SOLUTIONS

Physics 151
May 7, 2007

Score: 100 pts. possible (+1 pt. Bonus)

PHYS 151 Final Exam

Exam time limit: 120 minutes. You may use a calculator and both sides of TWO sheets of notes, *handwritten only*. Closed book; no collaboration.

Complete *ALL* questions. For each multiple choice question, choose the ONE best answer. There is no penalty for guessing.

Ignore friction and air resistance in all problems, unless told otherwise.

On your **BUBBLE SHEET**, please fill in: **"Last Name, First Name"** = your name
"Identification Number" = your ROSTER number for PHYS 151
NO other fields (birthdate, grade, etc.) are necessary.

Physical constants:

$g = 9.80$ m/s^2 $\quad G = 6.674 \times 10^{-11}$ N·m^2/kg^2

$N_A = 6.022 \times 10^{23}$ mol^{-1} $\quad k_B = 1.381 \times 10^{-23}$ J/K $\quad R = 8.314$ J/(mol·K) = 0.0821 L·atm/(mol·K)

Useful conversions:

1 year = 3.156×10^7 s $\quad$ 1 m^3 = 1000 L $\quad$ 1 atm = 1.013×10^5 Pa

1 cal = 4.186 J $\quad$ 0°C = 273.15 K

masses	*radii*	*orbital distances*	*orbital periods*
$M_{Sun} = 1.99 \times 10^{30}$ kg	$R_{Sun} = 6.96 \times 10^8$ m		
$M_{Earth} = 5.97 \times 10^{24}$ kg	$R_{Earth} = 6.38 \times 10^6$ m	$r_{Earth\text{-}Sun} = 1.50 \times 10^{11}$ m	$T_{Earth} = 1.00$ year
$M_{Moon} = 7.35 \times 10^{22}$ kg	$R_{Moon} = 1.74 \times 10^6$ m	$r_{Earth\text{-}Moon} = 3.84 \times 10^8$ m	$T_{Moon} = 27.3$ days

(2 pts. each) **Convert** the following quantities into the specified units:

1. 18,000 nm = ____________________ μm

A. 1.8×10^{-8} μm
B. 1.8×10^{-5} μm
C. 1.8×10^{-4} μm
D. 0.18 μm
E. 18 μm

$$(18{,}000\ \cancel{nm})\left(\frac{10^{-9}\ \cancel{m}}{1\ \cancel{nm}}\right)\left(\frac{1\ \mu m}{10^{-6}\ \cancel{m}}\right) = 18\ \mu m$$

2. 120 Pa = ____________________ atm

A. 1.2×10^{-4} atm
B. 1.2×10^{-3} atm
C. 0.012 atm
D. 1.2×10^{3} atm
E. 1.2×10^{4} atm

$$(120\ \cancel{Pa})\left(\frac{1\ atm}{1.013\times10^5\ \cancel{Pa}}\right) = 1.2\times10^{-3}\ atm$$

3. 5.0 μL = ____________________ mm^3

A. 0.050 mm^3
B. 0.50 mm^3
C. 5.0 mm^3
D. 50. mm^3
E. 500 mm^3

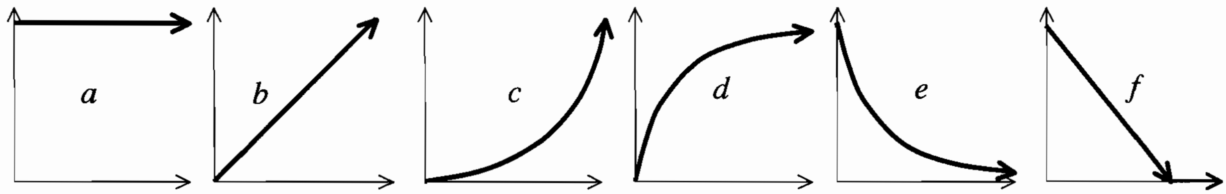
$$(5.0\ \cancel{\mu L})\left(\frac{10^{-6}\ \cancel{L}}{1\ \cancel{\mu L}}\right)\left(\frac{1\ \cancel{m^3}}{1000\ \cancel{L}}\right)\left(\frac{1\ mm}{10^{-3}\ \cancel{m}}\right)^3 = 5.0\ mm^3$$

4. 88 kg·m^2/s = ____________________ g·cm^2/s

A. 8.8×10^{-6} g·cm^2/s
B. 0.088 g·cm^2/s
C. 8.8 g·cm^2/s
D. 880 g·cm^2/s
E. 8.8×10^{8} g·cm^2/s

$$\left(88\ \frac{\cancel{kg}\cdot\cancel{m^2}}{s}\right)\left(\frac{1000\ g}{1\ \cancel{kg}}\right)\left(\frac{1\ cm}{10^{-2}\ \cancel{m}}\right)^2 = 88\times10^7\ \frac{g\cdot cm^2}{s}$$

$$= 8.8\times10^8\ \frac{g\cdot cm^2}{s}$$



Each of the graphs shown here represents the *position* for a different car as a function of time. (Each car is constrained to move only along the x-axis.)

5. (1 pt.) Which of the cars are **stationary** during the *entire* time period shown?

A. *a*　　D. *a* & *b*
B. *b*　　E. *b* & *f*
C. *f*

stationary $\Rightarrow v = 0$
$\Rightarrow x$ is constant
(or slope of x vs. t is zero) everywhere

6. (1 pt.) Which of the cars have a **constant velocity** (including rest) during the *entire* time period shown?

A. *a*　　D. *a* & *b*
B. *b*　　E. *a*, *b*, & *f*
C. *f*

v = slope of x vs. t graph
constant $v \Rightarrow$ constant slope of graph

7. (2 pts.) Which of the cars have a **negative velocity** during the *entire* time period shown?

A. *e*　　D. *d*, *e*, & *f*
B. *f*　　E. none
C. *e* & *f*

v = slope of x vs. t graph
negative $v \Rightarrow$ negative slope of graph

8. (1 pt. Bonus) Which of the cars are **slowing down** during the *entire* time period shown? (This is a tricky one!)

A. *d*　　D. *e* & *f*
B. *e*　　E. *d*, *e*, & *f*
C. *d* & *e*

v = slope of x vs. t graph.
"slowing down" $\Rightarrow$ positive v getting smaller (positive slope approaching zero) $\Rightarrow$ "d"
OR negative v getting smaller (negative slope approaching zero) $\Rightarrow$ "e"

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9. (2 pts.) What is the **magnitude** of the **resultant** (sum) of the following three displacement vectors?
$\mathbf{D_1} = (20.0, 5.0)$ m　　$\mathbf{D_2} = (-12.0, -28.0)$ m　　$\mathbf{D_3} = (-3.0, 7.0)$ m

A. 3.8 m　　D. 12.2 m
B. 5.5 m　　E. 16.8 m
C. 8.3 m

$\vec{D}_1 = (20, 5)$ m
$\vec{D}_2 = (-12, -28)$ m
$+\ \vec{D}_3 = (-3, 7)$ m
$\vec{R} = (5, -16)$ m.

10. (2 pts.) What is the **direction** of the same **resultant vector**?

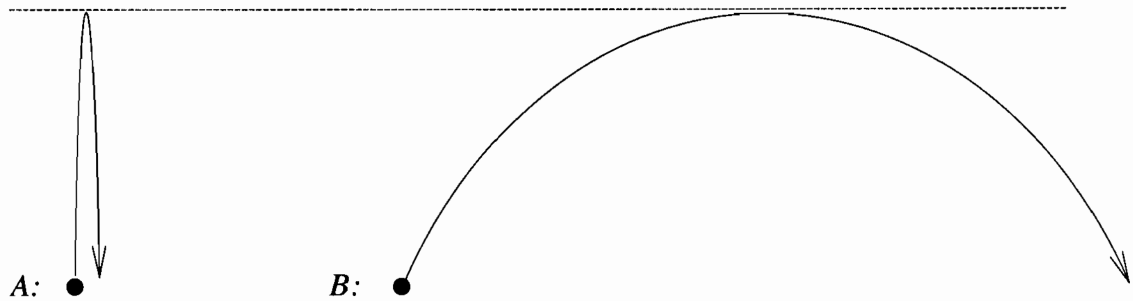
A. –73°　　D. 73°
B. –17°　　E. 107°
C. 17°

$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(5\text{m})^2 + (-16\text{m})^2} = 16.8\text{ m}$

$\theta_R = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{-16\text{m}}{5\text{m}}\right) = \tan^{-1}(-3.2)$

$\theta_R = -72.6°$ or $\cancel{107.4°}$

$+x$ and $-y$ components $\Rightarrow$ 4th Quadrant　(2nd Quadrant)



Two identical (equal-mass) cannonballs, *A* and *B*, are launched from different cannons that have *different launch speeds*. The slower cannon launches ball *A* straight up, and you measure all aspects of its trajectory. The faster cannon then launches ball *B* at a 45° angle to the horizontal, and you separately measure its trajectory. You discover that, in this case, the cannonballs had respective launch speeds that were just right to allow them to rise to the *same maximum height* before descending. The ground is level. No air resistance.

11. (1 pt.) Which cannonball has the **greater potential energy** at the *top of its arc*?
A. *A* B. *B* C. equal potential energy D. cannot determine from information given

12. (1 pt.) Which cannonball has the **greater kinetic energy** at the *top of its arc*?
A. *A* B. *B* C. equal kinetic energy D. cannot determine from information given

13. (1 pt.) Which cannonball has the **greater total time of flight**?
A. *A* B. *B* C. equal time D. cannot determine from information given

14. (2 pts.) Given the description of the problem above, ball *B* must have had a **launch speed** equal to ________ times that of ball *A*.

A. 1.15
B. 1.41
C. 1.50
D. 1.87
E. 2.00

Both balls reach same height. Therefore,

at launch: $v_{B0y} = v_{A0y}$

$v_{B0} \cdot \sin 45° = v_{A0} \cdot \cancel{\sin 90°}\ 1$

$\Rightarrow v_{B0} = \frac{v_{A0}}{\sin 45°} = \sqrt{2} \cdot v_{A0} \approx 1.41\ v_{A0}$.

15. (2 pts.) During the time that a cannonball launched at 45° (to the horizontal) is **ascending** toward the peak of its arc…

A. The ball is weightless. – the ball always has weight mg (toward center of Earth)
B. The ball's acceleration steadily decreases. – the ball's acceleration is a constant downward $9.80\ m/s^2$, always!
C. The ball's acceleration is always in the same direction as its instantaneous velocity.
D. The ball's acceleration is always exactly opposite to the direction of its instantaneous velocity.
E. None of the above.

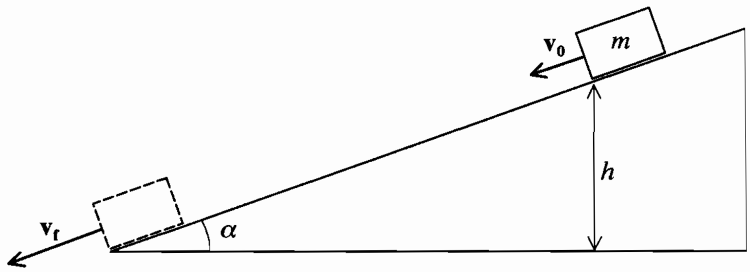
In a different experiment, you throw cannonball *A* and cannonball *C* straight up with the *same initial launch speed*, but ball *C* has *twice the mass* of ball *A*. They both start at the same spot, rise vertically, fall straight back down, and land in the same location from which they were thrown.

16. (1 pt.) Which cannonball reaches the **greater maximum height**?
A. *A* B. equal height C. *C* D. cannot determine from information given

17. (1 pt.) Which cannonball has the **greater acceleration**?
A. *A* B. equal acceleration C. *C* D. cannot determine from information given

18. (1 pt.) Which cannonball has the **greater landing speed**?
A. *A* B. equal speed C. *C* D. cannot determine from information given

19. (1 pt.) Which cannonball has the **greater total time of flight**?
A. *A* B. equal time C. *C* D. cannot determine from information given

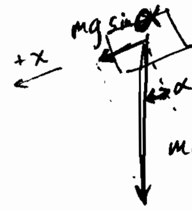


A mass m starts with an initial downhill speed v_0 at height h, and slides down a *frictionless* incline of angle α, as shown above.

20. (2 pts.) The mass's downhill **acceleration** (parallel to ~~along~~ the incline's surface) is:

A. $g\cos\alpha$ C. $\dfrac{g}{\cos\alpha}$ E. $g\tan\alpha$

B. $g\sin\alpha$ D. $\dfrac{g}{\sin\alpha}$



$\Sigma F_x = m \cdot a_x$

$mg\sin\alpha = m\cdot a_x$

$\Rightarrow a_x = g\cdot\sin\alpha.$

21. (2 pts.) The mass's **final speed** at the bottom of the incline is:

A. $\sqrt{2gh} + v_0$ C. $\sqrt{2gh + v_0^2}$ E. $\sqrt{2mgh}$

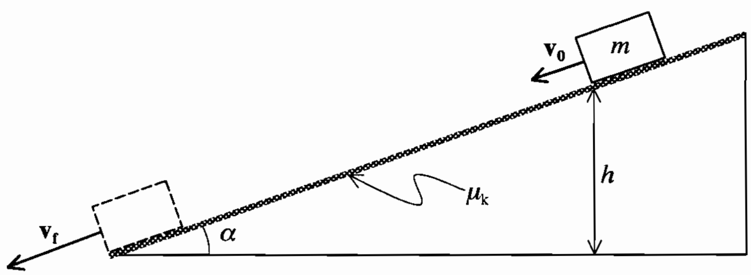
B. $\sqrt{mgh} + v_0$ D. $\sqrt{mgh + v_0^2}$

Cons. of Energy: $E_0 = E_f$

$K_0 + U_{gr,0} = K_f$

$\frac{1}{2}mv_0^2 + mgh = \frac{1}{2}mv_f^2$

$\Rightarrow v_f = \sqrt{2gh + v_0^2}.$



Suppose now that there *does* exist **kinetic friction** μ_k between the mass and the incline, but all other initial conditions are unchanged. (Let the kinetic friction be fairly weak, so that the mass does reach the bottom of the incline, and does so with a final speed $v_f > v_0$.)

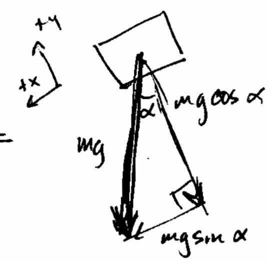
22. (2 pts.) As the mass descends, the **force of kinetic friction** is:

A. $\dfrac{mg\cos\alpha}{\mu_k}$ C. $\dfrac{\mu_k mg}{\cos\alpha}$ E. $\mu_k mg\cos\alpha$

B. $\dfrac{mg\sin\alpha}{\mu_k}$ D. $\dfrac{\mu_k mg}{\sin\alpha}$

$F_{fr} = \mu_k \cdot F_N$

$F_{fr} = \mu_k(mg\cos\alpha)$

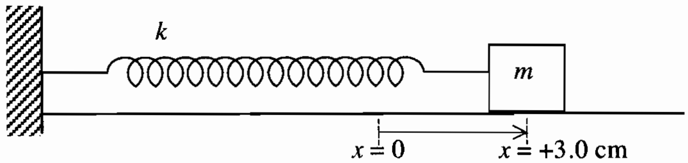


23. (1 pt.) The **direction** of this **kinetic friction force** is:

A. perpendicular and away from the surface
B. perpendicular and into the surface
C. parallel to the surface and downhill
D. parallel to the surface and uphill
E. toward the center of the Earth

24. (1 pt.) When kinetic friction is included, which one of the following is the **same** as it was in the frictionless case?

A. downhill acceleration
B. final speed
C. time of descent
D. normal force
E. final mechanical energy



A mass m = 450 g is attached to an ideal, massless spring (k = 85 N/m), as shown above. The surface is frictionless. The mass is initially pulled aside to a displacement of x = +3.0 cm. The mass is then released from rest and allowed to oscillate freely.

25. (2 pts.) What is the **frequency** of the oscillations?

A. 0.55 Hz
B. 0.79 Hz
C. 1.3 Hz
D. 2.2 Hz
E. 2.9 Hz

$f_0 = \frac{1}{2\pi}\omega_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{85\,N/m}{0.45\,kg}} = \underline{2.2\ Hz}$

26. (2 pts.) What is the **greatest acceleration** that the mass experiences during its oscillation?

A. 2.6 m/s²
B. 4.0 m/s²
C. 5.7 m/s²
D. 7.0 m/s²
E. 9.8 m/s²

$\Sigma F_x = F_{spr} = m \cdot a_x$
$\Rightarrow -k \cdot x = m \cdot a_x \Rightarrow a_x = -\frac{kx}{m}$. This is maximized when x is maximized: $\underline{x=A}$
$\Rightarrow a_{max} = -\frac{k}{m}A = \frac{85\frac{N}{m}}{0.45\,kg}\cdot(0.030\,m)$
$= \underline{5.7\ m/s^2}$

27. (2 pts.) What is the **total mechanical energy** of the system?

A. 0.038 J
B. 0.095 J
C. 0.13 J
D. 0.25 J
E. 0.41 J

$E_{tot} = (K + U_{el})$ at $x=A$, $x=0$, anywhere!
$= \left(\frac{1}{2}mv^2 + \frac{1}{2}kx^2\right)_{x=A} = \left(0 + \frac{1}{2}kA^2\right) = \frac{1}{2}\left(85\frac{N}{m}\right)(0.030\,m)^2$
$= \underline{0.038\ J}$.

28. (2 pts.) Which one of the following is **TRUE**? (Consider only magnitudes of vector quantities.)

A. The mass experiences its greatest speed at $x = \pm$ 3.0 cm. No, $v = \sqrt{\frac{k}{m}(A^2 - x^2)}$, so v = max at $\underline{center}$.
B. The mass experiences its greatest acceleration at $x = \pm$ 3.0 cm. YES: $a = -\frac{k}{m}\cdot x$, so a = max at $\underline{ends}$.
C. The mass experiences its greatest force at x = 0 cm. No, $F = -kx$, so F = max at $\underline{ends}$.
D. The mass has its greatest kinetic energy at $x = \pm$ 3.0 cm. No, K = max when v = max at $\underline{center}$.
E. The spring stores its greatest potential energy at x = 0 cm. No, $U_{el} = \frac{1}{2}kx^2$, so U_{el} = max at $\underline{ends}$.

29. (2 pts.) Suppose that *friction* and air resistance slowly act on the system. All of the following quantities will *decrease* over time **EXCEPT**:

A. maximum displacement
B. maximum speed
C. maximum acceleration
D. maximum force
E. period ←

As $E_{tot} = (K + U_{el})$ gradually decreases due to friction, then A, $v_{max} = \sqrt{\frac{k}{m}}A$, $a_{max} = \frac{k}{m}A$, and $F_{max} = kA$ will all decrease.

Only $T = 2\pi\sqrt{\frac{m}{k}}$ does NOT depend on A, so it will remain unaffected by damping.

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30. (2 pts.) A pendulum is flown to the Moon (assume that $g_{Moon} = g_{Earth}/6$, exactly), where its small-angle period is measured to be 4.0 seconds long. Assuming it is an "ideal" pendulum (consisting of a compact bob attached to a massless arm), what must be the **length** of the pendulum arm?

A. 0.23 m
B. 0.39 m
C. 0.66 m
D. 0.78 m
E. 0.99 m

$T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow L = \frac{g \cdot T^2}{(2\pi)^2} = \frac{\left[\frac{1}{6}(9.8\,m/s^2)\right](4.0\,s)^2}{4\pi^2}$

$\Rightarrow L = \underline{0.66\ m}$.

A 3800-kg truck and a 1400-kg car are sliding frictionlessly on a flat, icy road. The truck is moving forward at 8.0 m/s when it strikes the rear of the car, which was also moving in the same forward direction at 5.0 m/s. The two vehicles "lock bumpers" and *stick together* after colliding, gliding off down the road together. (No passengers were harmed during the creation of this problem.)

Cons. of Momentum: $\Sigma p_i = \Sigma p_f$

31. (2 pts.) After colliding, the pair of vehicles will have a **final velocity** of:

A. 6.8 m/s
B. 7.2 m/s
C. 7.5 m/s
D. 7.8 m/s
E. 8.5 m/s

$m_t v_{ti} + m_c v_{ci} = (m_t + m_c) v_f$

$(3800\text{ kg})(8.0\text{ m/s}) + (1400\text{ kg})(5.0\text{ m/s}) = (5200\text{ kg}) \cdot v_f$

$\Rightarrow v_f = 7.2\text{ m/s}$

32. (1 pt.) This particular collision is **inelastic** because: "Inelastic" means that K.E. is lost in the collision.

A. The vehicles' total momentum is *greater* after the collision than it was before the collision.
B. The vehicles' total momentum is *less* after the collision than it was before the collision.
C. The vehicles' total kinetic energy is *greater* after the collision than it was before the collision.
D. The vehicles' total kinetic energy is *less* after the collision than it was before the collision.
E. Ha! It's a trick question, since this is an *elastic* collision!

$K_i = \frac{1}{2} m_t v_{ti}^2 + \frac{1}{2} m_c v_{ci}^2 = 139\text{ kJ}$

$K_f = \frac{1}{2}(m_t + m_c) v_f^2 = 134\text{ kJ}$

$\Rightarrow \Delta K = -4.6\text{ kJ}$ lost.

33. (1 pt.) *During* the collision, which of the vehicles exerts a **force** on the other?

A. Only the *truck* pushes on the car.
B. Both push on each other, but the *truck's* force (pushing on the car) is greater.
C. Both push on each other with *equal* forces. ⇒ Newton's 3rd Law
D. Both push on each other, but the *car's* force (pushing on the truck) is greater.
E. Only the *car* pushes on the truck.

34. (1 pt.) During the collision, the magnitude of the **impulse** received by the car is ____________ the magnitude of the impulse received by the truck.

A. less than
B. equal to
C. greater than

$\Delta p = F_{av} \cdot \Delta t$

$\Delta p_{car} = m_c \cdot \Delta v_{car} = (1400\text{ kg})(2.19\text{ m/s}) = 3070\ \frac{\text{kg}\cdot\text{m}}{\text{s}}$.

$\Delta p_{truck} = m_t \cdot \Delta v_{truck} = (3800\text{ kg})(-0.81\text{ m/s}) = -3070\ \frac{\text{kg}\cdot\text{m}}{\text{s}}$

same

OR: F_{av} of each vehicle on other is same (see last question), and Δt of impact is same for both vehicles.

Much later, after the same car and truck have been separated, they are left *at rest* on the *frictionless* ice, with their centers-of-mass located 3.0 m apart. (*Recall*: the truck's mass is 3800 kg, and the car's mass is 1400 kg.)

35. (2 pts.) What is the **gravitational force** of the truck on the car?

A. 3.9×10^{-11} N
B. 3.9×10^{-9} N
C. 3.9×10^{-7} N
D. 3.9×10^{-5} N
E. 3.9×10^{-3} N

$F_G = \frac{G M_t \cdot m_c}{r^2} = \frac{(6.67\times10^{-11}\ \frac{\text{N}\cdot\text{m}^2}{\text{kg}^2})(3800\text{ kg})(1400\text{ kg})}{(3.0\text{ m})^2} = 3.9\times10^{-5}\text{ N}$

36. (1 pt.) Assume that the ice is perfectly frictionless, and ignore air resistance. Which of the two vehicles experiences a **greater acceleration** toward the other?

A. the car
B. the truck
C. both accelerations are equal

$a = \frac{F}{m}$ } F is same on both vehicles, but mass is NOT!

smaller mass ⇒ greater acceleration (given equal forces)

37. (2 pts.) To what distance must the two vehicles be separated so that the gravitational force between them becomes *25 times weaker*?

A. 3.5 m
B. 6.7 m
C. 15 m
D. 75 m
E. 1900 m

$F_{new} = \frac{1}{25} F_{old}$

$\frac{G m_t m_c}{r_{new}^2} = \frac{1}{25} \frac{G m_t m_c}{r_{old}^2}$

$\Rightarrow 25\, r_{old}^2 = r_{new}^2$

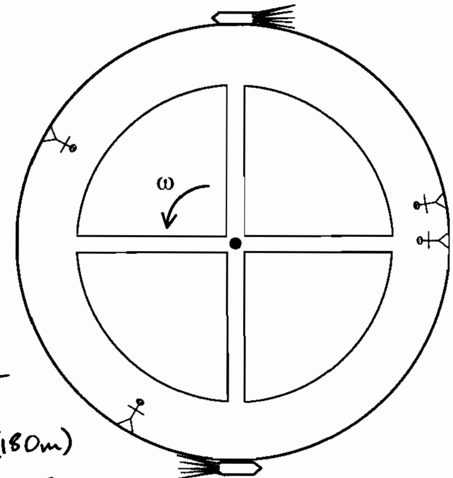
$\Rightarrow r_{new} = 5 \cdot r_{old} = 15\text{ m}$.

38. (1 pt.) To what distance must the two vehicles be separated so that the **gravitational force** between them becomes *zero*?

A. 6.4×10^6 m
B. 4.9×10^8 m
C. 6.7×10^{11} m
D. 2.6×10^{22} m
E. ∞

$F_G = \frac{G m_t m_c}{r^2} \Rightarrow F_G \to 0$ as $r \to \infty$.

A huge, wheel-shaped space station (radius = 180 m) starts at rest in space. Tiny thrusters along its edge fire their jets tangentially, providing a uniform angular acceleration of the space station about its center. The thrusters are shut off when the station is spinning at a desired angular speed for comfortable "artificial gravity" for people standing on the station's inside edge.



39. (2 pts.) If the space station's final angular speed is 0.20 rad/s, what is the **centripetal acceleration** at the edge of the "wheel"? One "gee" = 9.80 m/s^2. (People feel an apparent "gravity" equal to the magnitude of the centripetal acceleration at their location.)

A. 0.58 gee
B. 0.73 gee
C. 0.84 gee
D. 0.91 gee
E. 0.96 gee

$a_{rad} = \frac{v^2}{r} = \omega^2 \cdot r$

$= \left(0.20 \frac{rad}{s}\right)^2 \cdot (180 m)$

$= 7.2 m/s^2 = \underline{0.73 \text{ gee}}$

40. (2 pts.) While spinning at a constant 0.20 rad/s, how much **time** does it take the station to complete 1.0 rotation?

A. 8.5 s
B. 18 s
C. 31 s
D. 85 s
E. 310 s

$T = \frac{1}{f} = \frac{2\pi}{\omega} = \frac{2\pi}{\left(0.20 \frac{rad}{s}\right)} = \underline{\underline{31.4 s}}$

41. (2 pts.) With all thrusters firing continuously, it takes approximately one week (6.0×10^5 s) for the station to accelerate from rest to 0.20 rad/s. The station's moment of inertia is 2.4×10^{11} kg·m^2. What is the **total torque** of all thrusters acting together on the station?

A. 8.0×10^3 N·m
B. 8.0×10^4 N·m
C. 8.0×10^5 N·m
D. 8.0×10^6 N·m
E. 8.0×10^7 N·m

$\Sigma\tau = I \cdot \alpha = I \cdot \frac{\Delta\omega}{\Delta t}$

$= (2.4 \times 10^{11} \text{ kg}\cdot\text{m}^2)\left(\frac{0.20 \text{ rad/s} - 0}{6.0 \times 10^5 s}\right)$

$= \underline{\underline{8.0 \times 10^4 \text{ N}\cdot\text{m}}}$

42. (2 pts.) Which one of the following alterations would **increase** the **net torque** of the thrusters on the space station?

A. mounting the thrusters closer to the central axis ← No, this decreases r
B. directing the thrusters' jets radially instead of tangentially - No, decreases $(\sin\phi)$
C. firing the thruster jets for a longer period of time - increases total work, but does NOT change instantaneous τ
D. increasing the number of thrusters around the edge of the station ← $\Sigma\tau = \tau_1 + \tau_2 + \tau_3 + \cdots$, so yes.

43. (1 pt.) If the space station spins counter-clockwise, as shown in the diagram above, in which **direction** is the station's **angular momentum vector**?

A. out of the page
B. into the page
C. to the left
D. toward the top of the page
E. toward the bottom of the page

Right-hand rule: curl right-hand fingers in direction of ω, and thumb points out of page.

44. (1 pt.) Once the thrusters are shut off, suppose that *no further torque* acts on the station. (Also, assume that nobody moves mass around inside the station.) **What will happen**?

A. The station's angular speed will slowly diminish, and the station will eventually come to rest, but its spin axis will maintain a constant direction in space.
B. The station's angular speed will remain constant, but the direction of its spin axis will wobble around in space.
C. Both the station's angular speed and spin-axis direction will remain unchanged forever.

Conservation of angular momentum and/or Newton's 1st Law: In absence of outside torque, $\vec{\omega}$ remains constant forever.

A harbor buoy with a mass of 220 kg floats in seawater (ρ = 1025 kg/m^3).

45. (2 pts.) What is the **minimum volume** the buoy must have so that it can *float* in the ocean?

A. 0..21 m^3
B. 0.58 m^3
C. 1.0 m^3
D. 1.6 m^3
E. 2.2 m^3

The buoy will float only if $\rho_{buoy} < \rho_{water}$

$$\Rightarrow \frac{m_b}{V_b} < \rho_{water} \Rightarrow V_b > \frac{m_b}{\rho_{water}} = \frac{220\text{ kg}}{1025\frac{\text{kg}}{\text{m}^3}} = 0.21\text{ m}^3.$$

46. (2 pts.) Suppose this particular buoy has a volume of 2.5 m^3. While *floating* in the ocean, what **fraction** of its volume will be **submerged**?

A. 4.7%
B. 8.6%
C. 13%
D. 21%
E. 24%

Archimedes' Principle: Buoy will displace 220kg of seawater, which has a volume: $V_{water} = m/\rho = \frac{220\text{kg}}{1025\text{ kg/m}^3} = 0.21\text{ m}^3.$

$$\text{Fraction: } \frac{0.215\text{m}^3}{2.5\text{m}^3} = 0.086 = 8.6\%.$$

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47. (3 pts.) While using a knife to cut into a big melon, you lean down on the knife with 250 N of force. The entire area of the knife's edge in contact with the melon is 5.0 mm^2. What is the **pressure** under the knife's edge?

A. 95 atm
B. 260 atm
C. 490 atm
D. 850 atm
E. 1400 atm

$$P = \frac{F}{A} = \frac{250\text{ N}}{(5.0\text{mm}^2)\left(\frac{10^{-3}\text{m}}{1\text{mm}}\right)^2} = 5.0\times10^7\text{ Pa}\left(\frac{1\text{ atm}}{1.013\times10^5\text{ Pa}}\right)$$

$$= 494\text{ atm}.$$

48. (2 pts.) During deep-sea dives, the ocean can exert a pressure on submersibles that is comparable to the knife-edge pressure in the previous question. Assuming that seawater is incompressible (i.e., constant density at all pressures and depths: ρ = 1025 kg/m^3), **at what depth** does a submarine experience a water pressure of *100. atm*? (You may ignore the 1 atm of air pressure contributed by the Earth's atmosphere.)

A. 0.66 km
B. 0.75 km
C. 0.89 km
D. 1.0 km
E. 1.4 km

$$P_{Fluid} = \rho\cdot g\cdot h$$

$$\Rightarrow h = \frac{P}{\rho\cdot g} = \frac{(100.\text{atm})\left(\frac{1.013\times10^5\text{ Pa}}{1\text{ atm}}\right)}{(1025\text{ kg/m}^3)(9.80\text{ m/s}^2)} = 1010\text{ m}$$

Your friend's motor scooter has an engine that emits a loud 280-Hz sound when at rest. The speed of sound in air is 330 m/s.

49. (2 pts.) What is the **wavelength** of the sound waves that reach your ear?

A. 30. μm
B. 3.6 mm
C. 8.9 mm
D. 92 mm
E. 1.2 m

$$\lambda = \frac{v}{f} = \frac{330\text{ m/s}}{280\text{ Hz}} = 1.18\text{ m}.$$

50. (1 pt.) As you stand still, how much **time** does it take for one complete wave of this sound to pass your ear?

A. 30. μs
B. 3.6 ms
C. 8.9 ms
D. 92 ms
E. 1.2 s

$$T = \frac{1}{f} = \frac{1}{280\text{Hz}} = 3.57\times10^{-3}\text{ s}.$$

51. (1 pt.) These sound waves are:

A. **longitudinal** waves
B. **transverse** waves

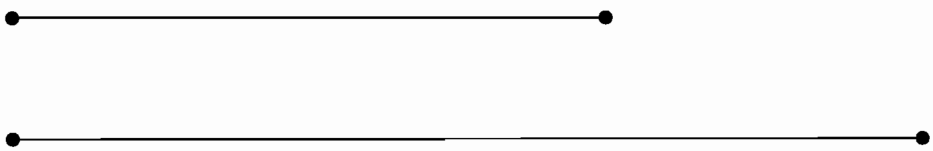
52. (1 pt.) Your friend gets on the scooter and rides away from you. You notice that the **pitch** (frequency) of the sound is _______________ when the scooter is at rest.

A. higher than
B. lower than
C. the same as

Doppler Effect:
As source recedes from observer, observed f decreases.

string A:

string B:



Two strings on a harp have different lengths, L_A and L_B. Both strings are stretched tight with the same tension force, both are made of the same type of string, and both have two fixed ends.

53. (1 pt.) Which string has a **longer wavelength** for its **fundamental mode**?
A. A B. B C. both have same wavelength

$L = \frac{1}{2}\lambda_1 \Rightarrow \lambda_1 = \underline{\underline{2L}}$.

54. (1 pt.) Which string has a **faster wave speed**?
A. A B. B C. both have same speed

$v = \sqrt{\frac{F_T}{(m/L)}}$, and F_T and $\left(\frac{m}{L}\right)$ are same for both strings, so v is same.

55. (1 pt.) When plucked, which string has the **higher-pitched** (i.e, higher-frequency) **fundamental**?
A. A B. B C. both have same frequency

$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$. v is same, so f is higher for shorter L_A.

56. (1 pt.) Which string has **more nodes** in its 5^{th} overtone?
A. A B. B C. both have same number of nodes

Same pattern for all fixed-end strings: 5^{th} overtone = 6^{th} harmonic:

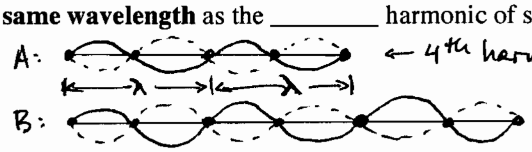
$\Rightarrow$ 7 nodes.

Suppose you now measure the two strings and find that $L_A = (2/3)L_B$ exactly.

57. (2 pts.) The **fundamental** of string A has a **frequency** equal to ________ times that of string B.
A. 2/3
B. 3/4
C. 1
D. 4/3
E. 3/2

$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$. $\Rightarrow \frac{f_A}{f_B} = \frac{v/2L_A}{v/2L_B} = \frac{1/(2/3)\cdot L_B}{1/L_B} = \frac{3}{2}$.

58. (2 pts.) The 4^{th} harmonic of string A has the **same wavelength** as the ________ harmonic of string B.
A. 2^{nd}
B. 3^{rd}
C. 4^{th}
D. 5^{th}
E. 6^{th}



59. (2 pts.) Which of the following **changes to string *A*** would be most effective in getting A's fundamental frequency closer to that of string B?
A. increase the tension in string A & replace it with lighter-weight material
B. increase the tension in string A & replace it with heavier-weight material
C. decrease the tension in string A & replace it with lighter-weight material
D. decrease the tension in string A & replace it with heavier-weight material

$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$ $\Rightarrow$ To decrease (lower) f_1 of string A, we want changes that will decrease v of waves along string.

$v = \sqrt{\frac{F_T}{(m/L)}}$ } v can be decreased by:
- lowering F_T.
- making $\left(\frac{m}{L}\right)$ heavier.

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60. (1 pt.) Many household electrical appliances have motors (and other moving or loose parts) that vibrate at 60 Hz, since that is the frequency of oscillation of electrical current in the U.S. Do the sound waves that they create lie within the typical **range of human hearing**?
A. yes B. no

typical human hearing: $20\text{ Hz} \lesssim f \lesssim 20{,}000\text{ Hz}$.

So, yes! You can easily hear this low "hum" coming from many appliances.

61. (2 pts.) Which one of the following statements is **TRUE**?

A. Joules cannot be used as units of heat. - No! Joules convert to calories, and heat is energy.
B. Food "Calories" are 1000 times smaller than heat "calories." No! 1 food "Calorie" = 1000 "calories".
C. A calorie is the amount of heat needed to raise 760 mg of mercury by 1°C. No! Raise 1g of H_2O by 1°C.
D. 100°C on the Celsius scale is the temperature at which H_2O boils (at 1 atm pressure). - YES.
E. Absolute zero on the Kelvin scale is the temperature at which H_2O freezes (at 1 atm pressure). - No!

Water freezes at 0°C = +273 K. Absolute zero (0K) is much lower!
Absolute zero is the temp. at which all atomic motion ceases.

62. (2 pts.) A sealed Mylar (shiny metal-coated) balloon during a hot graduation ceremony contains 15.0 L of helium at a temperature of 35°C and a pressure of 1.00 atm. (The balloon is not quite completely filled, so the Mylar is slightly slack and contributes no additional pressure.) Later, as an experiment, you place the balloon in the freezer, where the helium chills to a temperature of –10.°C, again at 1.00 atm. What is the balloon's new **volume** at this colder temperature? (Assume that helium is an ideal gas.)

A. 12.8 L
B. 13.3 L
C. 13.8 L
D. 14.3 L
E. 14.7 L

$\frac{\cancel{P_1} V_1}{T_1} = \frac{\cancel{P_2} V_2}{T_2} \Rightarrow V_2 = V_1 \cdot \frac{T_2}{T_1} = (15.0L) \frac{263 K}{308 K}$

$T_1 = 35°C = 308 K.$
$T_2 = -10°C = 263 K.$

$V_2 = \underline{\underline{12.8 L}}.$

63. (1 pt.) While the balloon was in the freezer, which of the following **happened** to the helium gas?

A. Its average kinetic energy per atom decreased.
B. Its average kinetic energy per atom increased.
C. Its average kinetic energy per atom was unchanged.

Ave. K.E. ⟷ Temperature, and Temp. decreased.

64. (1 pt.) The 2nd Law of Thermodynamics asserts that the net **entropy** of a "closed system," during any real-life (irreversible) physical process, must increase. This means that all closed systems, including the universe itself, experience a one-way increase in ____________ as time goes on.

A. density
B. disorder
C. pressure
D. temperature
E. spacetime wormholes

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65. (1 pt.) The Four Fundamental Forces of Physics are:

A. Newtonian, Non-Newtonian, Keplerian, and Galilean Force
B. Weight, Tension, Normal, and Friction Force
C. Electric, Magnetic, Mechanical, and Thermal Force
D. Gravitational, Electromagnetic, Nuclear Strong, and Nuclear Weak Force
E. Chocolate, Love, Krazy Glue, and Gollum's Preciousss Ring