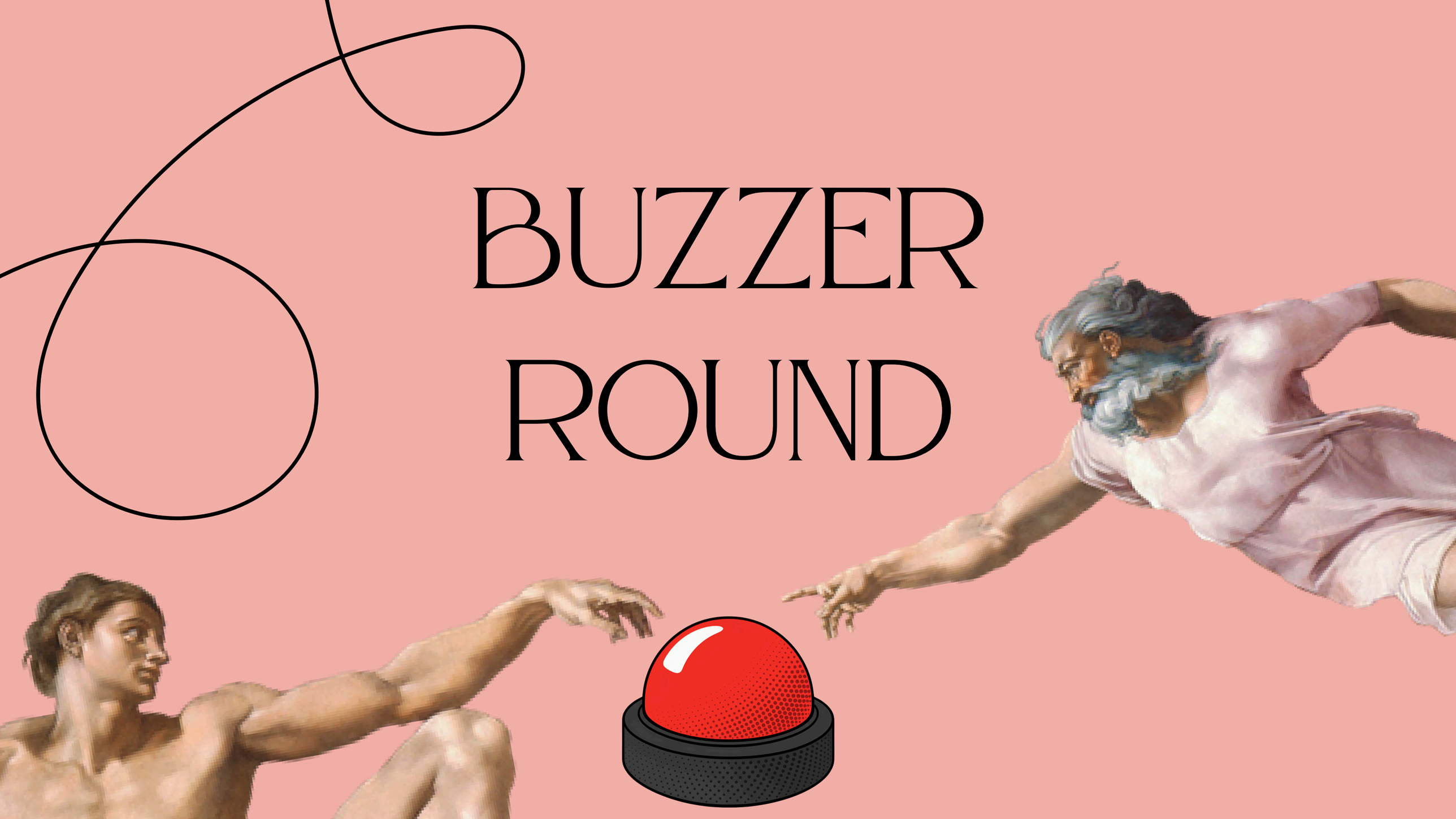
BUZZER ROUND



SAFETY SLIDE

QUESTION-1

Rock is not infinitely strong. If a mountain gets too tall, the rock at its base gets crushed and flows plastically, so mountains can't grow forever. Estimate the maximum height of a mountain on Earth in m. Then say roughly how much taller a mountain could be on Mars ($g = 3.7 m/s^2$). *Given:* Rock density $\rho = 3000 kg/m^3$, and the compressive strength of typical rock is $\sim 10^8\ Pa$.

SAFETY SLIDE

ANSWER

$3400m$ ($\sim$ 2.7 times taller)

SAFETY SLIDE

QUESTION-2

Before nuclear fusion was known, Kelvin and Helmholtz suggested the Sun shines by slowly shrinking, converting gravitational potential energy into light. Estimate how long the Sun could shine this way at its current luminosity, in years. Given:

$$M_o = 2\times10^{30}\ kg, R_o = 7\times10^{8}\ m, L_o = 3.8\times10^{26}\ W,$$

$$G = 6.67\times10^{-11}\ SI, 1\text{ year} \approx 3\times10^{7}\ s.$$

SAFETY SLIDE

ANSWER

$$\sim 10^6 \; to \; 10^9$$

SAFETY SLIDE

QUESTION-3

Two identical non-interacting spin-half electrons are in a 1-D infinite potential square well, both with spin up (a spin polarized pair). If a single particle's ground state energy is E_1, what is the ground-state energy of the pair?

SAFETY SLIDE

ANSWER

$$5E_1$$

$$(n = 1 \; and \; n = 2, \; so \; 1 + 4)$$

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QUESTION-4

A perfect sphere flies perpendicularly past a camera at 0.9c, and the camera captures the light that reaches it simultaneously. What does the sphere's outline look like in the photograph?

SAFETY SLIDE

ANSWER

A circle
(Penrose-Terrell effect)

SAFETY SLIDE

QUESTION-5

An underwater spark bubble pulsates with a period T that depends only on the energy E, water density ρ and ambient (absolute) pressure p. At 30 m depth, a sparker gives T = 5.0 ms. A sparker storing 64 times the energy is fired at 2550 m. Find T.

$(\rho = 1000 kg/m^3, g = 10 m/s^2,$

$p_{atm} = 1.0 \times 10^5 Pa)$

SAFETY SLIDE

ANSWER

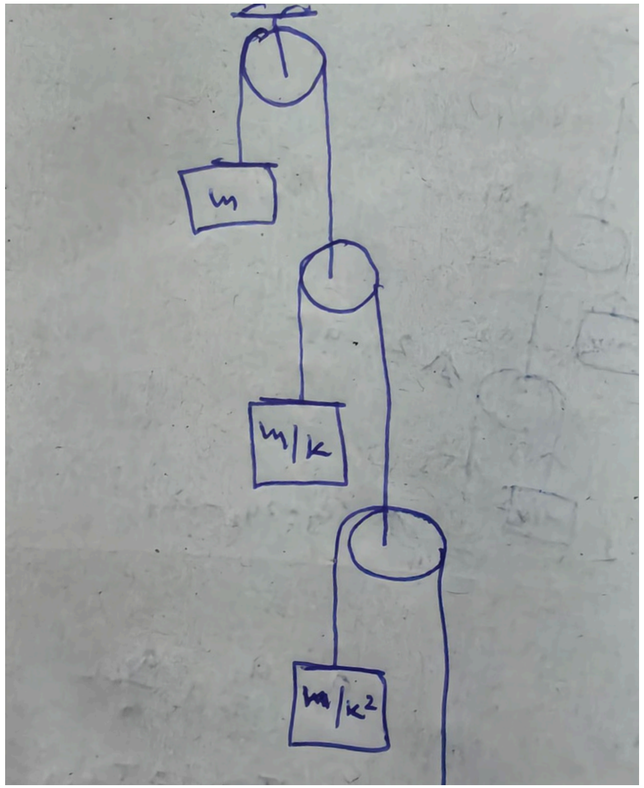
$$T = kE^{1/3}\rho^{1/2}p^{-5/6}$$

$$= 0.625\,ms$$

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QUESTION-6

Consider the infinite atwood machine as shown, find the acceleration of mass m in terms of g and k (assume $1 < k < 4$).



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ANSWER

$$g(\frac{k}{2}-1) \; or \; g(1-\frac{k}{2})$$

SAFETY SLIDE

QUESTION-7

Two ice skaters, Skater A and Skater B, have identical masses and stand completely at rest on a perfectly frictionless, horizontal frozen lake. They are holding opposite ends of a light rope of length L. Skater A decides to actively pull themselves towards Skater B by rapidly winding the rope around their own waist. Skater B, on the other hand, remains completely passive: they do not pull at all, they simply hold their end of the rope firmly. Assuming air resistance is negligible, how far does the passive Skater B travel across the ice before the two skaters collide?

SAFETY SLIDE

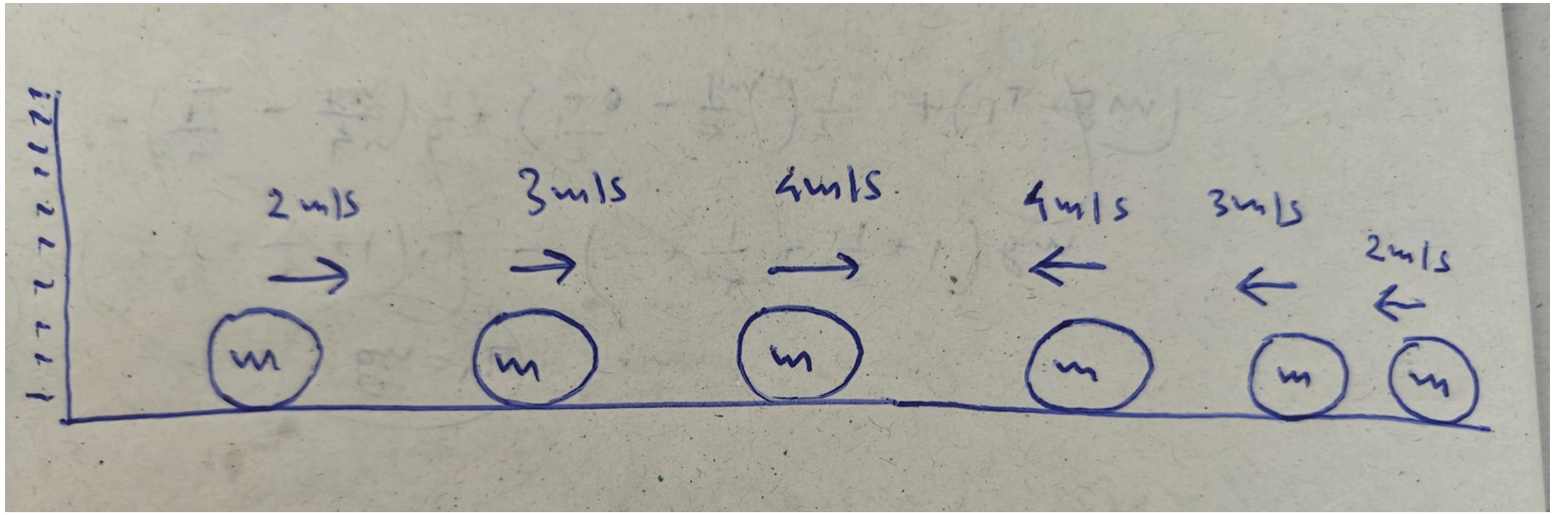
ANSWER

$$\frac{L}{2}$$

SAFETY SLIDE

QUESTION-8

Count the total number of collisions that would occur here (including the ones with the wall). Assume elastic collisions.



SAFETY SLIDE

ANSWER

18
(15 ball-ball + 3 wall collisions)

SAFETY SLIDE

QUESTION-9

Find the moment of inertia of a uniform circular ring (M, R) about an axis passing through its center and making $45°$ with the plane of the ring.

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ANSWER

$$\frac{3}{4}MR^2$$

SAFETY SLIDE

QUESTION-10

Position → velocity → acceleration → jerk → ?

Name the 4th derivative of position.

SAFETY SLIDE

ANSWER

Snap/Jounce

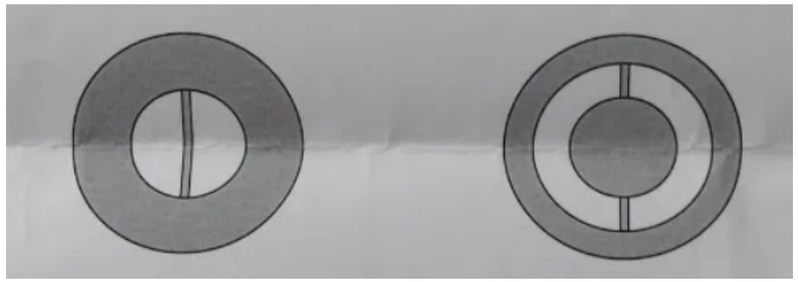
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QUESTION-11

Two tungsten spheres have the same radius, mass and surface finish, so they look identical. Tungsten is opaque even to hard X-rays.

- Sphere A is solid, with a small air cavity at its centre.
- Sphere B is a hollow shell with a solid tungsten core held at its centre by thin supports. Its air gap has the same volume as A's cavity.

You may not cut, drill or mark either sphere. Describe an experiment that tells them apart, and name the physical principle.



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ANSWER

Roll both spheres down a rough incline from rest. Since mass and radius are equal but the mass distribution differs, their moments of inertia differ. With $a = g\,sin\theta/(1 + I/mR^2)$, the sphere with the smaller I (the shell with suspended core, i.e. B) reaches the bottom first.

SAFETY SLIDE

QUESTION-12

(More than one option may be correct.)

A rigid body rotates about a fixed point with angular velocity ω and has angular momentum L. Which of the following guarantees that L and ω point in the same direction?

1. Neither direction is fixed in space
2. The direction of L is fixed
3. The direction of ω is fixed
4. The directions of both L and ω are fixed
5. None of these

SAFETY SLIDE

ANSWER

4. The directions of both L and ω are fixed

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