1. A potter's wheel ($I_{Disk} = \frac{1}{2}MR^2$) of mass 7.00 kg and radius 0.650 m spins about its central axis. A 2.10 kg lump of clay is dropped onto the wheel at a distance 0.410 m from the axis. Calculate the final rotational inertia of the system.

A) 2.99 kg-m^2
B) 0.55 kg-m^2
C) 4.42 kg-m^2
D) 3.31 kg-m^2
E) 1.49 kg-m^2
F) 1.83 kg-m^2
G) 2.33 kg-m^2
H) 4.82 kg-m^2

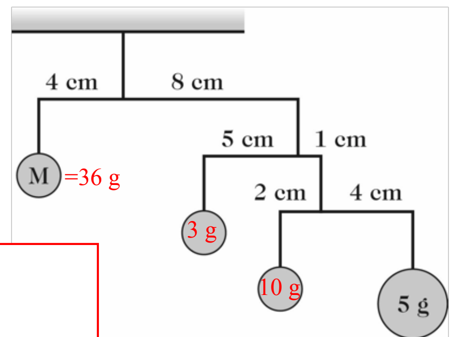
$$I_T = I_{Disk} + I_{Clay} = \tfrac{1}{2}MR^2 + mr^2$$
$$= [(0.5)(7.00)(0.650)^2 + (2.1)(0.41)^2]\,\mathrm{kg\cdot m^2}$$
$$= 1.83\,\mathrm{kg\cdot m^2}$$

2. A force of 16.88 N is applied tangentially to a wheel of radius 0.340 m and gives rise to an angular acceleration of 1.20 rad/s^2. Calculate the rotational inertia of the wheel.

A) 2.77 kg-m^2
B) 0.73 kg-m^2
C) 4.41 kg-m^2
D) 3.89 kg-m^2
E) 1.15 kg-m^2
F) 1.85 kg-m^2
G) 2.44 kg-m^2
H) 4.78 kg-m^2

$$I = \tau/\alpha,\ \tau = FR$$
$$= FR/\alpha = [(16.88)(0.34)/1.2]\,\mathrm{rad/s^2}$$
$$= 4.78\,\mathrm{kg\cdot m^2}$$

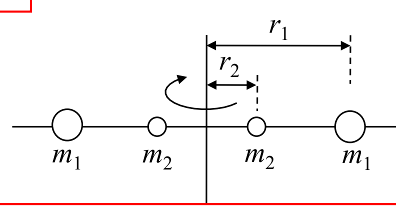
3. What is the value of the mass M that will balance the mobile?



A) 36 g
B) 26 g
C) 60 g
D) 30 g
E) 22 g
F) 46 g
G) 16 g
H) 100 g

$\sum \tau = 0$ on every mobile arm,
$0 = -m_1 g r_1 + m_2 g r_2$ (m_1 on right, m_2 on left)
For each arm: $m_2 = (m_1)(r_1/r_2)$
lowest arm: $m_2 = (5\,\mathrm{g})(4/2) = 10\,\mathrm{g}$, total mass = (5+10)g = 15 g
middle arm: $m_2 = (15\,\mathrm{g})(1/5) = 3\,\mathrm{g}$, total mass = $(15+3)\,\mathrm{g} = 18\,\mathrm{g}$
top arm : $\mathrm{M} = (18\,\mathrm{g})(8/4) = 36\,\mathrm{g}$

4. On a rod of negligible mass, two spheres with mass $m_1 = 0.50$ kg are placed symmetrically at $r_1 = 0.50$ m, and two spheres with mass $m_2 = 0.25$ kg are placed symmetrically at $r_2 = 0.20$ m, from a rotation axis, as shown in the figure. The bar rotates with an angular velocity of 0.60 rad/s. If both inner masses move outward to $r_2 = 0.40$ m, what is the new angular velocity.

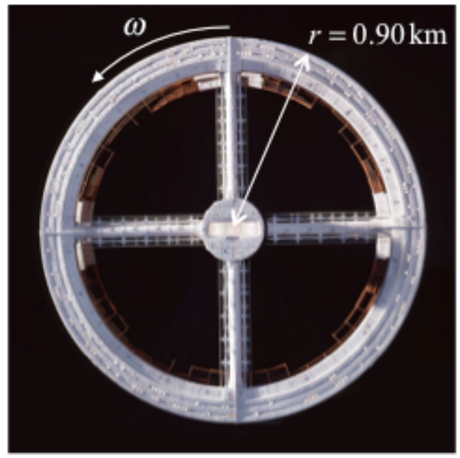


A) 0.550 rad/s
B) 0.524 rad/s
C) 0.491 rad/s
D) 0.425 rad/s
E) 0.393 rad/s
F) 0.301 rad/s
G) 0.285 rad/s
H) 0.251 rad/s

$$I_0 = \sum(mr^2)_i = 2m_1r_1^2 + 2m_2r_2^2$$
$$= 2(0.5)(0.5)^2\,\mathrm{kg\cdot m^2} + 2(0.25)(0.2)^2\,\mathrm{kg\cdot m^2}$$
$$= (0.25+0.02)\,\mathrm{kg\cdot m^2} = 0.27\,\mathrm{kg\cdot m^2}$$
$$I = 2(0.5)(0.5)^2\,\mathrm{kg\cdot m^2} + 2(0.25)(0.4)^2\,\mathrm{kg\cdot m^2}$$
$$= (0.25+0.08)\,\mathrm{kg\cdot m^2} = 0.33\,\mathrm{kg\cdot m^2}$$

Angular Momentum conservation: $I_0\omega_0 = I\omega$
$\omega = (I_0/I)\omega_0 = (0.27/0.33)0.60\,\mathrm{rad} = 0.491\,\mathrm{rad}$

5. Astronauts experience "artificial gravity" on the inside of the circular wall of a space station consisting of a large tube rotating about the central axis as shown in the picture. If the tube has a radius, r = 0.900 km, at what angular speed ω must the station be rotating to create the artificial acceleration of 9.81 m/s^2?



A) 0.055 rad/s
B) 0.084 rad/s
C) 0.127 rad/s
D) 0.143 rad/s
E) 0.134 rad/s
F) 0.128 rad/s
G) 0.111 rad/s
H) 0.104 rad/s

$$a_c = \omega^2 r = g$$
$$\omega = \sqrt{g/r} = \sqrt{9.81/900}\ \text{rad/s} = 0.104\ \text{rad/s}$$

6. A compact disk player is turned on causing the disk to begin to rotate. It reaches a rotation speed of 43.9 rad/s in 3.35 s. Find the average acceleration of the disk.

A) 13.1 rad/s^2
B) 15.5 rad/s^2
C) 9.33 rad/s^2
D) 8.98 rad/s^2
E) 4.39 rad/s^2
F) 14.6 rad/s^2
G) 5.55 rad/s^2
H) 7.26 rad/s^2

$$\alpha = \frac{\omega - \omega_0}{t} = \frac{43.9}{3.35}\text{rad/s}^2 = 13.1\,\text{rad/s}^2$$

7. An object in uniform circular motion (constant speed v around a circle with constant R) is acted upon by a centripetal force. Which statement below is **FALSE**?

The centripetal force:
A) Is directed inward toward the center of the circle.
B) Changes direction continuously.
C) Depends on the mass of the object.
D) Decreases for circles with a larger radius.
E) Increases linearly with the speed around the circle.
F) Cannot affect the net force in the direction of motion.
G) Cannot affect the tangential speed.
H) Cannot affect the tangential acceleration.

$F_c = mv^2/r$ depends on square of speed

8. A spinning circular saw rotates at 550 rpm as it starts to cut. The rotation has dropped to 450 rpm by the time it finished cutting. If the disk undergoes a constant angular acceleration of $-9.32\times10^{-2}\,\text{rad/s}^2$, find the angular displacement of the saw.

A) 8.33×10^3 rad
B) 8.92×10^3 rad
C) 5.89×10^3 rad
D) 5.45×10^3 rad
E) 7.31×10^3 rad
F) 7.91×10^3 rad
G) 6.59×10^3 rad
H) 6.02×10^3 rad

$$\omega = \left(\tfrac{2\pi}{60}\right)450\,\text{rpm} = 47.12\,\text{rad/s}$$
$$\omega_0 = \left(\tfrac{2\pi}{60}\right)550\,\text{rpm} = 57.60\,\text{rad/s}$$
$$\theta = \frac{\omega^2 - \omega_0^2}{2\alpha} = \frac{2220 - 3317}{2(-0.0932)}\text{rad} = 5.89\times10^3\,\text{rad}$$

9. The specific heat of water is 4186 J/(kg-°C) and water's heat of fusion is 333 kJ/kg. An insulated container with 2.09 kg of water and 0.25 kg of ice at 0 °C is heated. How much heat must be added to the contents to melt the ice and leave only water at 10 °C?

A) 385 kJ
B) 233 kJ
C) 155 kJ
D) 181 kJ
E) 495 kJ
F) 522 kJ
G) 333 kJ
H) 285 kJ

$m_I = 0.25\,\text{kg}.$

After ice melts, $m_W = 0.25\,\text{kg} + 2.09\,\text{kg} = 2.34\,\text{kg}$

$$Q = m_I L_f + m_W c \Delta T$$
$$= 0.25(333\times10^3)\,\text{J} + (2.34)(4186)(10^\circ)$$
$$= 181\ \text{J}$$

10. A hollow cube, 10.0 cm on a side floats with half of its volume above pure water. What volume of lead (density 11,500 kg/m^3) must be added inside the cube to just make it sink?

A) 43.5 cm^3
B) 39.8 cm^3
C) 33.2 cm^3
D) 29.5 cm^3
E) 22.2 cm^3
F) 153 cm^3
G) 37.7 cm^3
H) 25.6 cm^3

Cube volume: $V_C = (0.1)^3\,\text{m}^3$

To float $\frac{1}{2}$ under water: $\rho_C V_C g = \rho_W V_W g = \rho_W(\frac{1}{2}V_C)g$ (displaced)

Therefore, $\rho_C = \frac{1}{2}\rho_W = 0.5(1000)\,\text{kg/m}^3 = 500\,\text{kg/m}^3$

To just sink cube: $\rho_C V_C g + \rho_{Pb} V_{Pb} g = \rho_W V_C g$ (displaced)

$$V_{Pb} = \frac{(\rho_W - \rho_C)}{\rho_{Pb}} V_C = \frac{(1000-500)}{11.5\times10^3}(10^{-3}\,\text{m}^3)$$
$$= 43.5\times10^{-6}\,\text{m}^3 = 43.5\,\text{cm}^3$$

11. Helium atoms at 450.0 K have an RMS speed of 1675 m/s. If the temperature is increased to 600.0 K what is the new RMS speed of the helium atoms?

A) 2310 m/s
B) 1444 m/s
C) 1592 m/s
D) 1789 m/s
E) 1934 m/s
F) 1349 m/s
G) 2372 m/s
H) 2475 m/s

Starting Temperature T_0: $\frac{1}{2}mv_0^2 = \frac{3}{2}k_B T_0$

New Temperature T_1: $\frac{1}{2}mv_1^2 = \frac{3}{2}k_B T_1$

Divide Temp$_1$ by Temp$_0$: $\frac{v_1^2}{v_0^2} = \frac{T_1}{T_0}$

$$v_1 = v_0\sqrt{\frac{T_1}{T_0}} = (1675)\sqrt{\frac{600}{450}}\ \text{m/s} = 1934\ \text{m/s}$$

12. Use the ideal gas law (molar gas constant $8.315\ \text{J}\cdot\text{mol}^{-1}\text{K}^{-1}$) to compute the density of helium gas at a temperature of 25°C and 1 atm. of pressure ($1.013\times10^5\,\text{Pa}$). Note: a mole of Helium gas has a mass of $4.00\times10^{-3}\text{kg}$.

A) 0.067 kg/m^3
B) 0.075 kg/m^3
C) 0.089 kg/m^3
D) 0.101 kg/m^3
E) 0.129 kg/m^3
F) 0.147 kg/m^3
G) 0.155 kg/m^3
H) 0.164 kg/m^3

$PV = nRT \quad T(\text{Kelvin}) = (25^\circ + 273) = 298\,\text{K}$

$$\frac{n}{V} = \frac{P}{RT} = \frac{1.013\times10^5}{(8.315)(298)}\frac{\text{mol}}{\text{m}^3} = 40.88\frac{\text{mol}}{\text{m}^3}$$

$$\rho = \left(4\times10^{-3}\,\text{kg/mol}\right)\left(40.88\,\text{mol/m}^3\right) = 0.164\ \text{kg/m}^3$$

13. The gravitational force on a mass m on the surface of the earth is $F = GmM / R^2$, where M and R are the mass and radius of the earth. The mass and radius of the moon are 7.40 × 10^{22} kg and 1.70 × 10^6 m, respectively. What is the weight of a 1.0-kg object on the surface of the moon? $(G = 6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)$

A) 1.71 N
B) 3.73 N
C) 8.81 N
D) 4.35 N
E) 0.67 N
F) 1.17 N
G) 2.97 N
H) 5.82 N

$$F = \frac{GmM}{R^2} = \frac{(6.67\times10^{-11})(1.0)(7.40\times10^{22})}{\left(1.70\times10^{6}\right)^2}\text{N}$$
$$= 17.1\times10^{-1}\text{N} = 1.71\text{N}$$

14. Which one of the following statements best explains why an astronaut experiences "weightlessness" in an orbit 1237 km above the earth?

A) The centripetal force of the earth on the astronaut in orbit is zero newtons.
B) The pull of the earth on the spaceship is canceled by the pull of the other planets.
C) The spaceship is in free fall so its floor cannot press upward on the astronaut.
D) The force decreases as the inverse square of the distance from the earth's center.
E) The force of the earth on the spaceship and the force of the spaceship on the earth cancel because they are equal in magnitude but opposite in direction.
F) The location of the spaceship is equidistant between the earth and the moon
G) The earth's gravitation force is balanced by the centrifugal force on the astronaut.
H) Since the spaceship is above the atmosphere, no air presses down on the astronaut.

15. Young's modulus of nylon is 3.70 × 10^9 N/m^2. A force of 6.00 × 10^5 N is applied to a length of nylon 1.50-m long and it stretches 0.973 mm. What is the cross sectional area of the nylon?

A) 0.729 m^2
B) 0.250 m^2
C) 0.455 m^2
D) 0.627 m^2
E) 0.552 m^2
F) 0.873 m^2
G) 0.666 m^2
H) 0.315 m^2

$$\frac{F}{A} = Y\frac{\Delta L}{L}$$
$$A = \frac{FL}{Y\Delta L} = \frac{(6.0\times10^5)(1.5)}{(3.7\times10^9)(9.73\times10^{-4})}\text{m}^2$$
$$= 0.250\,\text{m}^2$$

16. Water flows horizontally through a pipe at a pressure of 2.05 × 10^5 Pa with a speed of 10.0 m/s. The pipe then rises 4m higher and again becomes horizontal. What is the pressure in the pipe at this new height?

A) 2.01 × 10^5 Pa
B) 5.45 × 10^4 Pa
C) 8.97 × 10^4 Pa
D) 1.34 × 10^5 Pa
E) 1.66 × 10^5 Pa
F) 4.62 × 10^4 Pa
G) 7.02 × 10^4 Pa
H) 2.05 × 10^5 Pa

Same pipe throughout, v = constant

Bernoulli's Eq.: $P_1 + \rho g h_1 = P_2 + \rho g h_2$

$$P_2 = P_1 + \rho g(h_1 - h_2) = 2.05\times10^5\ \text{Pa} + (10^3)(9.81)(-4)\,\text{Pa}$$
$$= (2.05 - 0.39)\times10^5\,\text{Pa} = 1.66\times10^5\ \text{Pa}$$