SJPO2025 Questions

lopital

May 21, 2025

1. Estimate the minimum temperature required for the molecules of a typical classical gas to approach the speed of light.

A. 10^6 K
B. 10^8 K
C. 10^{10}K
D. 10^{14}K
E. 10^{18}K

2. A monkey climbs up a tree with speed v_1. It then climbs down with speed v_2. What is the average speed of the monkey throughout its motion?

A. $v_1 + v_2$
B. $\frac{1}{2}(v_1 + v_2)$
C. $\frac{v_1 v_2}{v_1 + v_2}$
D. $\frac{1}{2}(\frac{v_1 v_2}{v_1 + v_2})$
E. $2(\frac{v_1 v_2}{v_1 + v_2})$

3. A speeding car drives with constant velocity u. Right when it passes a stationary police van, the police van begins chasing after the car with constant acceleration a. What is the distance travelled by the police van before it catches up with the car?

A. $\dfrac{u}{a}$
B. $\dfrac{2u}{a}$
C. $\dfrac{u^2}{a}$
D. $\dfrac{2u^2}{a}$
E. $\dfrac{4u^2}{a}$

4. Jake is standing on a train accelerating at $a\ ms^{-2}$. He jumps up from P at $t = 0$ vertically with velocity u relative to the train. What is the distance between the new position he lands at, P', and P?

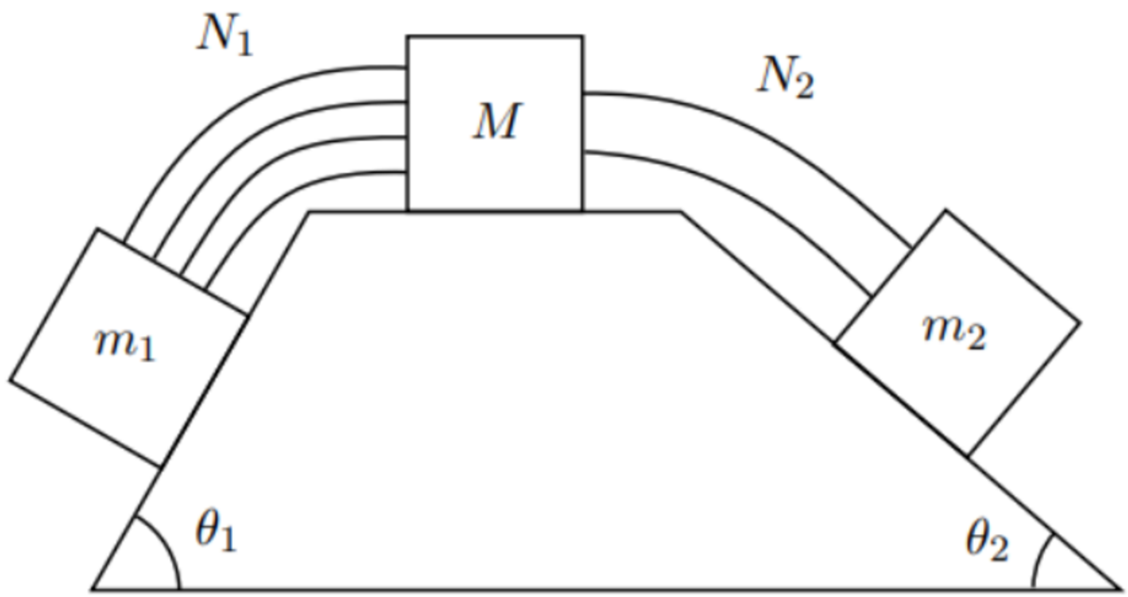
I don't have the question, so this is just a recreation of the question and sadly I don't have the actual answer choices too :(

A. ?
B. ?
C. ?
D. ?
E. ?

5. When Chris measures his weight at home, the scale reads 60 kg. One day, when Chris measures his weight while on a lift, the scale reads 40 kg. What is the acceleration of the lift?

A. $\frac{1}{3}g$ upwards
B. $\frac{1}{3}g$ downwards
C. $\frac{2}{3}g$ upwards
D. $\frac{2}{3}g$ downwards
E. $20g$ downwards

6. A block of mass M lies on a horizontal surface. The block is connected on the left by N_1 ropes to a mass m_1 on an incline of angle θ_1, and connected on the right by N_2 ropes to a mass m_2 on an incline of angle θ_2. When the setup is released from rest, what is the condition required for the block to move towards the left? All surfaces are frictionless.



A. $m_1 N_1 > m_2 N_2$

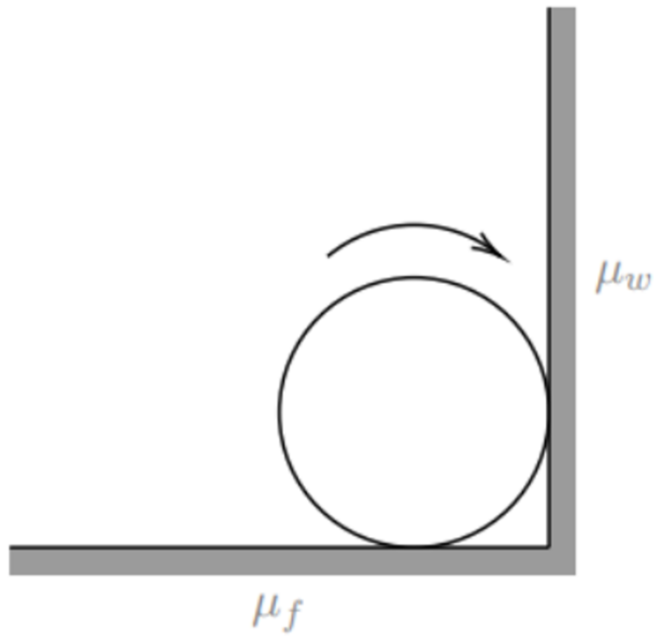
B. $m_1 \sin\theta_1 > m_2 \sin\theta_2$

C. $m_1 \cos\theta_1 > m_2 \cos\theta_2$

D. $m_1 N_1 \sin\theta_1 > m_2 N_2 \sin\theta_2$

E. $m_1 N_1 \cos\theta_1 > m_2 N_2 \cos\theta_2$

7. A ball of mass m rolls against a corner, maintaining contact with the horizontal floor of frictional coefficient μ_f, and the vertical wall of frictional coefficient μ_w. What is the frictional force f_f exerted by the floor, and the frictional force f_w exerted by the wall on the ball?



A. $f_f = \mu_f mg, f_w = 0$

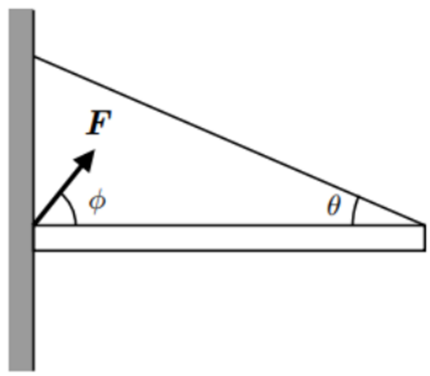
B. $f_f = \mu_f mg, f_w = \mu_w mg$

C. $f_f = \mu_f mg, f_w = \mu_f \mu_w mg$

D. $f_f = \dfrac{\mu_f mg}{\mu_w \mu_f + 1}, f_w = \dfrac{\mu_w mg}{\mu_w \mu_f + 1}$

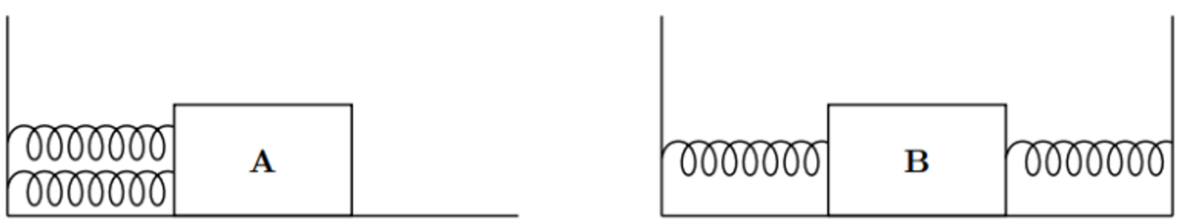
E. $f_f = \dfrac{\mu_f mg}{\mu_w \mu_f + 1}, f_w = \dfrac{\mu_w \mu_f mg}{\mu_w \mu_f + 1}$

8. A uniform rod is hinged to a vertical wall on one end and held horizontal by a string on the other end. The string makes an angle θ with the horizontal. What is the angle ϕ from the horizontal made by the force F exerted by the hinge on the rod?



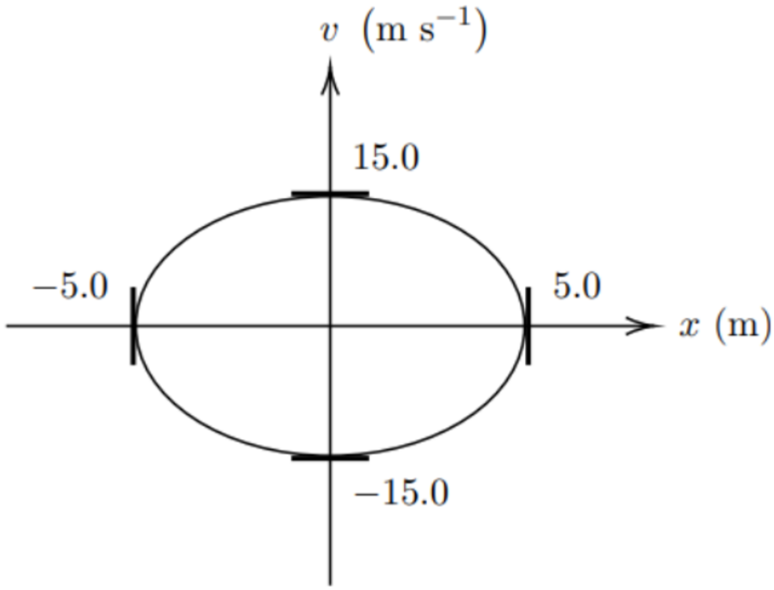
A. θ
B. 2θ
C. $90^\circ - \theta$
D. $90^\circ - 2\theta$
E. 45°

9. Two identical blocks, A and B, and four identical springs are arranged in separate configurations shown below. What is the correct relation between the periods of oscillations T_A and T_B of blocks A and B respectively?



A. $T_A = \frac{1}{4} T_B$
B. $T_A = \frac{1}{2} T_B$
C. $T_A = T_B$
D. $T_A = 2T_B$
E. $T_A = 4T_B$

10. A mass undergoes a type of motion where its graph of velocity v against displacement x is an ellipse. Throughout its motion, its maximum displacement is $x_{max} = 5.0$m and its maximum velocity is $v_{max} = 15.0ms^{-1}$. WHat is its maximum acceleration a_{max}?



A. $3.0ms^{-2}$
B. $23ms^{-2}$
C. $45ms^{-2}$
D. $75ms^{-2}$
E. $90ms^{-2}$

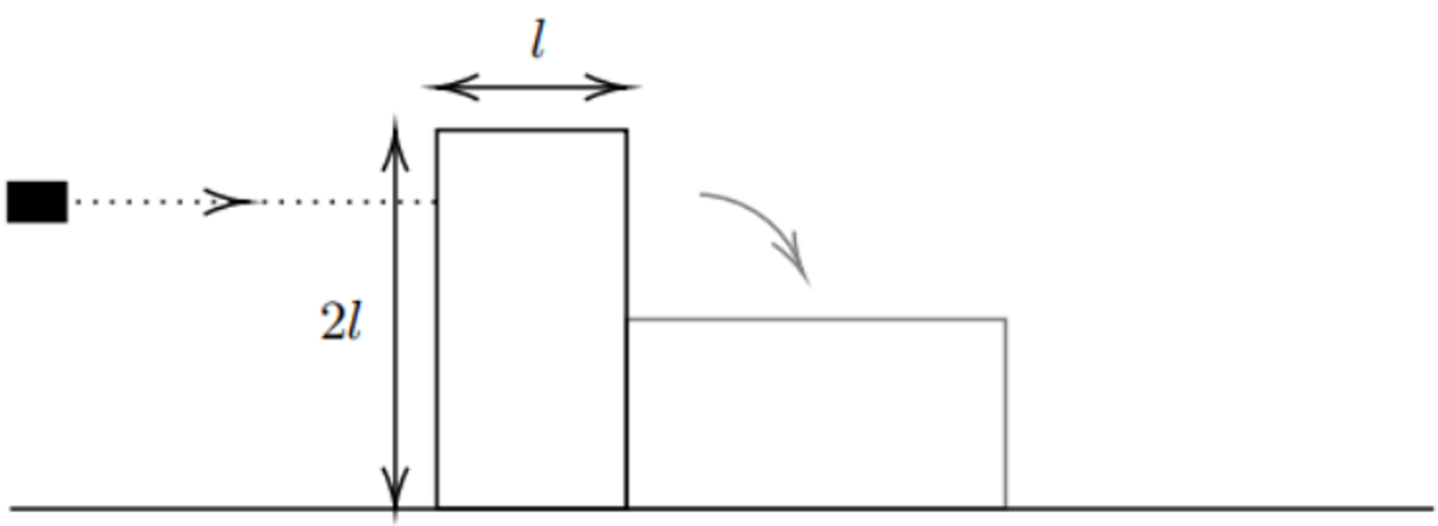
11. Ten identical masses are spaced at equal distances along a horizontal line. The mass on the left end is given a push towards the right, starting a chain of collisions between the masses. Given that every collision is perfectly inelastic, what is the total percentage of energy dissipated as heat throughout the process?

A. 1%
B. 10%
C. 50%
D. 90%
E. 99%

12. N hard billiard balls, each of mass m and with negligible size, are on a smooth horizontal table. The table is square with side l, and has a wall on each edge. Every ball is travelling with the same average speed v but in a random direction. As the balls collide with the walls, they exert forces on the walls. What is the average force exerted on one wall? Assume all collisions to be perfectly elastic.

A. $\dfrac{mv^2}{l}$
B. $\dfrac{1}{4}\dfrac{mNv^2}{l}$
C. $\dfrac{1}{2}\dfrac{mNv^2}{l}$
D. $\dfrac{mNv^2}{l}$
E. $2\dfrac{mNv^2}{l}$

13. A bullet is fired at the left face of a cuboid of mass m, width l, and height $2l$, causing the cuboid to tip. In order for the cuboid to topple completely on its right face, what is the minimum energy that the bullet must transfer to the cuboid? Assume that the cuboid does not slip.



A. $0.12mgl$
B. $0.50mgl$
C. $0.75mgl$
D. mgl
E. $1.2mgl$

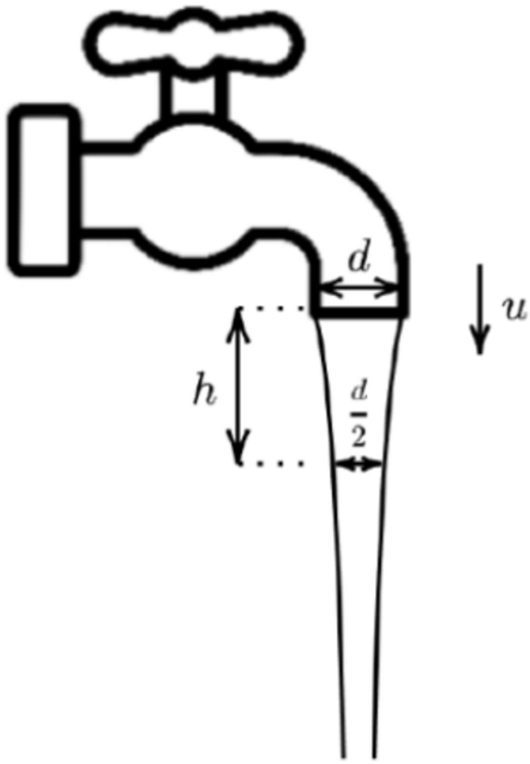
14. A car engine is set to deliver a constant power P. When driven along flat ground, the car moves at constant speed u. When driven up an incline of angle $30°$ above the horizontal, the car moves at constant speed $\frac{2}{3}u$. At what constant speed will the car move when driven up an incline of angle $60°$ above the horizontal? Assume that the frictional force exerted on the car remains constant in each case.

A. $0.25u$
B. $0.33u$
C. $0.38u$
D. $0.44u$
E. $0.54u$

15. Juncheng is on a boat that is floating in a small lake. What is the effect of each action below on the equilibrium water level in the lake?
I. He drops his phone into the lake and the phone reaches the riverbed.
II. He drinks some water from the lake.
III. He picks up some litter floating on the lake.

A. **I**: Increase, **II**: No change, **III**: No change
B. **I**: Decrease, **II**: No change, **III**: No change
C. **I**: Decrease, **II**: No change, **III**: Decrease
D. **I**: Decrease, **II**: Decrease, **III**: Decrease
E. **I**: Increase, **II**: Decrease, **III**: Decrease

16. From daily life, it is well-known that as a stream of water descends, it becomes thinner. Consider a vertical stream emitted at speed u from a tap of diameter d. At what height h below the tap does the diameter of the stream reduce to $\frac{1}{2}d$? Assume that the flow is laminar with no energy losses.



A. $\frac{1}{2}\frac{u^2}{g}$

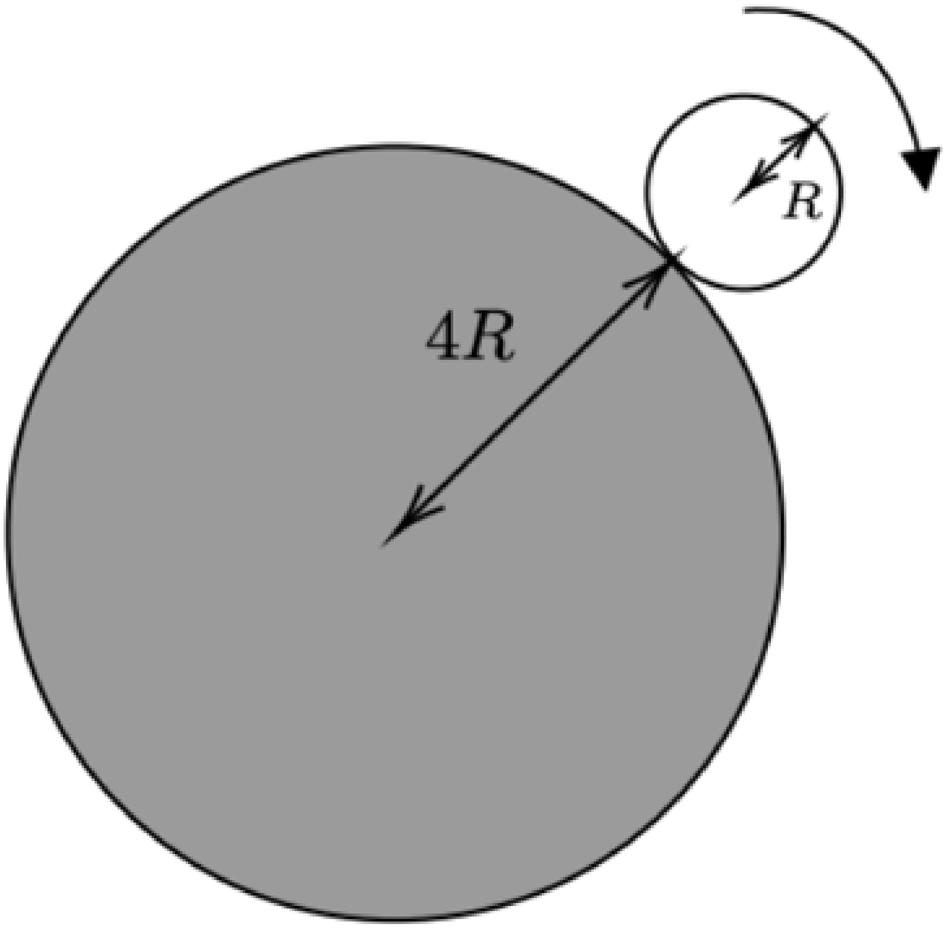
B. $\frac{3}{2}\frac{u^2}{g}$

C. $2\frac{u^2}{g}$

D. $\frac{15}{2}\frac{u^2}{g}$

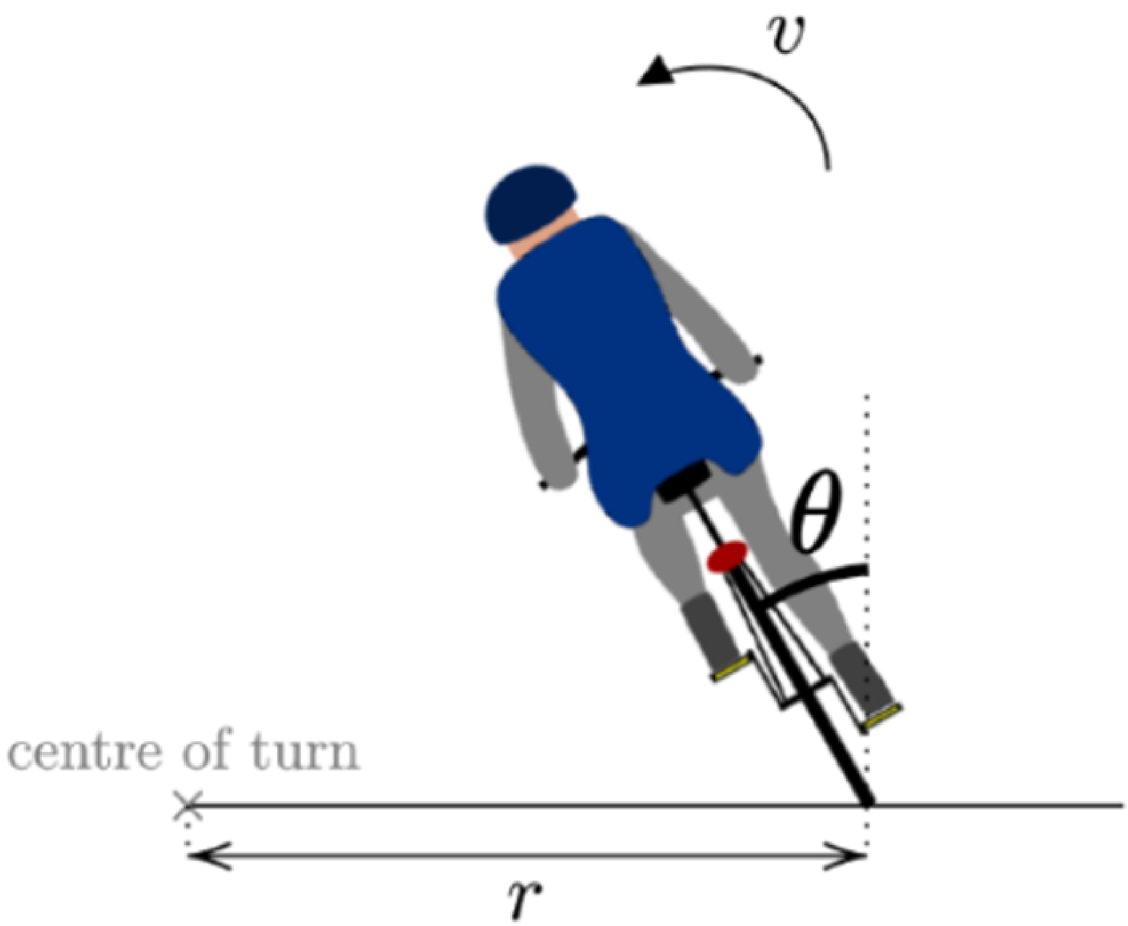
E. $8\frac{u^2}{g}$

17. A small coin of radius R contacts a large coin of radius $4R$ as shown in the figure (top-down view). The small coin is slowly moved such that it rolls without slipping around the large coin, while the large coin is held stationary. By the time the small coin returns to its starting position, how many revolutions has it completed (relative to you)?



A. 1
B. 2
C. 4
D. 5
E. 8

18. A cyclist travels at a constant speed v along a smooth horizontal ground. When he makes a left turn of radius r, he tilts towards the left by an angle θ from the vertical. Find θ.



A. $\frac{v}{r}$

B. $\arcsin(\frac{gr}{v^2})$

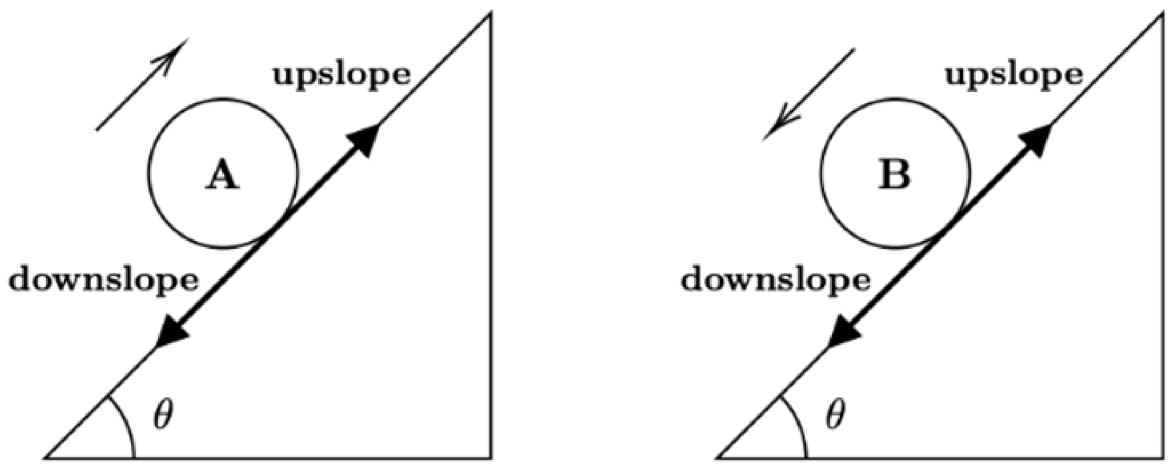
C. $\arcsin(\frac{v^2}{gr})$

D. $\arctan(\frac{gr}{v^2})$

E. $\arctan(\frac{v^2}{gr})$

Use this information to answer Q19 and Q20.

Two spheres, A and B, roll without slipping along an incline of angle θ. Sphere A is launched from the bottom of the incline and rolls upslope. Sphere B is launched from the top of the incline and rolls downslope.



19. What is the direction of friction acting on each sphere?

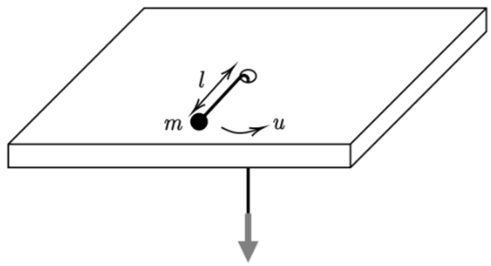
A. Upslope for both spheres
B. Downslope for both spheres
C. Upslope for sphere A, downslope for sphere B
D. Upslope for sphere B, downslope for sphere A
E. There is no friction acting on both spheres

20. It is known the moment of inertia for a solid sphere of mass M and radius R about its centrax axis is $I = \frac{2}{5}MR^2$.

What is the minimum coefficient of friction μ such that both spheres can roll without slipping?

A. $\tan\theta$
B. $\dfrac{2}{5}\tan\theta$
C. $\dfrac{2}{7}\tan\theta$
D. $\dfrac{2}{5}\sin\theta$
E. $\dfrac{2}{7}\sin\theta$

21. A bead of mass m is on a smooth horizontal table. The head is tied to a string, whose end passes through a small hole in the table. Initially, the bead circles the hole at speed u while the string is held firmly. The string is then slowly pulled until the length of the string on the table decreases from l to $\frac{1}{2}l$. How much work is done by the pulling force?



A. 0

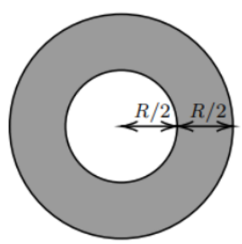
B. $\frac{1}{2}mu^2$

C. $\frac{3}{2}mu^2$

D. $2mu^2$

E. $\frac{15}{2}mu^2$

22. Suppose that we dug out from the Earth's centre a large spherical hole whose radius is half of the Earth's radius. What would be the new gravitational field on the Earth's surface, in terms of the original g? Assume that the Earth is a uniform sphere.



A. $\frac{1}{8}g$

B. $\frac{1}{4}g$

C. $\frac{1}{2}g$

D. $\frac{3}{4}g$

E. $\frac{7}{8}g$

23. A rocket takes off from the surface of the Earth with speed v. However, its launch speed is smaller than the escape speed v_E (i.e. the minimum speed required to reach infinity) by a factor $\alpha < 1$, with $v = \alpha v_E$. What is the maximum height above the Earth's surface reached by the rocket, in terms of the Earth's radius R?

A. $\alpha^2 R$

B. $\dfrac{1}{1-\alpha^2}R$

C. $\dfrac{\alpha^2}{1-\alpha^2}R$

D. $\dfrac{1}{1+\alpha^2}R$

E. $\dfrac{\alpha^2}{1+\alpha^2}$

24. Shaun stands midway between two parallel plane mirrors that are placed a distance d apart. He sees infinitely many images of himself when facing one of the mirror. What is the distance between two adjacent images of Shaun?

A. $\dfrac{1}{2}d$

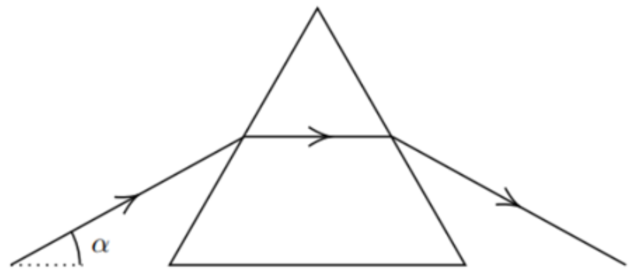
B. $\dfrac{1}{4}d$

C. d

D. $2d$

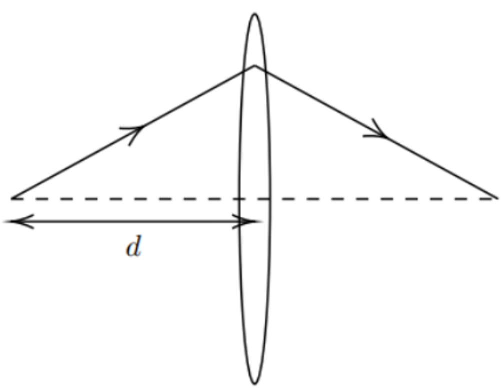
E. $4d$

25. A ray of light enters a glass prism at an angle α from the horizontal. The prism has the shape of an equilateral triangle with a horizontal base, and has refractive index $n = 1.5$. For what angle α will the path of the ray be symettrical shown in the figure?



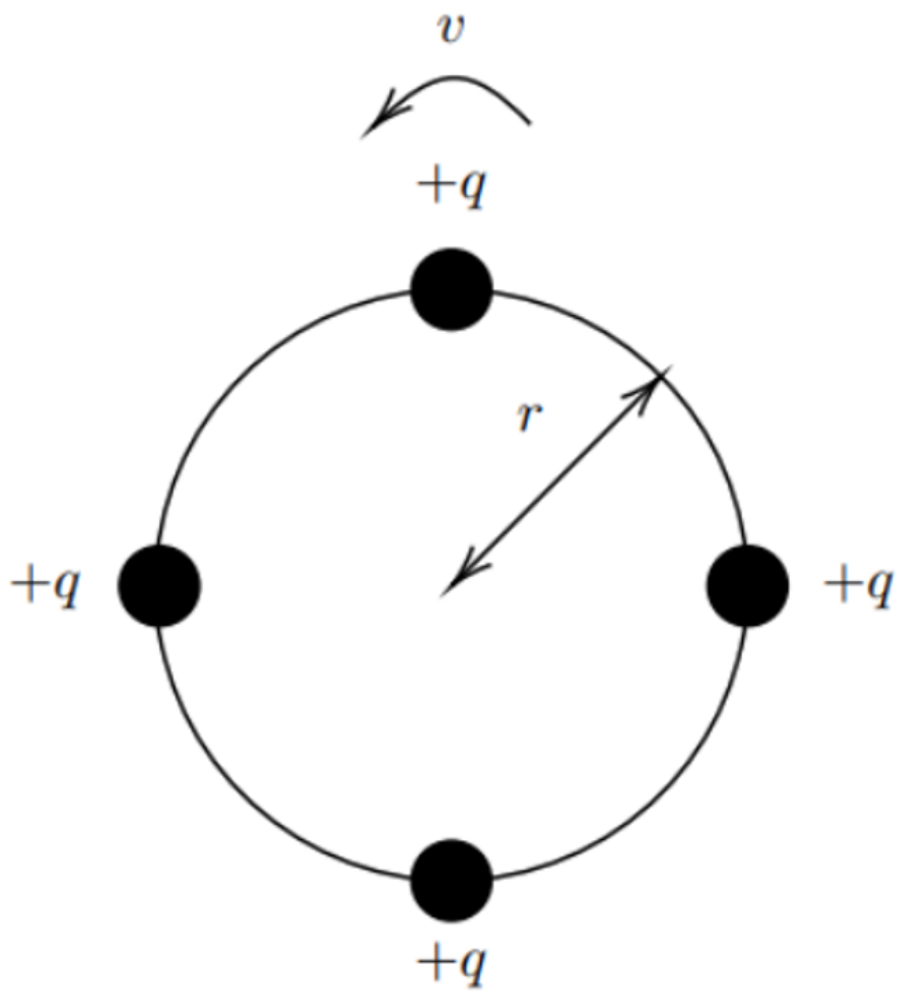
A. $0°$
B. $11°$
C. $19°$
D. $30°$
E. $42°$

26. A ray of light enters a thin convex lens of focal length f. The ray originated from a point along the optical axis at a distance d from the lens. For what distance d will the path of the ray be symettrical?



A. $\frac{1}{2}f$
B. f
C. $\frac{3}{2}f$
D. $2f$
E. $4f$

27. Four identical charges $+q$ are glued to the rim of a disc of radius r. The disc is rotated such that every charge moves at constant speed v. What is the average current generated at the rim of the disc?



A. $\frac{1}{2}\frac{qv}{\pi r}$

B. $2\frac{qv}{\pi r}$

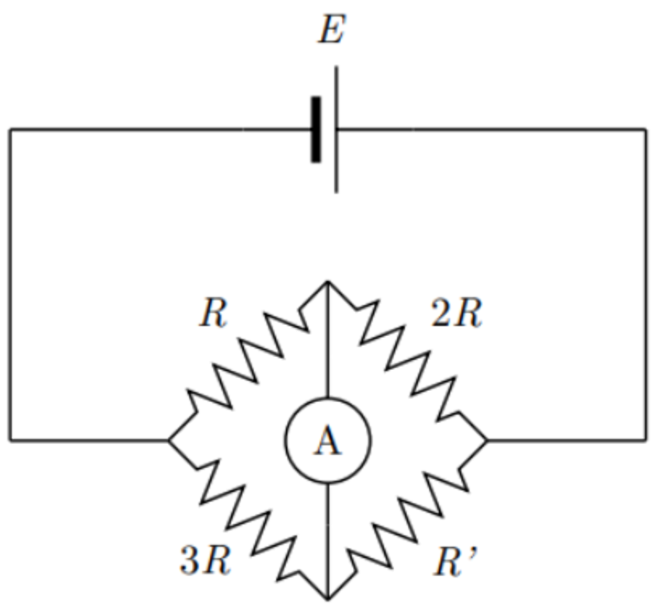
C. $4\frac{qv}{\pi r}$

D. $\frac{qv}{r}$

E. $4\frac{qv}{r}$

Use this information to answer Q28 and Q29.

A Wheatstone bridge is a circuit comprising an ideal battery of e.m.f. E, four resistors, and an ideal ammeter between them.



28. The Wheatstone bridge is said to be *balanced* when there is no flow of current through the ammeter. To what value must the resistor R' be set for the Wheatstone bridge to be balanced?

A. 0

B. $\frac{2}{3}R$

C. R

D. $2R$

E. $6R$

29. The Wheatstone bridge is said to be *unbalanced* when there is current flowing through the ammeter. What is the current through the ammeter in the unbalanced Wheatstone bridge with $R' = 4R$?

A. $\frac{1}{25}\frac{E}{R}$

B. $\frac{12}{25}\frac{E}{R}$

C. $\frac{1}{5}\frac{E}{R}$

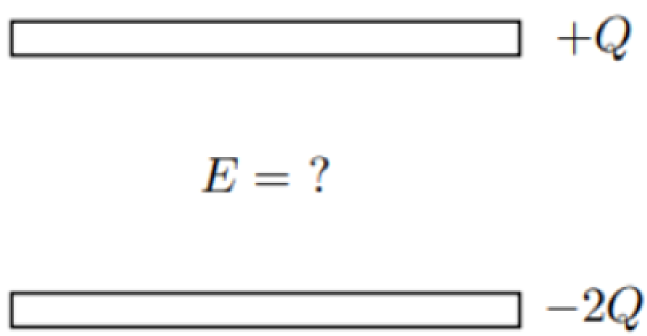
D. $\frac{1}{2}\frac{E}{R}$

E. $\frac{21}{10}\frac{E}{R}$

30. There are two forces responsible for the attraction between a proton and an electron: a gravitational force $\vec{F_G}$ and an electric force $\vec{F_E}$. Find the ratio $\frac{|\vec{F_G}|}{|\vec{F_E}|}$.

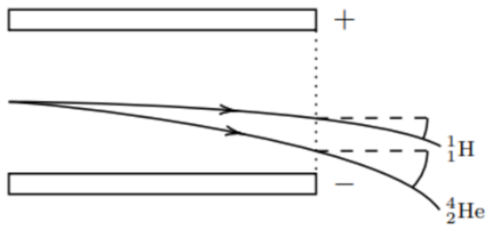
A. 4×10^{-20}
B. 8×10^{-37}
C. 4×10^{-40}
D. 2×10^{-43}
E. It depends on the distance between the proton and the electron.

31. Consider two metal plates that are oppositely charged and parallel with equal areas A. One plate contains charge $+Q$, while the other plate contains charge $-2Q$. What is the electric field between the two plates?



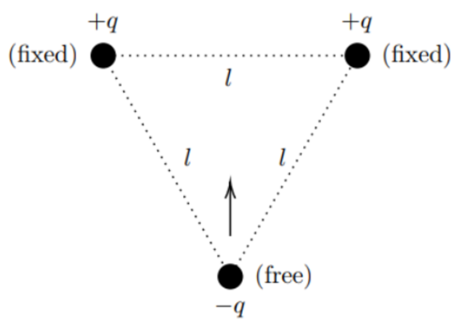
A. $\frac{1}{2}\frac{Q}{\epsilon_0 A}$
B. $\frac{Q}{\epsilon_0 A}$
C. $\frac{3}{2}\frac{Q}{\epsilon_0 A}$
D. $2\frac{Q}{\epsilon_0 A}$
E. $3\frac{Q}{\epsilon_0 A}$

32. Consider two metal paltes that are oppositely charged and horizontal with equal areas. Two beams of nuclei, ${}^1_1$H and ${}^4_2$He, are sent horizontally at equal speeds through the two plates. The ${}^1_1$H beam exits the region between the two places with an angle of deflection of 30°. What is the angle of deflection of the ${}^4_2$He beam? Neglect gravity.



A. 30°
B. 49°
C. 60°
D. 67°
E. 90°

33. Three charges of mass m are initially arranged to form an equilateral triangle of side l, with two fixed $+q$ charges, and one free $-q$ charge. The $-q$ charge is now released from rest, and it begins to undergo oscillatory motion. What is its maximum speed?



A. $\dfrac{q}{\sqrt{\pi\epsilon_0 ml}}$

B. $\dfrac{1}{2}\dfrac{q}{\sqrt{\pi\epsilon_0 ml}}$

C. $\dfrac{1}{\sqrt{2}}\dfrac{q}{\sqrt{\pi\epsilon_0 ml}}$

D. $\dfrac{\sqrt{3}}{2}\dfrac{q}{\sqrt{\pi\epsilon_0 ml}}$

E. $\sqrt{\dfrac{\sqrt{3}}{2}}\dfrac{q}{\sqrt{\pi\epsilon_0 ml}}$

Use this information to answer Q34, Q35 and Q36.

Suppose that the Earth's magnetic field has a strength of $B = 60\mu T$ and makes an angle of $\theta = 20°$ from the vertical.

34. A horizontal straight wire has mass per unit length $\lambda = 0.010kgm^{-1}$. The wire can be magnetically suspended in mid-air. What minimum current I must be supplied through the wire for this to be possible?

A. $560A$
B. $1640A$
C. $1740A$
D. $4780A$
E. $5090A$

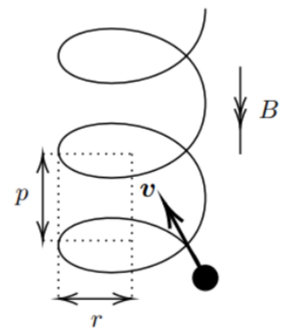
35. A compass is placed inside a horizontal solenoid of $N = 200$ turns and length $l = 0.10m$. The solenoid axis is oriented perpendicular to the direction of the compass needle. Initially, there is no current through the solenoid. What current I must be supploed through the solenoid for the compass needle to deflect by an angle of $\varphi = 60°$?

A. $0.004A$
B. $0.007A$
C. $0.014A$
D. $0.041A$
E. $0.141A$

36. A horizontal circular loop has radius $r = 1.0m$ and resistance $R = 5.0\Omega$. When the loop is flipped (i.e. rotated by 180° about its horizontal axis), a brief current is induced through the loop. What is the total charge Q that flows through the loop during this time?

A. $0\mu C$
B. $26\mu C$
C. $35\mu C$
D. $71\mu C$
E. $75\mu C$

37. A particle of charge q and mass m in a uniform magnetic field B travels in a helical path of radius r and pitch p. What is its speed v?



A. $\frac{qB}{m}r$

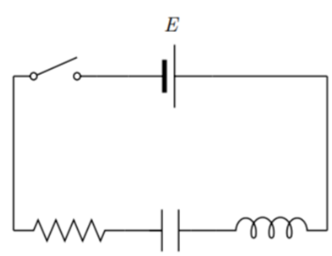
B. $\frac{qB}{m}p$

C. $\frac{qB}{m}\sqrt{(2r)^2 + p^2}$

D. $\frac{qB}{m}\sqrt{(2\pi r)^2 + p^2}$

E. $\frac{qB}{m}\sqrt{r^2 + (\frac{p}{2\pi})^2}$

38. A resistor, an uncharged capacitor and an inductor are connected in series with a battery of e.m.f. E. The switch has initially been open for a long time. At time $t = 0$, the switch is closed. What is the voltage V_C across the capacitor and the voltage V_L across the inductor at times $t = 0$ and $t = \infty$?



A. $V_C = 0, V_L = 0$ at $t = 0$; $V_C = 0, V_L = 0$ at $t = \infty$

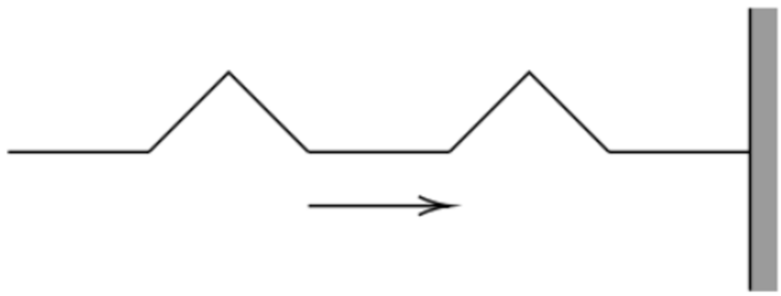
B. $V_C = 0, V_L = 0$ at $t = 0$; $V_C = E, V_L = 0$ at $t = \infty$

C. $V_C = 0, V_L = E$ at $t = 0$; $V_C = 0, V_L = 0$ at $t = \infty$

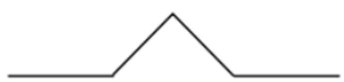
D. $V_C = 0, V_L = E$ at $t = 0$; $V_C = E, V_L = 0$ at $t = \infty$

E. $V_C = E, V_L = 0$ at $t = 0$; $V_C = 0, V_L = E$ at $t = \infty$

39. A rope is secured to a wall on one end. Two triangular pulses travel through the rope towards the wall, as shown in the snapshot below, Which of the following options shows a possible shape of the rope some time later?



A.

B. 

C. 

D. 

E. 

Apologies from the author - I don't know how to format this

40. A man whose body has an effective surface area $A = 2.0m^2$ stands in sunlight with intensity $I = 1200Wm^{-2}$ and wavelength $\lambda = 550nm$. How many photons are received by the man every second?

(Hint: The energy E of a photon with frequency f is given by $E = hf$, where $h = 6.63 \times 10^{-34}Js$ is Planck's constant.)

A. 3.3×10^{21}
B. 6.6×10^{21}
C. 6.6×10^{30}
D. 6.6×10^{34}
E. 6.6×10^{42}

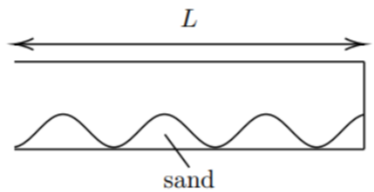
41. A thin film of water with refractive index $n = 1.33$ and thickness $d = 400nm$ lies on a flat surface. When viewed normally, what colour does it appear to have?

A. Violet (wavelength: $380 - 450nm$)
B. Blue (wavelength: $450 - 500nm$)
C. Green (wavelength: $500 - 570nm$)
D. Yellow (wavelength: $570 - 630nm$)
E. Red (wavelength: $630 - 700nm$)

42. Unpolarised light of intensity I_0 is passed through a series of two polarisers. No light emerges from the end. However, when a third polariser is now placed between the two polarisers, some light of intensity I emerges from the end. What is the maximum possible value of I?

A. $\frac{1}{8}I_0$
B. $\frac{1}{4}I_0$
C. $\frac{1}{2}\sqrt{2}I_0$
D. $\frac{1}{2}I_0$
E. I_0

43. A pipe of length L is open on one end and contains fine sand that is initially uniformly scattered. When a sound is played through the open end of the pipe, the sane forms the periodoc pattern shown below. What is the frequency of the sound, in terms of the speed of sound c?



A. $\frac{2}{7}\frac{c}{L}$

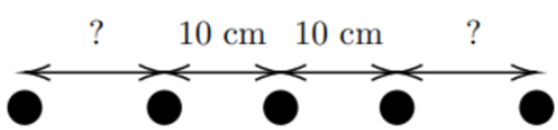
B. $\frac{4}{7}\frac{c}{L}$

C. $\frac{c}{L}$

D. $\frac{7}{4}\frac{c}{L}$

E. $\frac{7}{2}\frac{c}{L}$

44. Monochromatic light of wavelength λ is passed through a diffraction grating of slit spacing $d = 3\lambda$, and the resulting pattern is observed in a screen. The first-order bright spots are found to be a distance $10cm$ from the central spot. What is the distance between the first-order and second-order bright spots on each side?



A. $0.10m$

B. $0.15m$

C. $0.18m$

D. $0.21m$

E. $0.25m$

45. Two bodies of temperatures T_1 and T_2 and heat capacities C_1 and C_2 are placed in thermal contact. What is their final temperature? Assume no heat loss to the surrounding.

A. $\dfrac{T_1 + T_2}{2}$

B. $\dfrac{T_1C_1 + T_2C_2}{2}$

C. $\dfrac{T_1C_1 + T_2C_2}{C_1 + C_2}$

D. $\dfrac{T_1C_1 - T_2C_2}{C_1 - C_2}$

E. $\dfrac{T_1C_1 + T_2C_2}{2(C_1 + C_2)}$

46. A sample of ideal gas has pressure P and temperature T. Every molecule of the gas has mass m. What is the mass density ρ of the gas?

A. $\dfrac{P}{k_BT}$

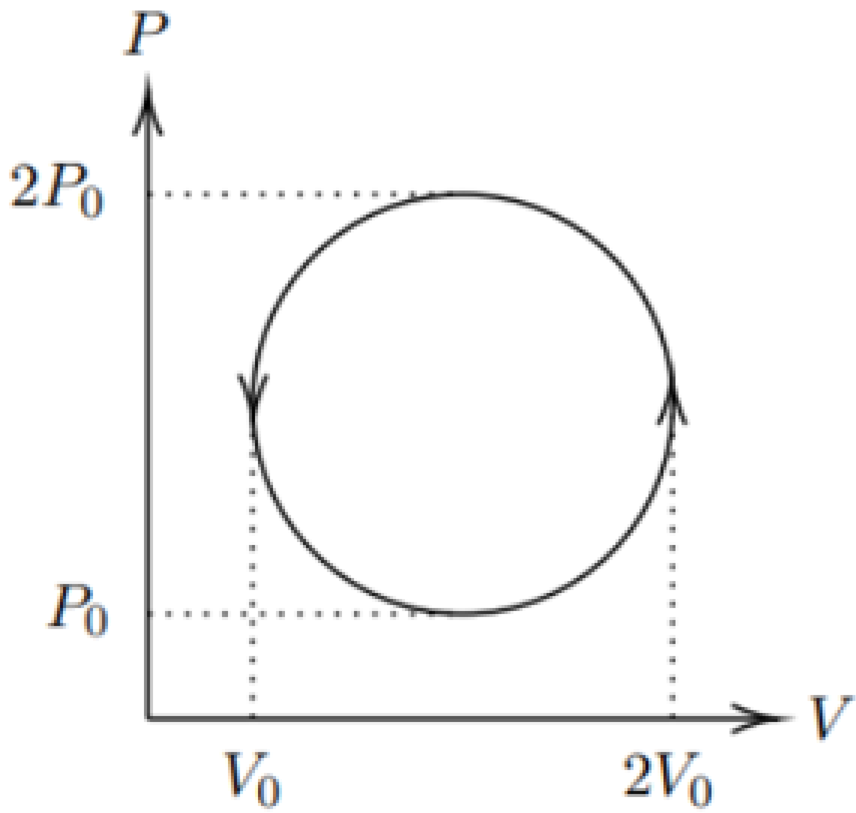
B. $\dfrac{mP}{RT}$

C. $\dfrac{mP}{k_BT}$

D. $\dfrac{P}{mRT}$

E. $\dfrac{P}{mk_BT}$

47. A gas undergoes a thermodynamic cycle that is represented by a counter-clockwise circular path on the $P - V$ diagram. Throughout the cycle, the gas reaches pressures between P_0 and $2P_0$, and volumes between V_0 and $2V_0$. What is the total heat flow in or out of the gas in one cycle?



A. No heat flow

B. Heat flow of $\pi P_0 V_0$ into the gas

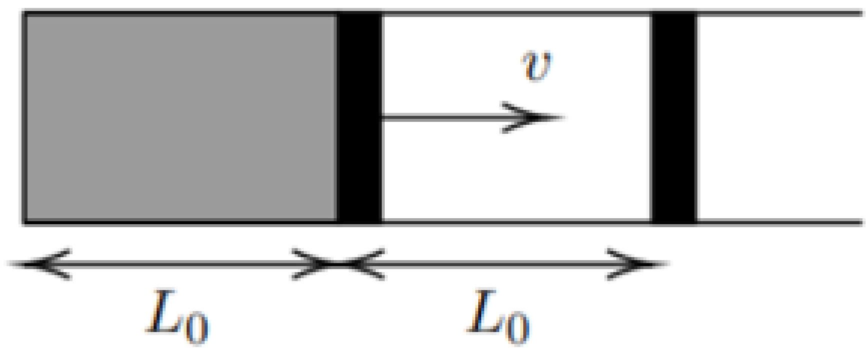
C. Heat flow of $\pi P_0 V_0$ out of the gas

D. Heat flow of $\frac{1}{4}\pi P_0 V_0$ into the gas

E. Heat flow of $\frac{1}{4}\pi P_0 V_0$ out of the gas

Use this information to answer Q34, Q35 and Q36.

A monatomic ideal gas is placed in the chamber of a piston with length L_0. The piston is **not** insulated, so the gas is free to exchange heat with its surroundings. Initially the gas is at equilibrium with pressure P_0. The piston is now moved outwards with speed v, causing the gas to expand, until a legnth $2L_0$ is reached.



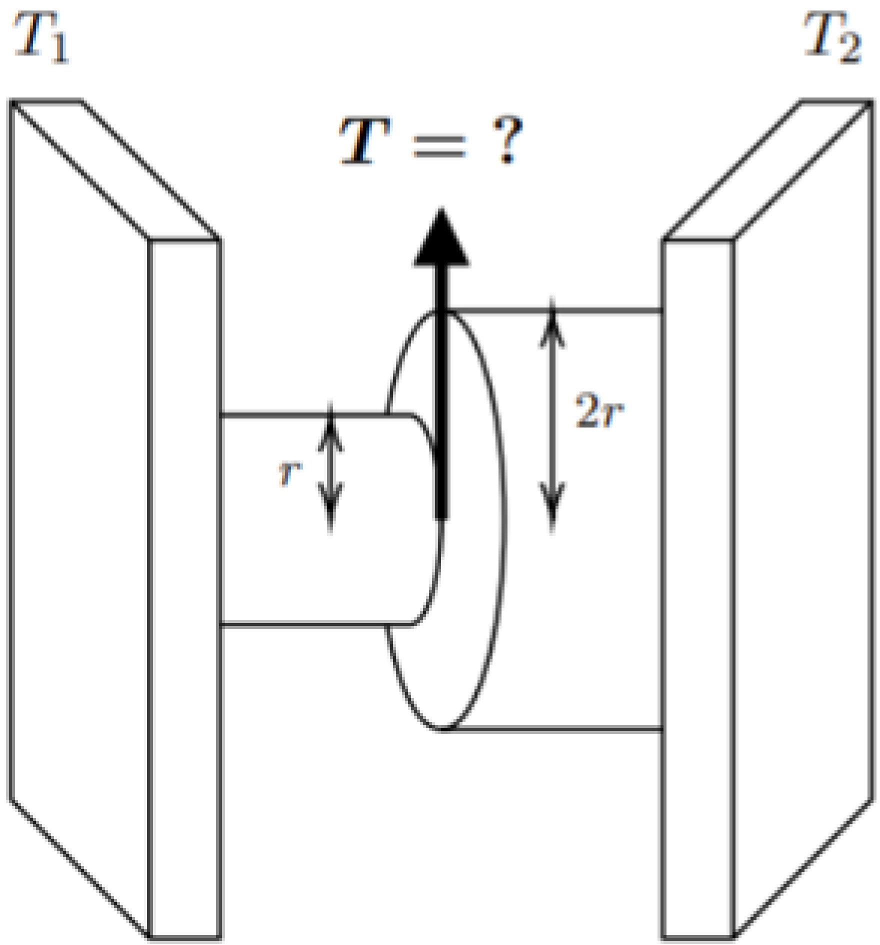
48. In the limit $v \to 0$, what is the pressure of the gas at the moment the piston reaches length $2L_0$?

A. $0.25P_0$
B. $0.31P_0$
C. $0.50P_0$
D. $2.0P_0$
E. $3.2P_0$

49. In the limit $v \to \infty$, what is the pressure of the gas at the moment the piston reaches length $2L_0$?

A. $0.25P_0$
B. $0.31P_0$
C. $0.50P_0$
D. $2.0P_0$
E. $3.2P_0$

50. Two cylinders of radii r and $2r$ are joined along a common axis. They connect two reservoirs which are maintained at temperatures T_1 and T_2. What is the steady state temperature T of the point at which they are joined? The cylinders have the same length and are made of the same material.



A. $\frac{1}{2}(T_1 + T_2)$

B. $\frac{1}{3}(2T_1 + T_2)$

C. $\frac{1}{3}(T_1 + 2T_2)$

D. $\frac{1}{5}(4T_1 + T_2)$

E. $\frac{1}{5}(T_1 + 4T_2)$