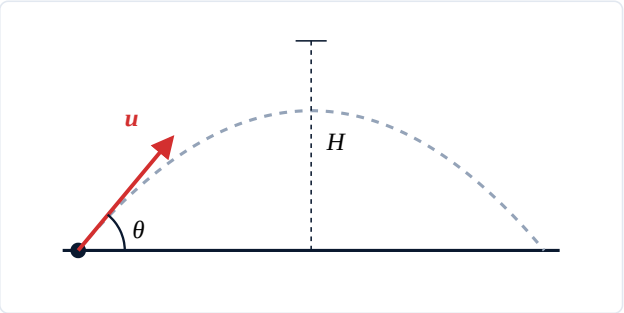
One Mentor Academy

BPhO Round 0 - Kinematics & Dynamics

Instructions: Attempt all 30 multiple-choice questions. Select the single best answer for each. Take acceleration due to gravity $g = 9.81\ \mathrm{m/s^2}$ unless otherwise stated. Air resistance is negligible unless explicitly mentioned. *Note: Diagrams strictly illustrate physical setups and kinematics; internal/external force vectors are deliberately omitted.*

1. A projectile is launched from horizontal ground with an initial velocity u at an angle θ to the horizontal. Which expression correctly gives the maximum vertical height H reached by the projectile?



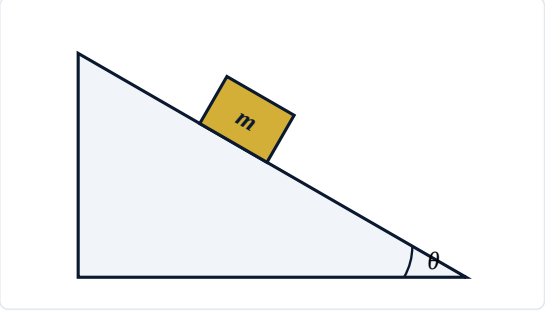
A $\frac{u^2 \sin\theta}{g}$

B $\frac{u^2 \sin 2\theta}{g}$

C $\frac{u^2 \sin^2\theta}{2g}$

D $\frac{u^2 \cos^2\theta}{2g}$

2. A block of mass m rests on a rough inclined plane at an angle θ to the horizontal. If the block is on the absolute verge of slipping down the plane, which of the following expressions defines the coefficient of static friction μ_s?



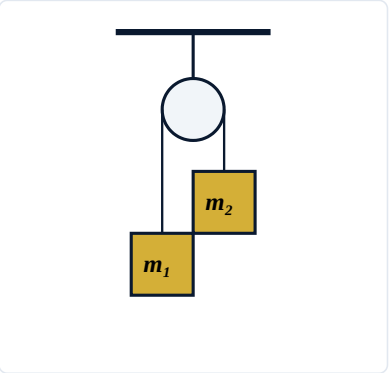
A $\mu_s = \sin\theta$

B $\mu_s = \cos\theta$

C $\mu_s = \tan\theta$

D $\mu_s = \cot\theta$

3. An Atwood machine consists of two masses m_1 and m_2 (where $m_1 > m_2$) connected by a light inextensible string passing over a frictionless, massless pulley. What is the magnitude of the acceleration of the masses?



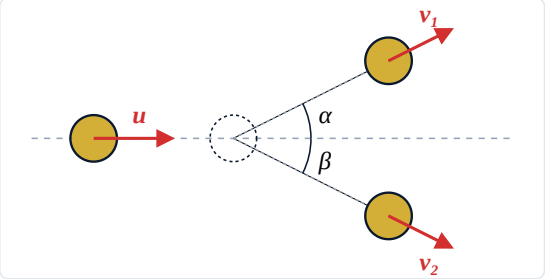
A $\frac{m_1-m_2}{m_1+m_2}g$

B $\frac{m_1+m_2}{m_1-m_2}g$

C $\frac{2m_1m_2}{m_1+m_2}g$

D $(m_1-m_2)g$

4. A smooth sphere of mass m moving with initial velocity u undergoes a glancing elastic collision with an identical stationary sphere. After the collision, they diverge at angles α and β relative to the original line of motion. Which equation describes the conservation of momentum perpendicular to the initial direction of motion?



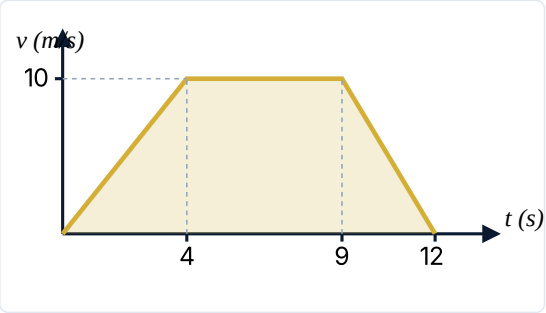
A $mu = mv_1\cos\alpha + mv_2\cos\beta$

B $0 = mv_1\sin\alpha - mv_2\sin\beta$

C $mu = mv_1\sin\alpha + mv_2\sin\beta$

D $0 = mv_1\cos\alpha + mv_2\cos\beta$

5. The physical motion of a car is recorded and its velocity-time graph is plotted below. What is the total displacement of the car during the entire 12-second interval?



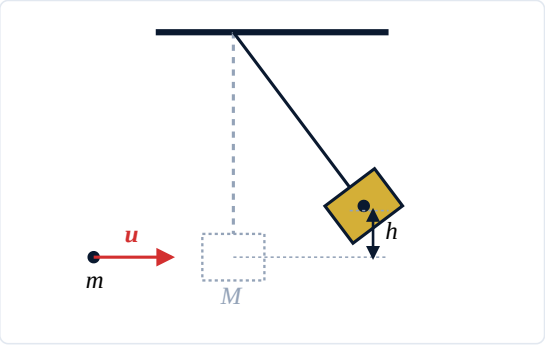
A 65 m

B 85 m

C 120 m

D 45 m

6. A bullet of mass m moving horizontally with velocity u embeds itself entirely within a stationary wooden block of mass M suspended by a light string. The combined system swings upwards, its center of mass rising by a vertical height h. What is the initial velocity u of the bullet?



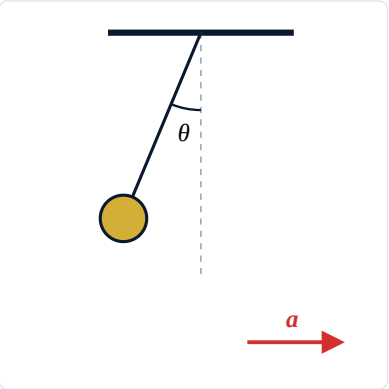
A $\sqrt{2gh}$

B $\left(\frac{m+M}{m}\right)\sqrt{2gh}$

C $\left(\frac{m}{m+M}\right)\sqrt{2gh}$

D $\left(\frac{M}{m}\right)\sqrt{gh}$

7. A bob of mass m hangs from the ceiling of a train carriage via a light string. The train accelerates horizontally with a constant acceleration a. The string makes a steady angle θ with the vertical. Which relation accurately links the acceleration a to the angle θ?



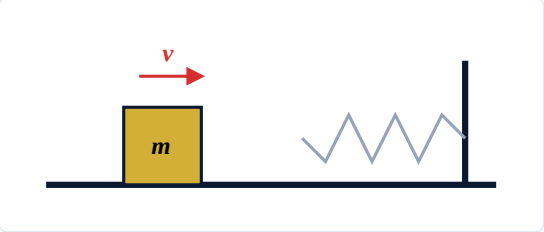
A $a = g\sin\theta$

B $a = g\cos\theta$

C $a = g\tan\theta$

D $a = g\cot\theta$

8. A block of mass m moving with speed v on a frictionless horizontal surface strikes a light horizontal spring of spring constant k attached to a rigid wall. What is the maximum compression x of the spring?



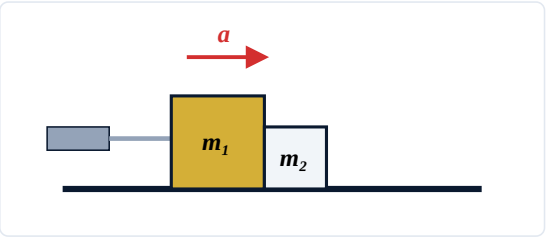
A $x = v\sqrt{\frac{m}{k}}$

B $x = v\sqrt{\frac{k}{m}}$

C $x = \frac{1}{2}v\sqrt{\frac{m}{k}}$

D $x = \frac{mv^2}{k}$

9. Two blocks of masses $m_1 = 3\ \text{kg}$ and $m_2 = 2\ \text{kg}$ are in direct contact on a smooth horizontal table. An external mechanical plunger pushes on block m_1 such that the entire system accelerates at $2\ \text{m/s}^2$. Based on the physical arrangement below, what is the magnitude of the mutual contact force between the two blocks?



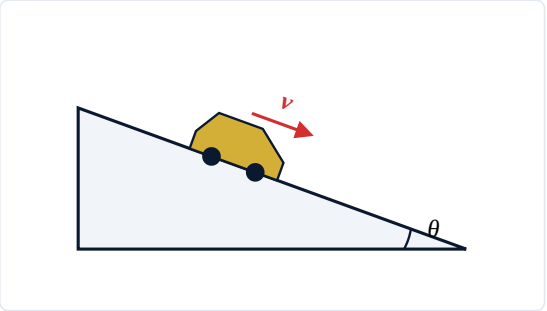
A $2\ \text{N}$

B $4\ \text{N}$

C $6\ \text{N}$

D $10\ \text{N}$

10. A vehicle of mass M coasts down a hill inclined at an angle θ to the horizontal. If the driver applies the brakes to produce a constant mechanical braking friction f_k against the motion, which expression represents the vehicle's resulting acceleration a down the plane?



A $a = g\sin\theta - \frac{f_k}{M}$

B $a = g\sin\theta + \frac{f_k}{M}$

C $a = \frac{f_k}{M} - g\cos\theta$

D $a = g\cos\theta - \frac{f_k}{M}$

11. A particle accelerates uniformly from rest. If it travels a distance x in the first t seconds, what is the distance traveled in the next t seconds?

A x

B $2x$

C $3x$

D $4x$

12. A lift of mass $800\ \text{kg}$ is moving downwards but decelerating at a rate of $2.0\ \text{m/s}^2$. What is the tension in the single supporting cable?

A $6248\ \text{N}$

B $7848\ \text{N}$

C $9448\ \text{N}$

D $1600\ \text{N}$

13. The displacement s of a particle varies with time t according to the equation $s = 4t^3 - 6t^2 + 2t$. What is its acceleration exactly at $t = 1\ \text{s}$?

A $0\ \text{m/s}^2$

B $12\ \text{m/s}^2$

C $2\ \text{m/s}^2$

D $24\ \text{m/s}^2$

14. Two perfectly elastic spheres of equal mass collide head-on. Sphere A is initially moving at $5\ \text{m/s}$ to the right, and Sphere B is initially at rest. What are their velocities immediately after the collision?

A Both move right at$2.5\ \text{m/s}$

B A is at rest, B moves right at$5\ \text{m/s}$

C A rebounds left at$5\ \text{m/s}$, B remains at rest

D Both move left at$2.5\ \text{m/s}$

15. A rocket ejects exhaust gas at a constant relative velocity v_e and a constant mass rate $\frac{dm}{dt}$. In the absence of external gravitational or drag forces, the thrust acting on the rocket is defined by:

A $\frac{1}{2}\frac{dm}{dt}v_e^2$

B $\frac{dm}{dt}v_e$

C $m\frac{dv_e}{dt}$

D $\frac{dm}{dt}\frac{1}{v_e}$

16. An object of mass m falls freely through a fluid and experiences a drag force strictly proportional to its velocity ($F_d = kv$). What is its terminal velocity v_t?

A $v_t = \sqrt{\frac{mg}{k}}$

B $v_t = \frac{mg}{k}$

C $v_t = \frac{k}{mg}$

D $v_t = \frac{m}{kg}$

17. A ball of mass m is dropped from a height H and bounces vertically back to a maximum height h. What is the magnitude of the impulse exerted by the floor on the ball during the impact?

A $m\sqrt{2g}(\sqrt{H}+\sqrt{h})$

B $m\sqrt{2g}(\sqrt{H}-\sqrt{h})$

C $mg(H+h)$

D $m\sqrt{gh}$

18. Two objects of masses m and $4m$ possess identical magnitudes of momentum. What is the ratio of their kinetic energies $K_m : K_{4m}$?

A 1 : 1

B 1 : 4

C 4 : 1

D 2 : 1

19. A cyclist outputs a constant mechanical power P while riding on a flat road. If air resistance is strictly proportional to the square of the speed ($F_{air} = cv^2$), what is the maximum steady speed v_{max} attainable?

A $\left(\frac{P}{c}\right)^{1/3}$

B $\left(\frac{P}{c}\right)^{1/2}$

C $\frac{P}{c}$

D $\sqrt{\frac{P}{mc}}$

20. A particle is moving in a uniform circle of radius r with constant angular velocity ω. What is the magnitude of its centripetal acceleration?

A ωr^2

B $\omega^2 r$

C $\frac{\omega^2}{r}$

D $\frac{v^2}{r^2}$

21. In an inelastic collision between two isolated macroscopic solid objects, which of the following statements universally holds true?

A Both momentum and kinetic energy are conserved.

B Momentum is conserved, but kinetic energy is not.

C Kinetic energy is conserved, but momentum is not.

D Neither momentum nor kinetic energy is conserved.

22. An object is launched vertically upwards with an initial speed u in a vacuum. If this initial speed u is doubled, how does the new maximum height compare to the original height H?

A It doubles.

B It quadruples.

C It increases by a factor of $\sqrt{2}$.

D It increases by a factor of 8.

23. A time-varying force $F = 5t + 2$ Newtons acts on a 2 kg mass for exactly 4 seconds. If the mass starts from rest, what is its final velocity?

A $24\ \text{m/s}$

B $48\ \text{m/s}$

C $12\ \text{m/s}$

D $36\ \text{m/s}$

24. Water is ejected horizontally from a hose of cross-sectional area A at a steady speed v. The water hits a vertical wall and stops dead without splashing back. Given the water density is ρ, what is the continuous force exerted on the wall?

A $\rho A v$

B $\frac{1}{2}\rho A v^2$

C $\rho A v^2$

D $2\rho A v^2$

25. A block is observed sliding down a rough inclined plane at a constant velocity. The angle of incline is θ. What is the coefficient of kinetic friction μ_k for this interaction?

A $\sin\theta$

B $\cos\theta$

C $\tan\theta$

D Cannot be determined from the given information.

26. A 500 g sphere is dropped from a height of 5 m onto a hard horizontal surface and rebounds to a height of 3.2 m. The duration of the collision with the ground is 0.02 s. What is the average force exerted by the ground on the sphere during impact?

A $\approx 200\ \text{N}$

B $\approx 445\ \text{N}$

C $\approx 395\ \text{N}$

D $\approx 890\ \text{N}$

27. A static machine gun fires 20 bullets per second. Each bullet has a mass of 10 g and exits the barrel with a speed of 400 m/s. What is the average recoil force exerted on the gun mount?

A 80 N

B 800 N

C 40 N

D 8000 N

28. Two completely inelastic masses, m and $3m$, approach each other head-on with speeds $2v$ and v respectively. After they collide and stick together, what is the absolute loss in the total kinetic energy of the system?

A $\frac{3}{8}mv^2$

B $\frac{3}{2}mv^2$

C $\frac{15}{8}mv^2$

D $\frac{5}{2}mv^2$

29. An object is projected straight up a smooth inclined plane of angle 30° with initial velocity v_0. How far up the plane does it travel before momentarily coming to rest?

A $\frac{v_0^2}{g}$

B $\frac{v_0^2}{2g}$

C $\frac{2v_0^2}{g}$

D $\frac{v_0^2}{g\sqrt{3}}$

30. A constant retarding force is applied to stop a moving train. If the train is moving at initial velocity v, its stopping distance is d. If the train is moving at $2v$ and the exact same retarding force is applied, what is the new stopping distance?

A $2d$

B $4d$

C $8d$

D $\sqrt{2}d$

Answer Key

1. C	**2.** C	**3.** A	**4.** B	**5.** B
6. B	**7.** C	**8.** A	**9.** B	**10.** A
11. C	**12.** C	**13.** B	**14.** B	**15.** B
16. B	**17.** A	**18.** C	**19.** A	**20.** B
21. B	**22.** B	**23.** A	**24.** C	**25.** C
26. B	**27.** A	**28.** C	**29.** A	**30.** B