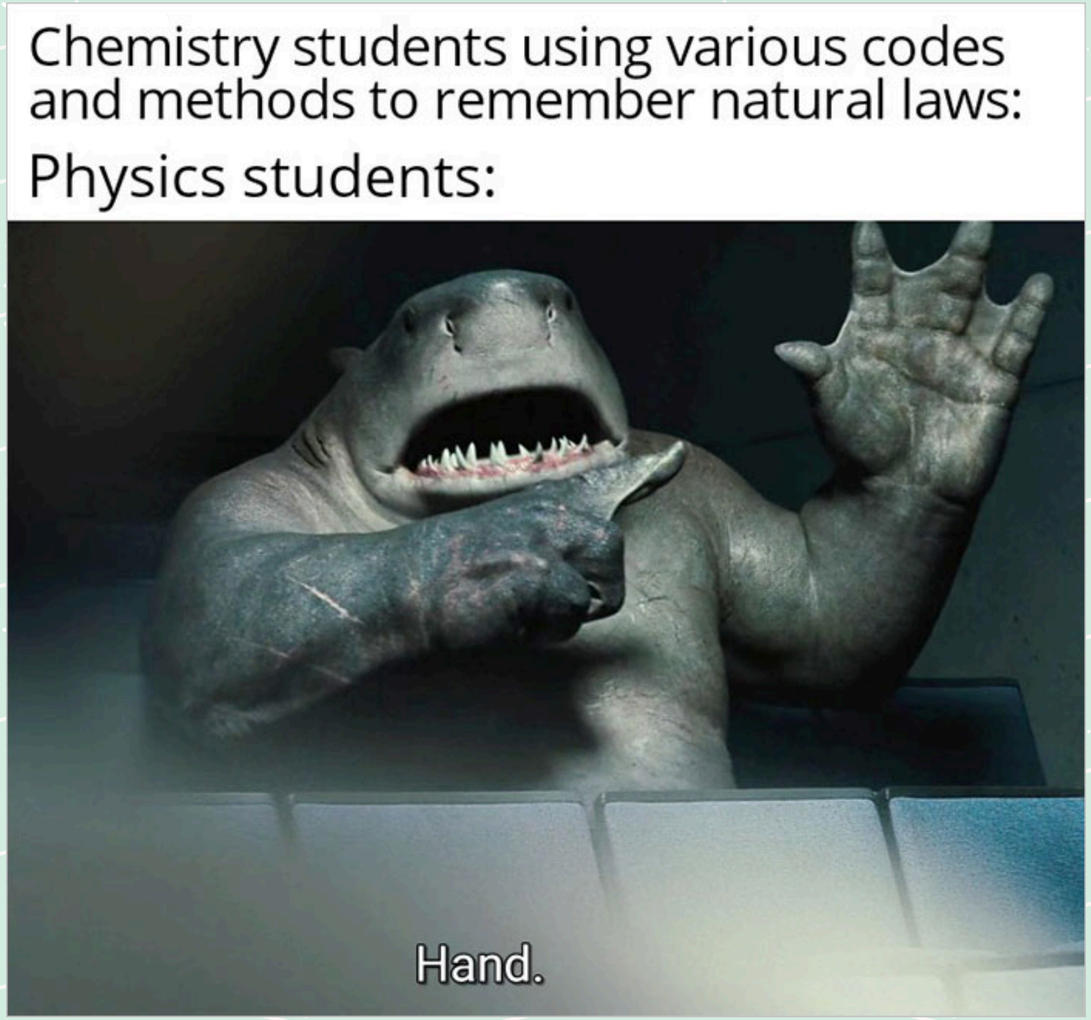
Answer 1.1



$$4kL > Mg$$

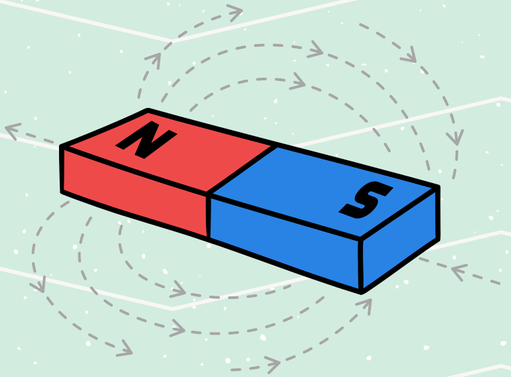
Hint: tilt the rod by a small θ, then compare the spring torque (about $-2kL^2\theta$) with gravity's destabilizing torque (about $+MgL\theta/2$), and require the net torque to push the rod back toward vertical.

SAFETY SLIDE !!





Question 1.2



A pendulum consists of a massless rigid rod of length l and a point-mass bob. Its pivot is driven vertically by a high-frequency harmonic oscillation with amplitude a and angular frequency ω

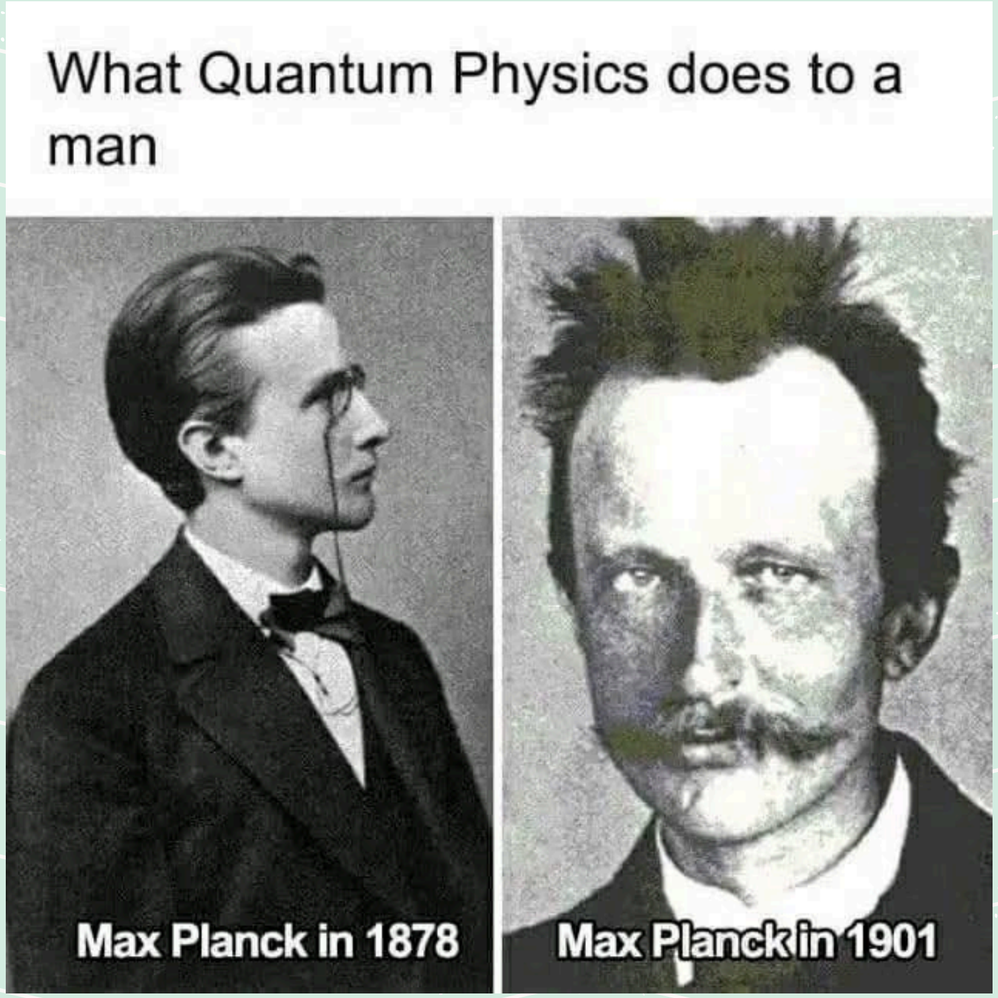
$$\text{(such that } a \ll l \text{ and } \omega \gg \sqrt{\frac{g}{l}}\text{)}.$$

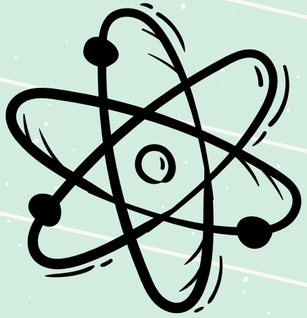
Assuming the vertical displacement of the pivot is

$$y(t) = a\sin(\omega t),$$

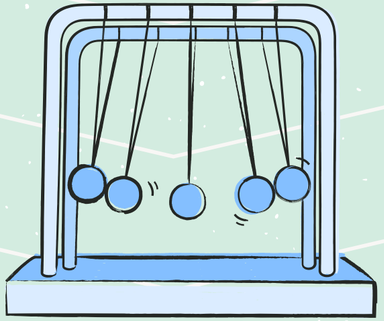
which condition ensures the stability of the inverted position (where the bob is held straight up)?

SAFETY SLIDE !!





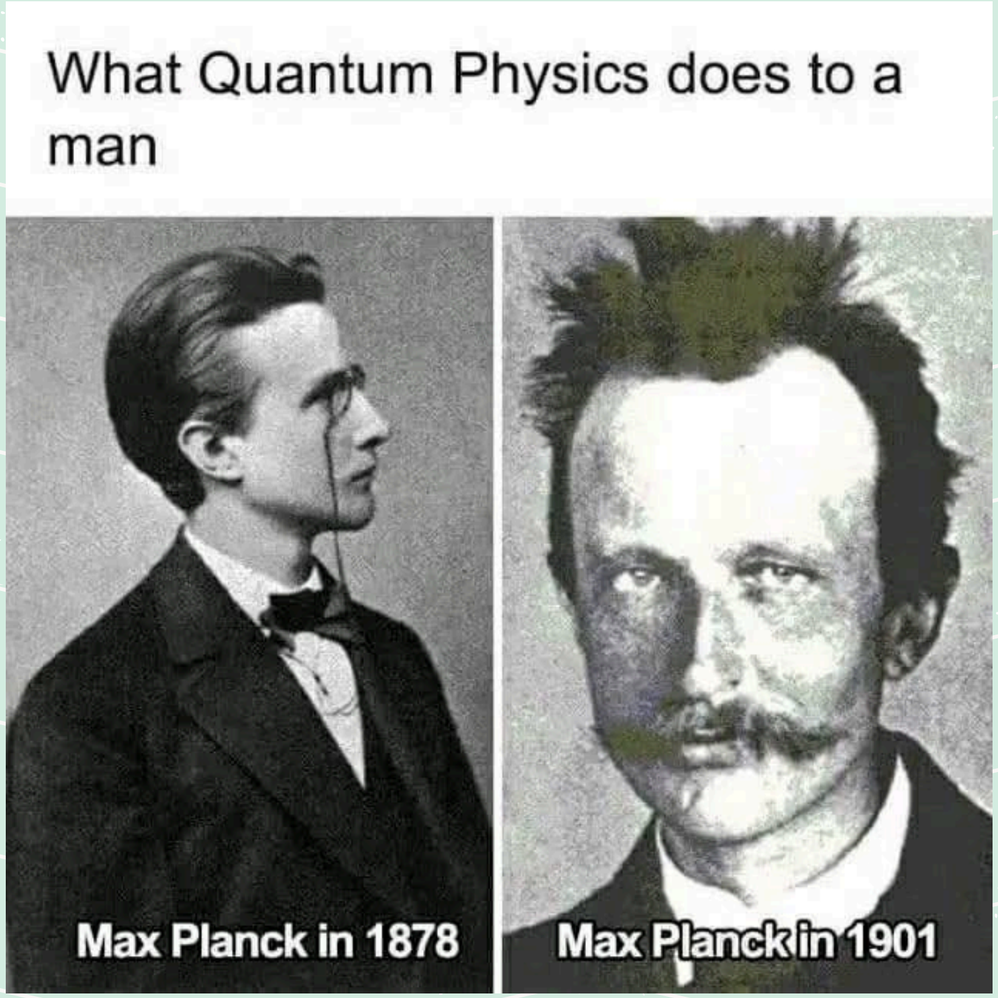
Answer 1.2



$$a^2\omega^2 > 2gl$$

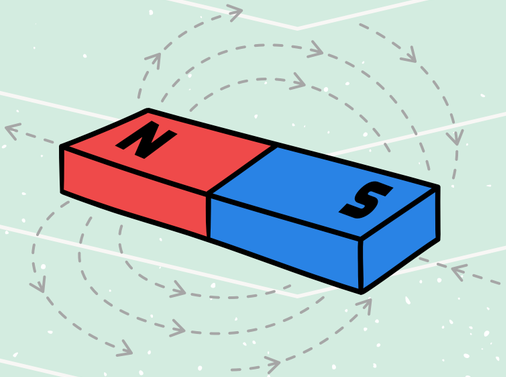
Hint: Use the effective gravity in the oscillating frame and apply the stability condition for the inverted pendulum.

SAFETY SLIDE !!





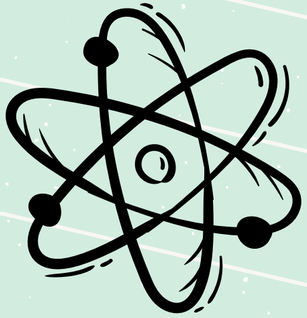
Question 1.3



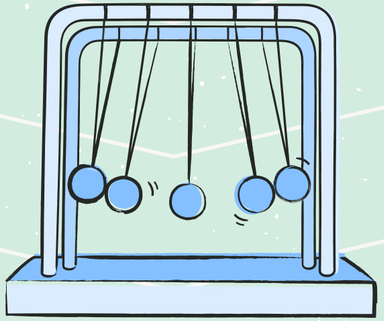
A heat engine operates between a high-temperature reservoir at $T_H = 900\,\mathrm{K}$ and a low-temperature reservoir at $T_C = 400\,\mathrm{K}$. While the theoretical Carnot efficiency for these temperatures is 55.6%, Carnot engines operate reversibly and thus yield zero net power output in finite time. Assuming an endoreversible engine model governed by linear heat conduction between the working fluid and the external reservoirs, determine the thermal efficiency of the engine when it is tuned for maximum power output.

SAFETY SLIDE !!





Answer 1.3



$$\eta_{\max} = 33.3\%$$

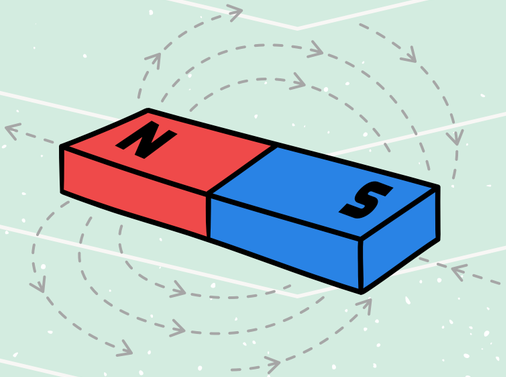
Hint: Use the Carnot efficiency as the theoretical upper bound, then account for irreversibility using the given second-law efficiency to find the actual thermal efficiency.

SAFETY SLIDE !!



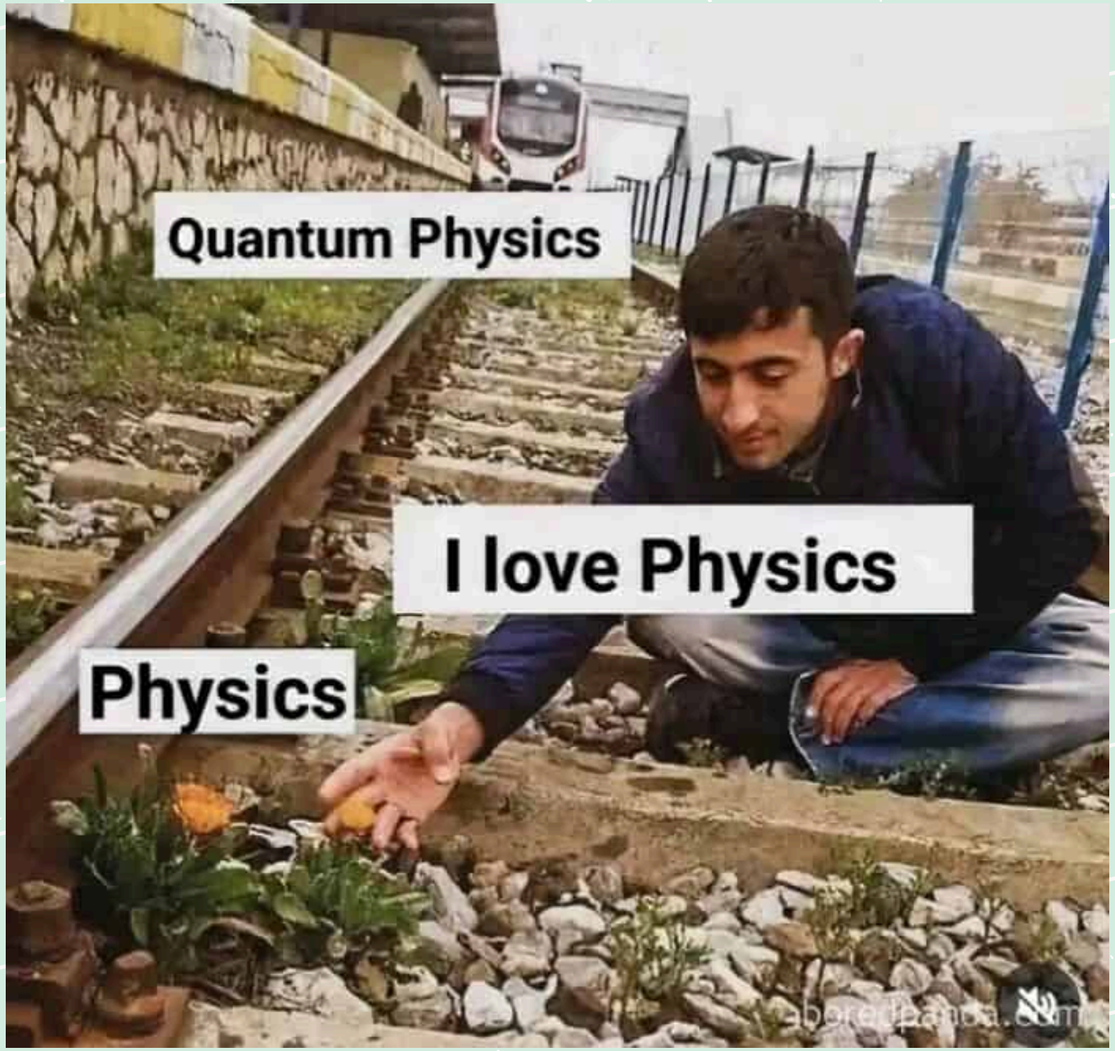


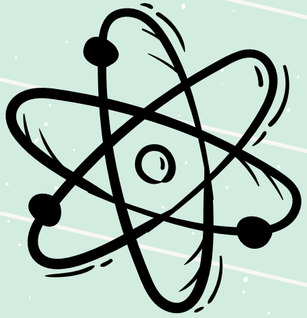
Question 1.4



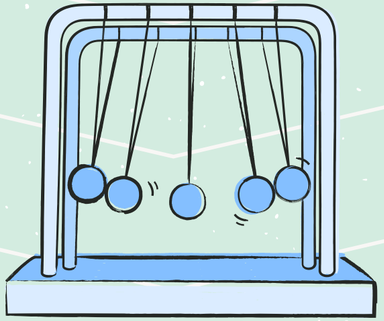
There are n identical parallel plates which reflect a fraction r of the incident light. A beam of intensity I is incident perpendicular to the plane of the plates. Find the intensity of the beam that exits the beam (in the same direction), as a function of $I,\ n,\ r$.

SAFETY SLIDE !!





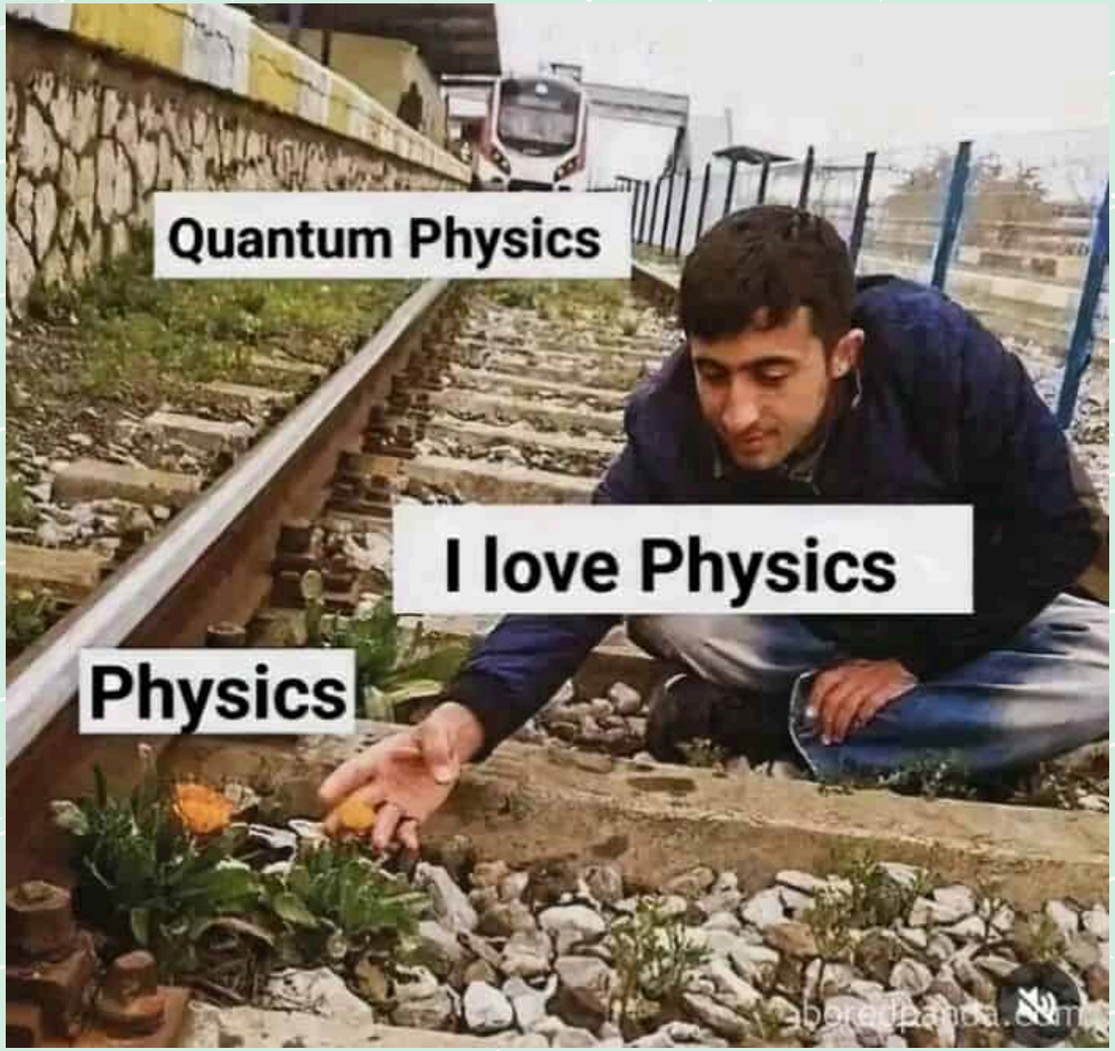
Answer I.4



$$I_{\text{out}} = I\frac{1-r}{rn+1-r}$$

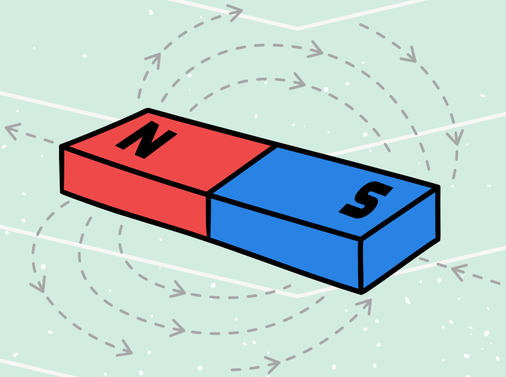
Hint: Write a recurrence relation for the transmitted intensity after n plates, then take its reciprocal to obtain a linear relation.

SAFETY SLIDE !!





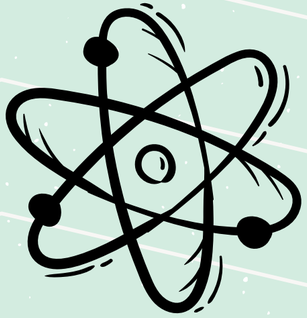
Question 1.5



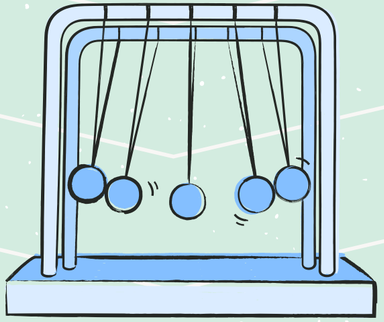
When a slinky hangs vertically under its own weight, its density is uniform before hanging. If its relaxed length is $10m$, its spring constant is $55N/m$, and its mass is $4kg$, find the distance of its center of mass below its top.

SAFETY SLIDE !!





Answer 1.5



$$
\begin{aligned}
y_{\mathrm{CM}} &= \frac{L}{2} + \frac{mg}{3K} \\
&= \frac{10}{2} + \frac{4(9.8)}{3(55)} \\
&= 5 + \frac{39.2}{165} \\
&\approx 5.24\ \mathrm{m}
\end{aligned}
$$

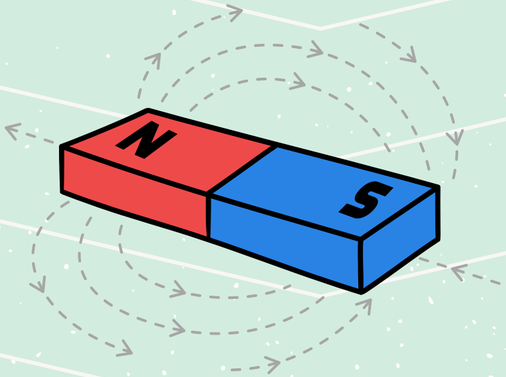
Hint: Consider the tension at each point of the slinky due to the weight hanging below it, then integrate to find the centre of mass.

SAFETY SLIDE !!



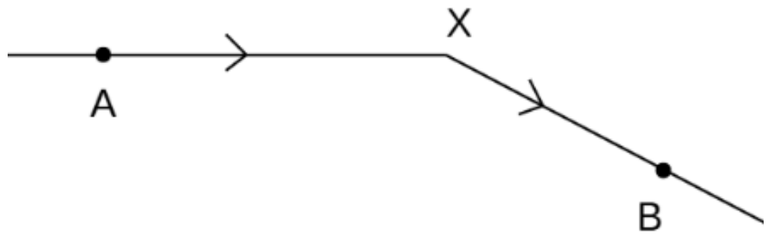


Question 1.6

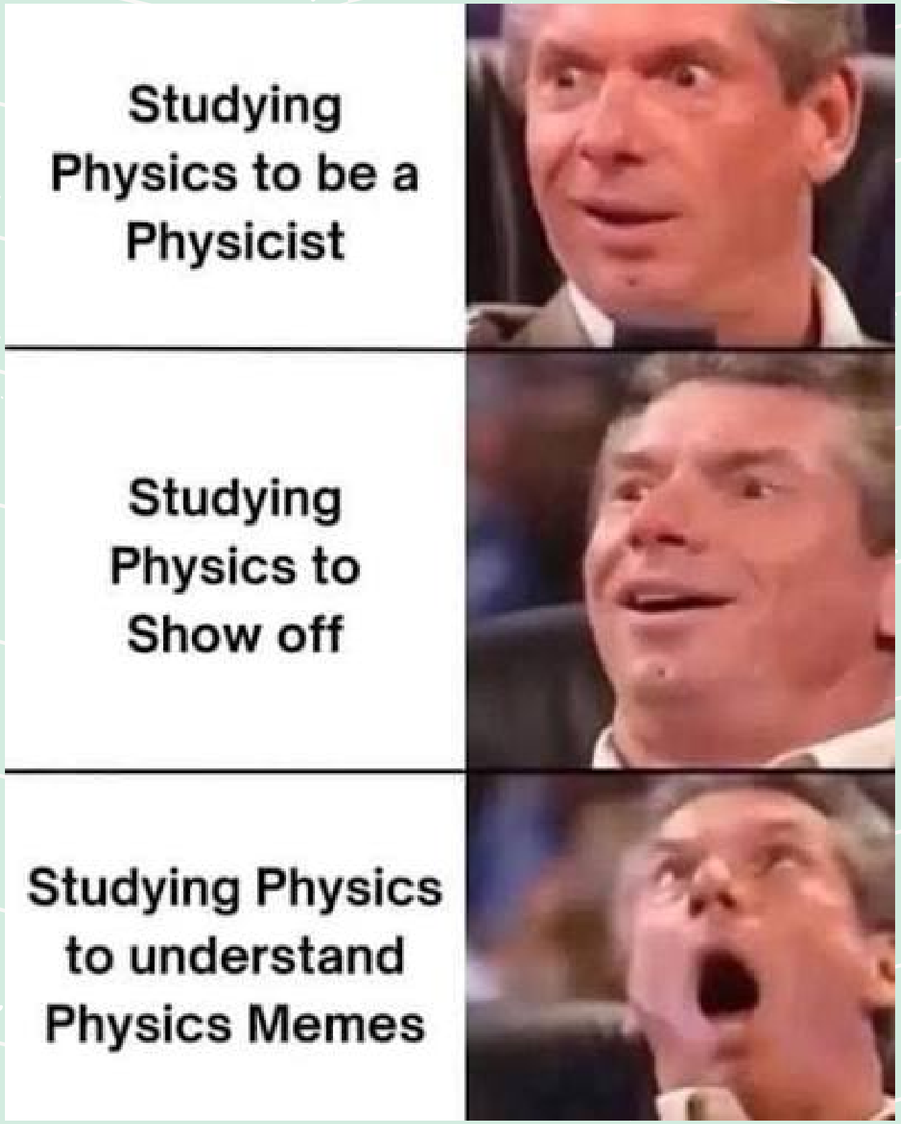


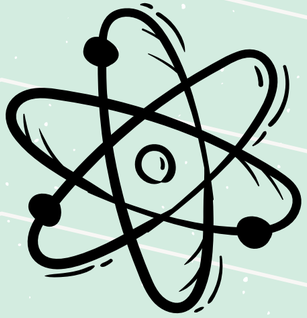
Given the ray diagram for a ray of light passing through a convex lens, it is given that A and B are in the focal planes of the two foci of the lens.

If $AX = 16cm, \quad BX = 24\sqrt{3}cm,$ and the acute angle between AX and BX is 30°, find the height above the optical centre where the ray strikes the lens.

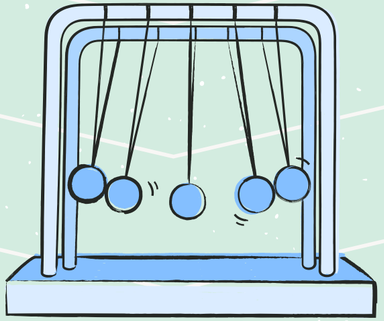


SAFETY SLIDE !!





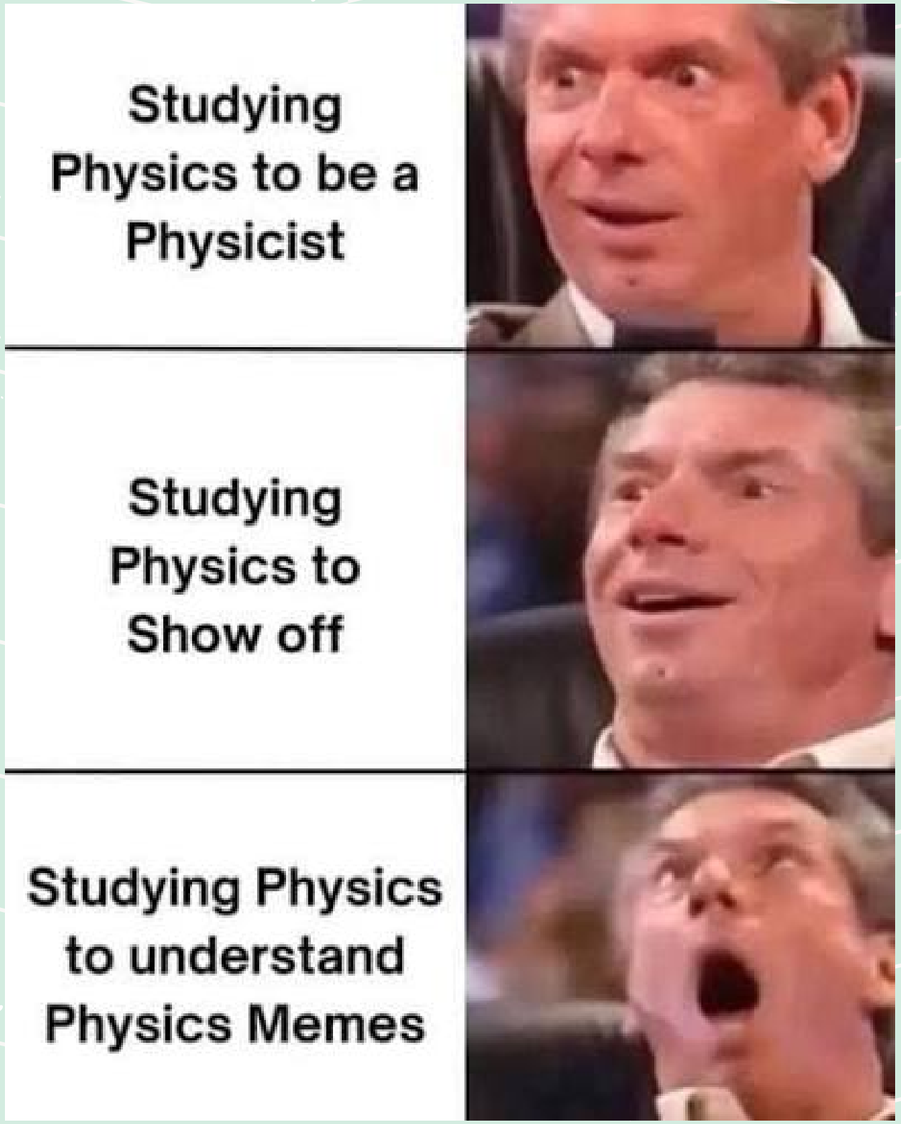
Answer 1.6



$$8\sqrt{13}\text{cm} \approx 28.84\text{cm}$$

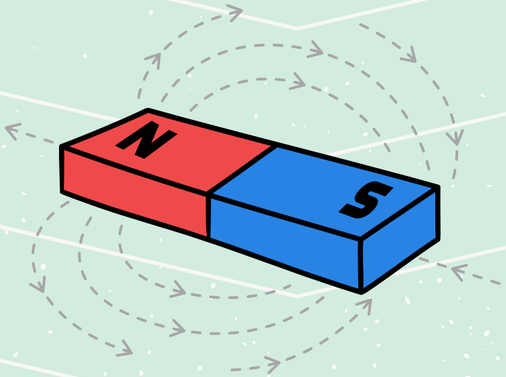
Hint: Use the geometry of the ray and the fact that the object-side and image-side focal planes are separated by the lens.

SAFETY SLIDE !!





Question 2.1



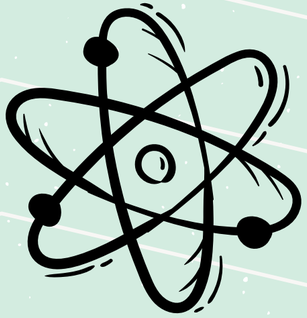
A tiny raindrop falls from rest through still mist, collecting mass at a rate proportional to its cross-sectional area multiplied by its speed. Find its acceleration as a function of g.

SAFETY SLIDE !!

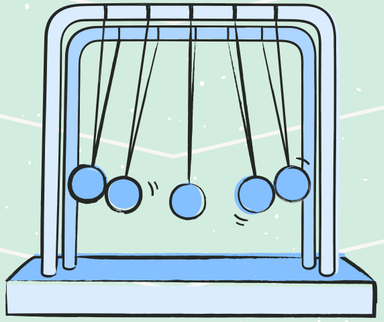
Physics teacher ~ You have a lot of potential, you should use it

~Me realizing we are standing at the top of a building





Answer 2.1



$$\frac{g}{7}$$

Hint: Apply conservation of momentum for a variable-mass system and use m is proportional to x^3 where x is the distance fallen.

SAFETY SLIDE !!

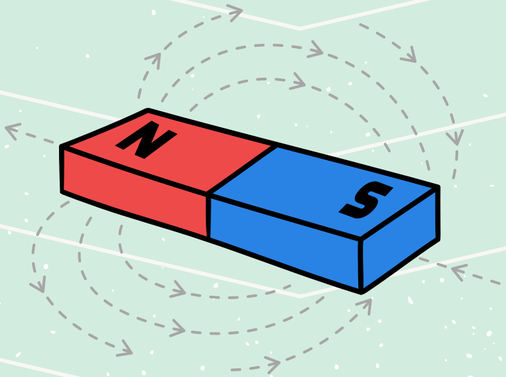
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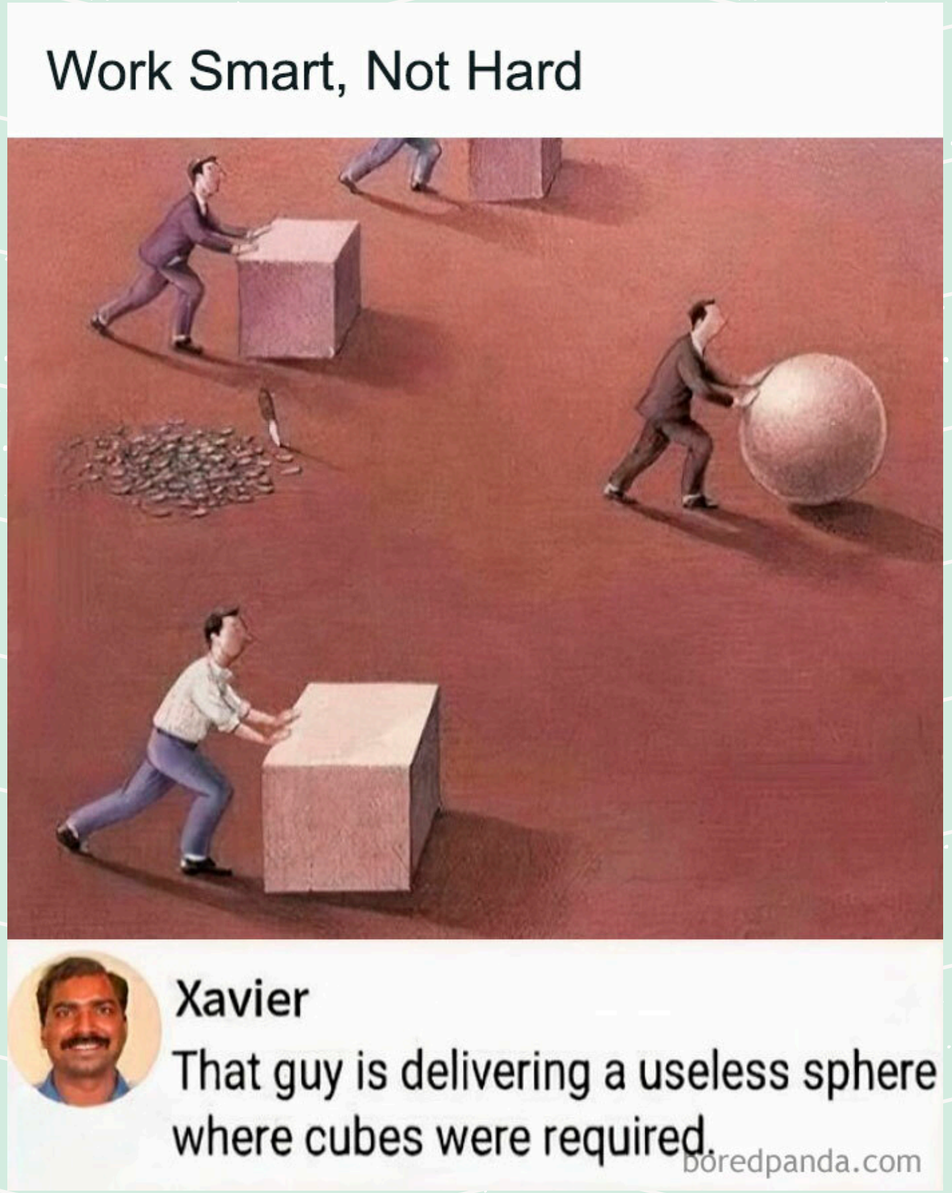


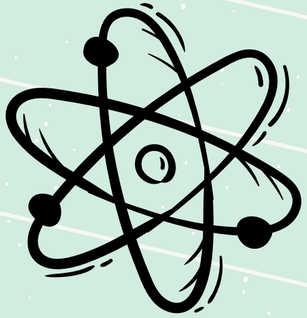
Question 2.2



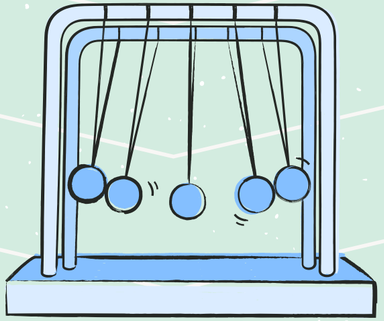
A non-rotating planet of radius R_0 and uniform density ρ_0 suddenly loses all internal pressure and collapses under its own gravity. Assuming its mass remains constant, its density stays uniform, and relativistic effects are negligible, determine the time taken for the planet to collapse in terms of G, ρ_0 and R_0.

SAFETY SLIDE !!





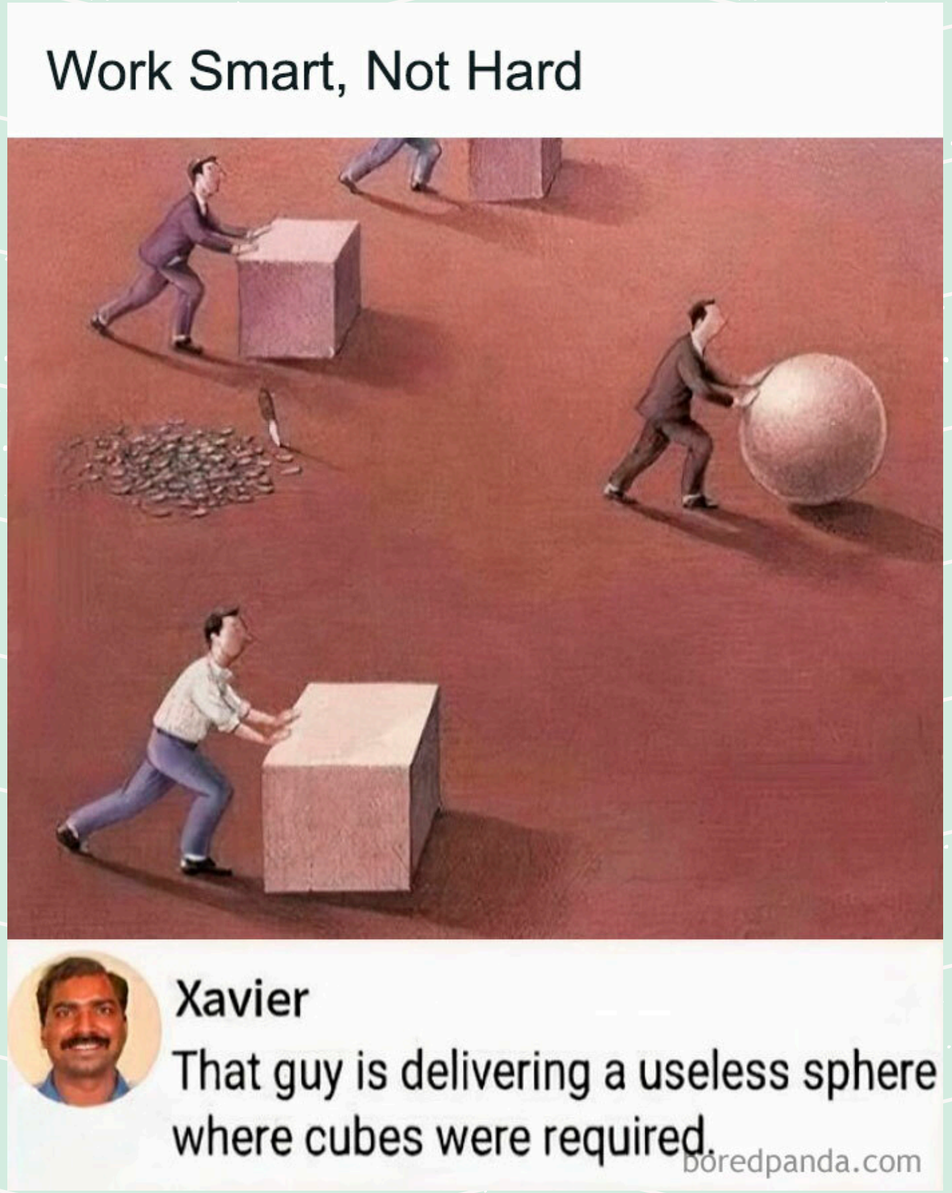
Answer 2.2



$$\sqrt{\frac{3\pi}{32G\rho_0}}$$

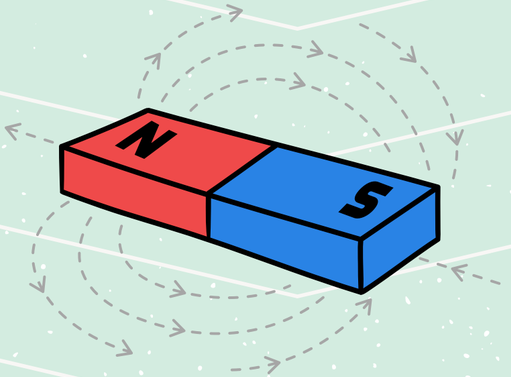
Hint: tilt the rod by a small θ, then compare the spring torque (about $-2kL^2\theta$) with gravity's destabilizing torque (about $+MgL\theta/2$), and require the net torque to push the rod back toward vertical.

SAFETY SLIDE !!





Question 2.3



You are given an ellipsoidal surface:

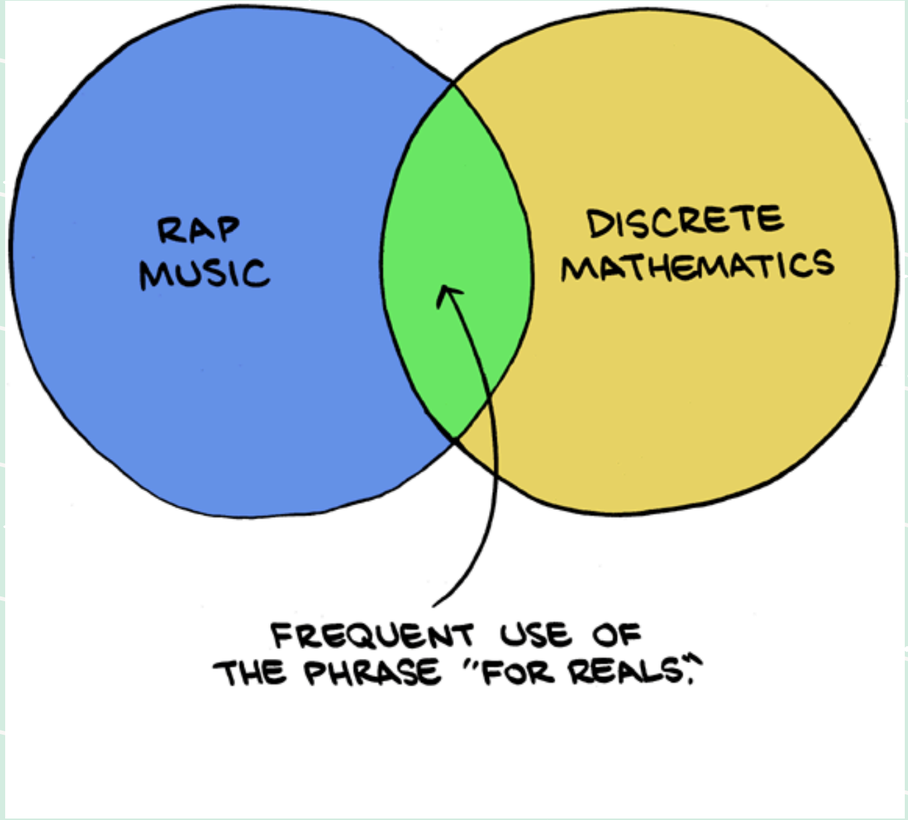
$$\frac{x^2}{25} + \frac{y^2}{36} + \frac{z^2}{4} = 1.$$

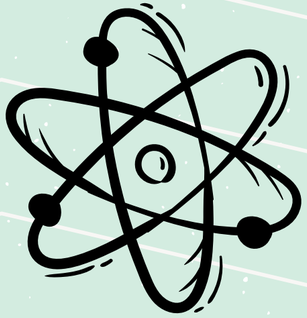
The electric field is

$$\vec{E} = \frac{2}{\pi}\left[\left(\frac{x}{x^2+y^2} + \frac{x}{x^2+z^2}\right)\hat{\mathbf{i}} + \left(\frac{y}{x^2+y^2} + \frac{y}{y^2+z^2}\right)\hat{\mathbf{j}} + \left(\frac{z}{y^2+z^2} + \frac{z}{x^2+z^2}\right)\hat{\mathbf{k}}\right].$$

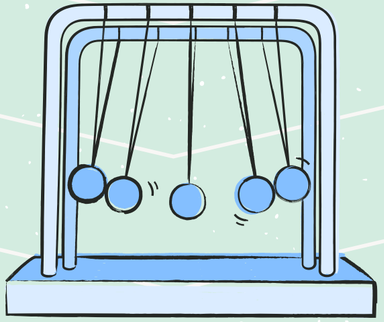
Find the electric flux through the ellipsoidal surface.

SAFETY SLIDE !!





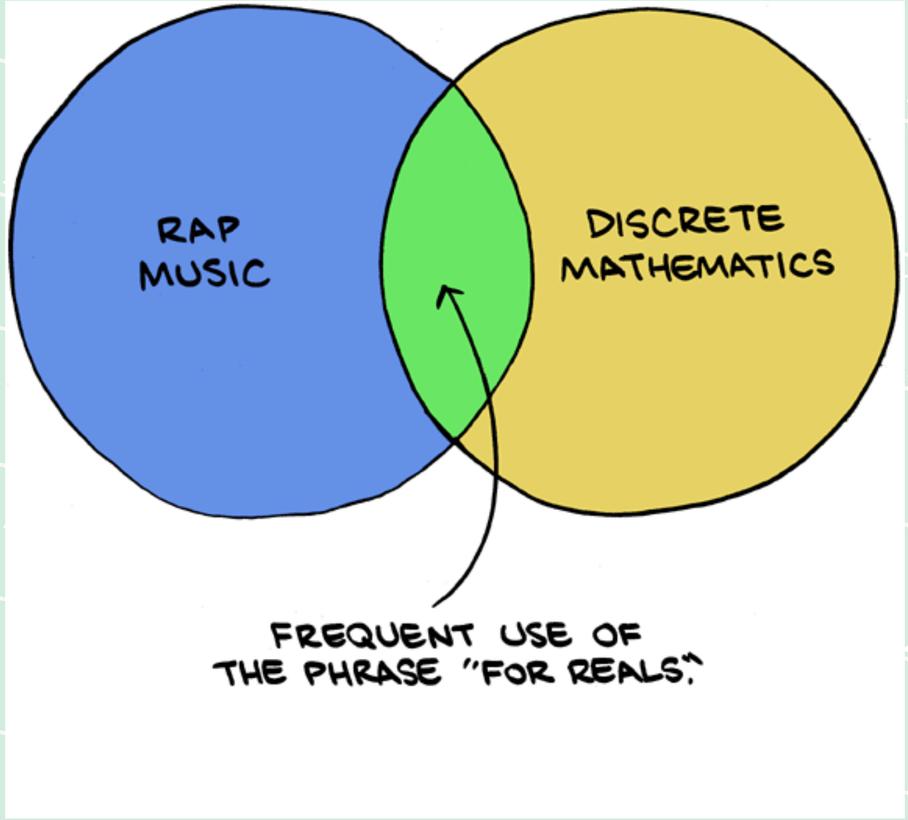
Answer 2.3



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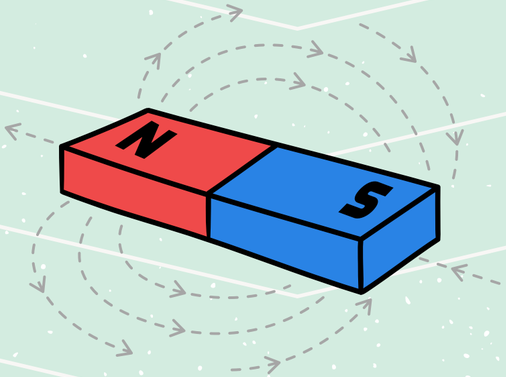
Hint: The given electric field is combined electric field of three wires kept along X, Y, Z axes. Find flux by charge enclosed inside the ellipsoid which is basically the charge carried by the wires along the axes of the ellipsoid.

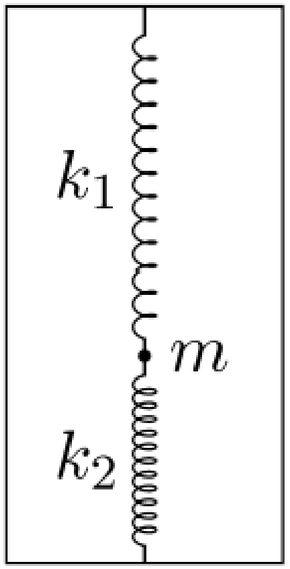
SAFETY SLIDE !!





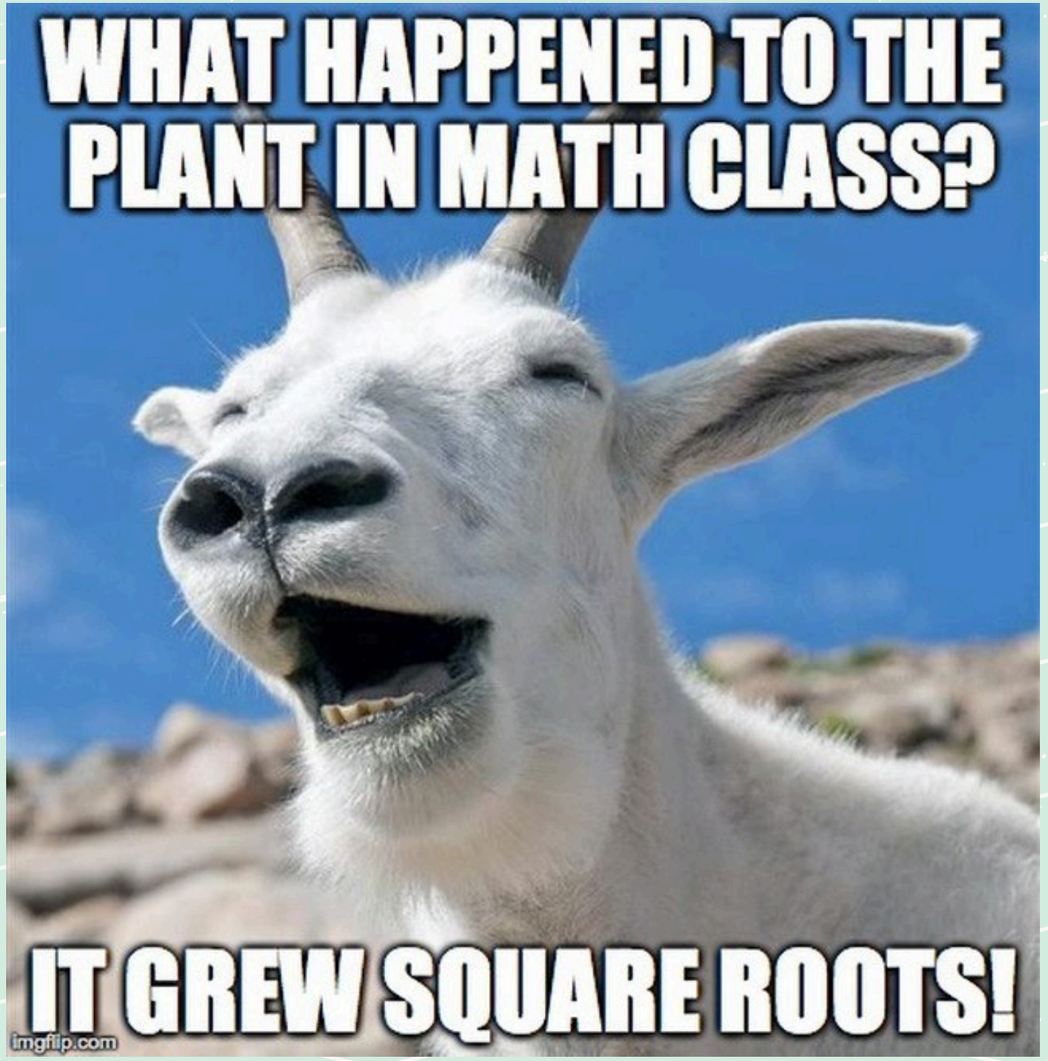
Question 2.4

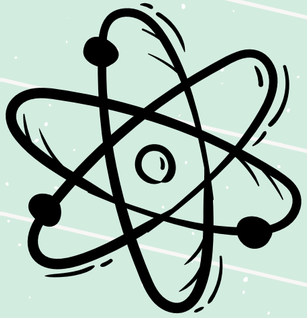




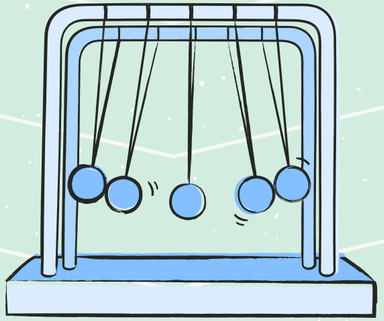
A ball of negligible radius and mass m is connected to two ideal springs. Each spring has rest length ℓ_0. The springs are connected to the ball inside a box of height $2\ell_0$, and the ball is allowed to come to equilibrium, as shown. Under what condition is this equilibrium point stable with respect to small horizontal displacements?

SAFETY SLIDE !!





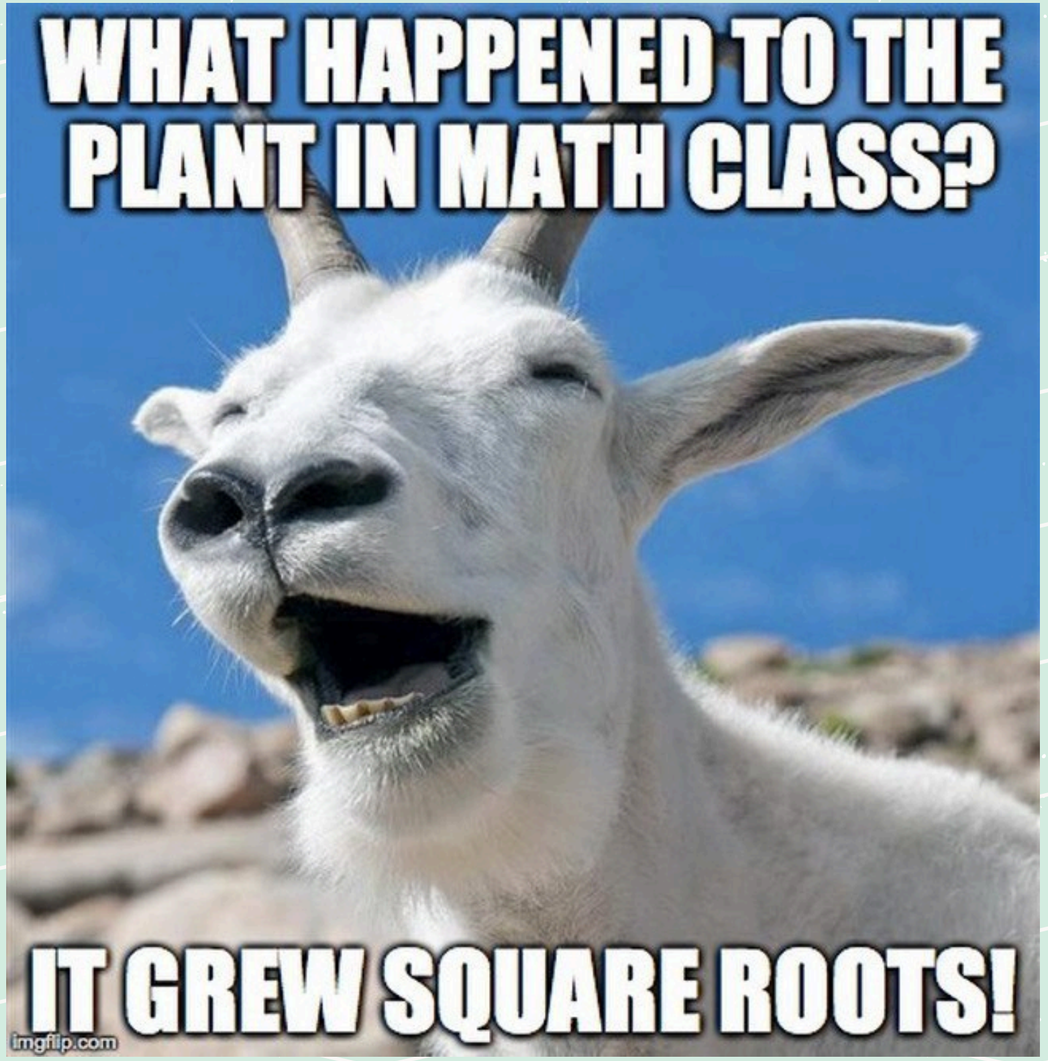
Answer 2.4



$$k_1 - k_2 > \frac{mg}{\ell_0}$$

Hint: Displace the ball horizontally by a small distance x and compare the horizontal restoring force from both springs to obtain the stability condition.

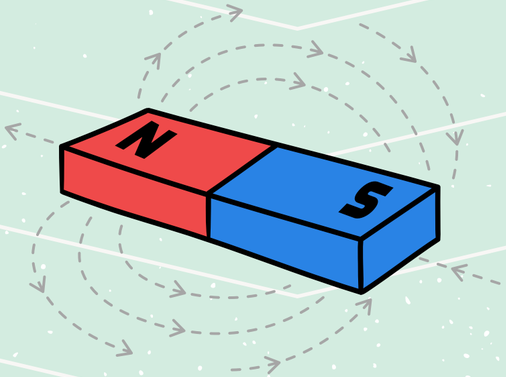
SAFETY SLIDE !!





Question 2.5

extend time for this q



After his valiant attempt at poisoning Sanaa, Nirav has to make a run for it. However, Visharad is smart and has placed a device on Nirav which measures his velocity and direction. Nirav begins running east with velocity

$$v_0 = \frac{d\omega}{d\theta}.$$

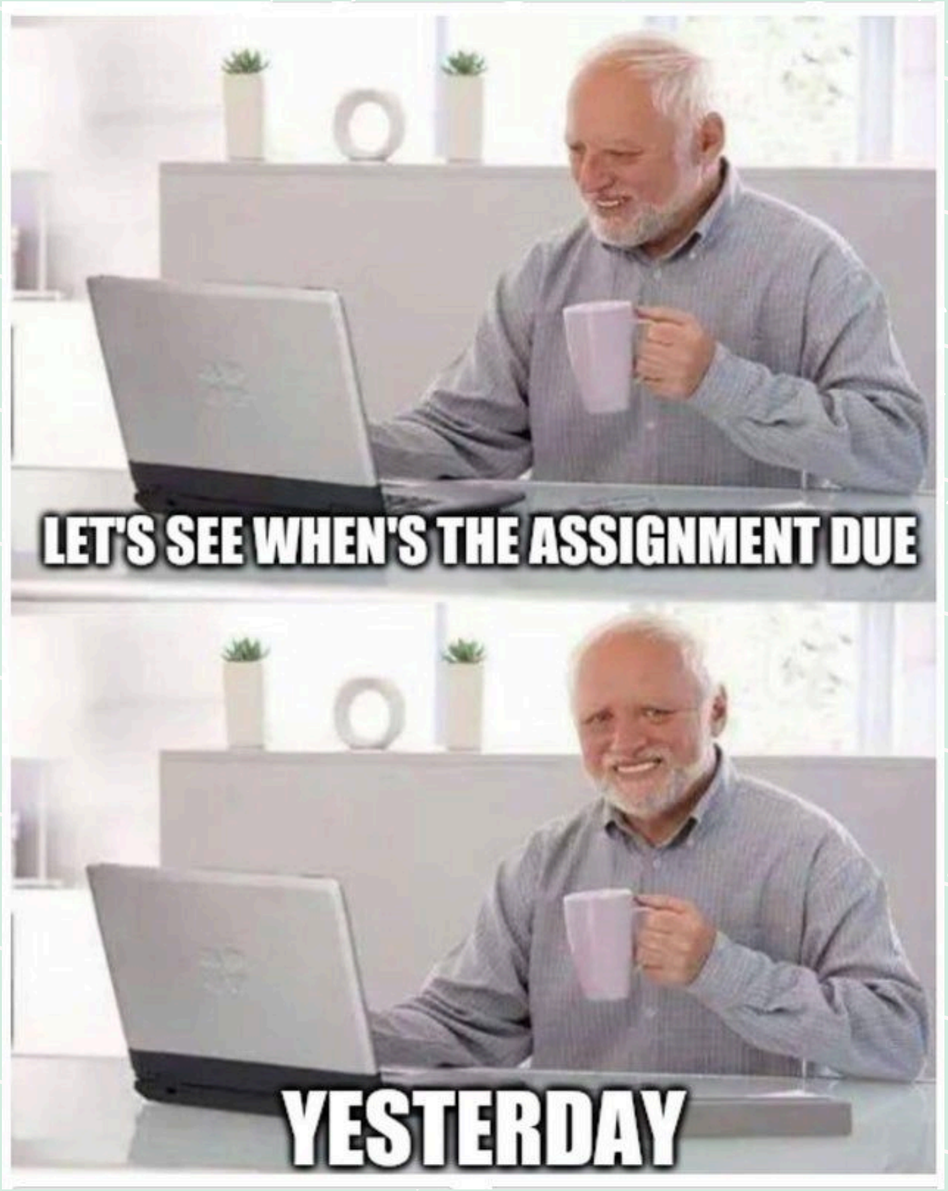
His velocity vector rotates anticlockwise uniformly at the rate of ω and its magnitude exponentially decays such that in time $T = \frac{\theta}{\omega}$, velocity is multiplied by a factor of $r < 1$. The device only updates every T seconds. Visharad has programmed a robot which starts chasing Nirav shortly after, and after every T seconds (when the device updates), it changes its velocity and direction to match Nirav. Suppose the robot and Nirav start simultaneously (they start with the same velocity and direction as well). Assuming Nirav is never caught, let

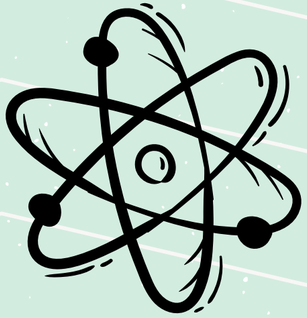
$$\gamma = \frac{d_{\text{robot}}}{d_{\text{Nirav}}}$$

where d refers to magnitude of displacement.

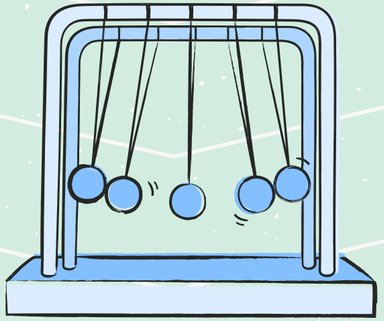
Find $\lim_{r \to 1/2} \lim_{\theta \to 0} \gamma$

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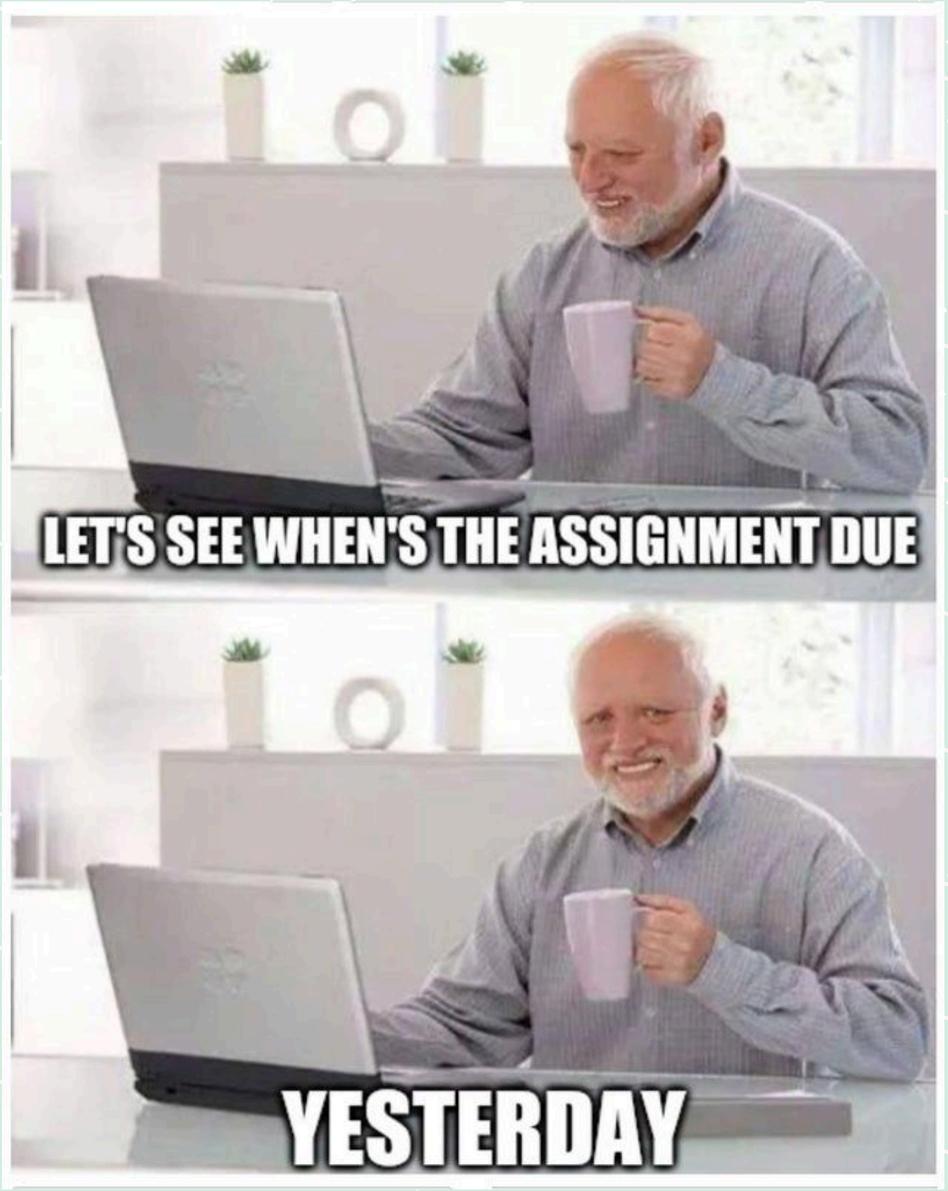
Answer 2.5



$$2ln(2)$$

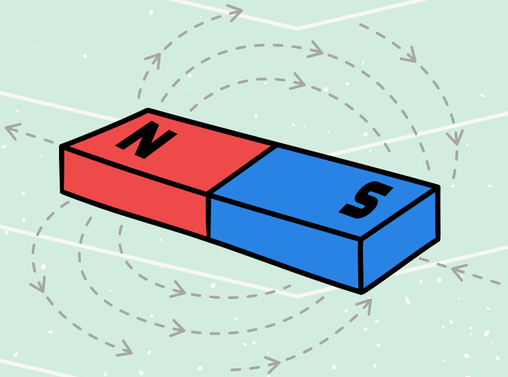
Hint: Since Nirav's velocity magnitude decays exponentially while its direction rotates, integrate the velocity over each interval T and sum the displacement magnitudes for Nirav and the robot.

SAFETY SLIDE !!





Question 2.6



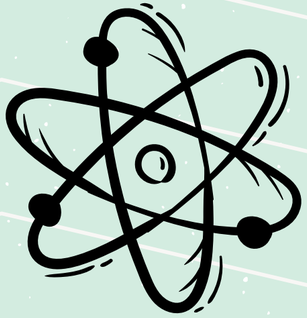
For a monoatomic ideal gas consisting of non-relativistic particles, the adiabatic process is governed by the relation

$$PV^{\gamma} = \text{constant}, \qquad \gamma = \frac{C_P}{C_V} = \frac{5}{3}.$$

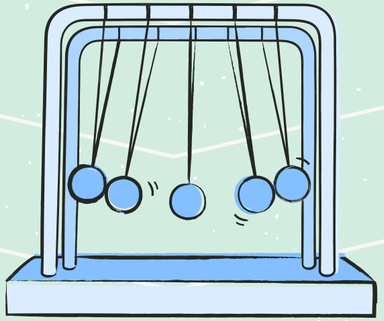
Now, consider a box containing a gas of photons instead of non-relativistic particles. Assuming that the photon gas undergoes a reversible adiabatic process, derive the corresponding relation between pressure P and volume V.

SAFETY SLIDE !!





Answer 2.6



$$PV^{4/3} = \text{constant}$$

Hint: For a photon gas, the internal energy is given by U=(sigma)VT^4 (stefan boltzmann law) and the equation of state is PV=U/3, unlike an ideal gas, for which PV=2U/3 Using the first law of thermodynamics, dQ=dU+dW, derive the required relation.

SAFETY SLIDE !!



---END OF ROUND---