In this version the first answer is the correct one. 10 problems have 3 versions. So although your exam had 20 problems, this answer key has 40 problems. Make sure you compare with the numbers that you had in the exam. Complete solutions are at the end of the document except for concept questions.

77777

Instructor: *Biswas/Ihas/Whiting*

PHYSICS DEPARTMENT

PHY 2053 | Exam 3, 120 minutes | December 12, 2009

Name (print, last first): ______________________ Signature: ______________________

On my honor, I have neither given nor received unauthorized aid on this examination.

DIRECTIONS

(1) **Code your test number (THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE) on your answer sheet using lines 76–80. Write your test number down and take it with you.** Code your name on your answer sheet. Code your UFID number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) You may do scratch work anywhere on this exam. **Circle your answers on the test form.** At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.
(4) **Fill in the circles of your intended answers completely on the answer sheet, using a #2 pencil or blue or black ink.** Do not make any stray marks or some answers may be counted as incorrect.
(5) The answers are rounded off. Choose the closest to exact. There is no penalty for guessing.
(6) **Hand in the answer sheet separately, showing your UFID.**

Useful information:

$g = 9.80$ m/s^2	$Y_{\rm Al} = 7.0 \times 10^{10}$ Pa	$Y_{\rm Cu} = 11 \times 10^{10}$ Pa	Neglect air resistance except when stated otherwise.
1 m = 3.281 ft.	$\rho_{\rm water} = 1000$ kg/m^3	$G = 6.67 \times 10^{-11}$Nm^2/kg^2	speed of light $c = 3 \times 10^8$m/s

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1. A cart moving across a level surface accelerates uniformly at 1.0 m/s^2 for 2.0 seconds. What additional information is required to determine the distance traveled by the cart during this 2.0-second interval?

(1) initial velocity of the cart
(2) net force acting on the cart
(3) coefficient of friction between the cart and the surface
(4) mass of the cart
(5) initial position of the cart

2. An arrow is shot through an apple. If the 0.1 kg arrow changes speed by 10 m/s during the collision (from 30 m/s to 20 m/s) and the apple goes from rest to a speed of 2 m/s during the collision, then what must be the mass of the apple?

(1) 0.5 kg (2) 0.2 kg (3) 0.8 kg (4) 1.0 kg (5) 2.0 kg

3. An arrow is shot through an apple. If the 0.1 kg arrow changes speed by 10 m/s during the collision (from 30 m/s to 20 m/s) and the apple goes from rest to a speed of 1 m/s during the collision, then what must be the mass of the apple?

(1) 1.0 kg (2) 0.5 kg (3) 0.2 kg (4) 0.8 kg (5) 2.0 kg

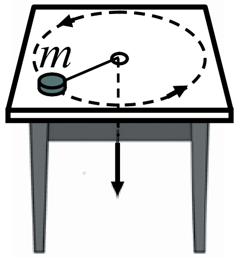
4. An arrow is shot through an apple. If the 0.1 kg arrow changes speed by 10 m/s during the collision (from 30 m/s to 20 m/s) and the apple goes from rest to a speed of 5 m/s during the collision, then what must be the mass of the apple?

(1) 0.2 kg (2) 0.5 kg (3) 0.8 kg (4) 1.0 kg (5) 2.0 kg

5. Why does a scientist in the International Space Station experience “weightlessness”?

(1) She is in free fall along with the Space Station and its contents.
(2) At an orbit of 200 miles above the Earth, the gravitational force of the Earth on her is 2% less than on its surface.
(3) In space she has no mass.
(4) The gravitational pull of the Moon has canceled the pull of the Earth on her.
(5) There is no gravitational force from the Earth acting on her.

6. An object m, on the end of a string, moves in a circle on a horizontal frictionless table as shown in the figure. As the string is pulled very slowly through a small hole in the table, which of the following is correct for an observer measuring from the hole in the table?



(1) The angular momentum of m remains constant.
(2) The angular momentum of m decreases.
(3) The kinetic energy of m remains constant.
(4) The kinetic energy of m decreases.
(5) None of these.

7. A radio signal with a wavelength of 1.2×10^{-4} m is sent to a distance asteroid, is reflected, and returns to Earth 72 hours and 48 minutes later. How far from Earth is the asteroid?

(1) 3.9×10^{10} km (2) 1.9×10^{10} km (3) 7.9×10^{10} km (4) 1.9×10^{11} km (5) 2.9×10^{10} km

8. A radio signal with a wavelength of 1.6×10^{-4} m is sent to a distance asteroid, is reflected, and returns to Earth 35 hours and 12 minutes later. How far from Earth is the asteroid?

(1) 1.9×10^{10} km (2) 3.9×10^{10} km (3) 7.9×10^{10} km (4) 1.9×10^{11} km (5) 2.9×10^{10} km

9. A radio signal with a wavelength of 1.4×10^{-4} m is sent to a distance asteroid, is reflected, and returns to Earth 53 hours and 42 minutes later. How far from Earth is the asteroid?

(1) 2.9×10^{10} km (2) 3.9×10^{10} km (3) 1.9×10^{10} km (4) 7.9×10^{10} km (5) 1.9×10^{11} km

10. The best leaper in the animal kingdom is the puma, which can jump to a height of 12.3 ft when leaving the ground at an angle of 37°. With what speed must the animal leave the ground to reach that height?

(1) 14.2 m/s (2) 46.5 m/s (3) 28.0 m/s (4) 8.55 m/s (5) 20.1 m/s

11. Approximately how much would it cost to keep a 100 W light bulb lit continuously for 1 year at a rate of $0.10/kW·hr?

(1) $100.00 (2) $1.00 (3) $10.00 (4) $1,000.00 (5) $100,000.00

12. Approximately how much would it cost to keep a 60 W light bulb lit continuously for 2.5 months at a rate of $0.08/kW·hr?

(1) $10.00 (2) $1.00 (3) $100.00 (4) $1,000.00 (5) $100,000.00

13. Approximately how much would it cost to keep a 600 W light bulb lit continuously for 1 year at a rate of $0.16/kW·hr?

(1) $1,000.00 (2) $1.00 (3) $10.00 (4) $100.00 (5) $100,000.00

14. Which of the following could be a correct unit for pressure?

(1) $kg/(m{\cdot}s^2)$ (2) kg/m^2 (3) $kg/(m{\cdot}s)$ (4) kg/s^2 (5) $m{\cdot}s/kg$

15. What is the average angular speed of the second hand on a clock (in rad/s)?

(1) 0.105 rad/s (2) 6.28 rad/s (3) 0.0167 rad/s (4) 1.745×10^{-3} rad/s (5) 1.454×10^{-4} rad/s

16. What is the average angular speed of the minute hand on a clock (in rad/s)?

(1) 1.745×10^{-3} rad/s (2) 0.105 rad/s (3) 6.28 rad/s (4) 0.0167 rad/s (5) 1.454×10^{-4} rad/sv

17. What is the average angular speed of the hour hand on a clock (in rad/s)?

(1) 1.454×10^{-4} rad/s (2) 0.105 rad/s (3) 6.28 rad/s (4) 0.0167 rad/s (5) 1.745×10^{-3} rad/s

18. A boat moves through the water of a river at 10 m/s relative to the water, regardless of the boat's direction. If the water in the river is flowing at 1.1 m/s, how long does it take the boat to make a round trip consisting of a 260 m displacement downstream followed by a 260 m displacement upstream?

(1) 52.6 s (2) 60.9 s (3) 40.9 s (4) 35.7 s (5) 10.3 s

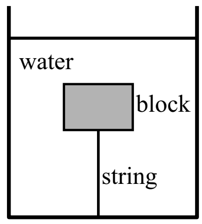
19. A boat moves through the water of a river at 13 m/s relative to the water, regardless of the boat's direction. If the water in the river is flowing at 1.9 m/s, how long does it take the boat to make a round trip consisting of a 260 m displacement downstream followed by a 260 m displacement upstream?

(1) 40.9 s (2) 52.6 s (3) 60.9 s (4) 35.7 s (5) 10.3 s

20. A boat moves through the water of a river at 8 m/s relative to the water, regardless of the boat's direction. If the water in the river is flowing at 1.5 m/s, how long does it take the boat to make a round trip consisting of a 235 m displacement downstream followed by a 235 m displacement upstream?

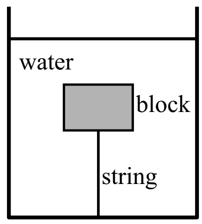
(1) 60.9 s (2) 52.6 s (3) 40.9 s (4) 35.7 s (5) 10.3 s

21. A block is connected to a light string attached to the bottom of a large container of water. The tension in the string is 3.0 N. The gravitational force from the earth on the block is 5.0 N. What is the block's volume?



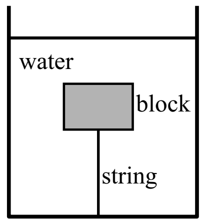
(1) $8.0 \times 10^{-4} m^3$
(2) $2.0 \times 10^{-4} m^3$
(3) $3.0 \times 10^{-4} m^3$
(4) $5.0 \times 10^{-4} m^3$
(5) $1.0 \times 10^{-3} m^3$

22. A block is connected to a light string attached to the bottom of a large container of water. The tension in the string is 5.0 N. The gravitational force from the earth on the block is 5.0 N. What is the block's volume?



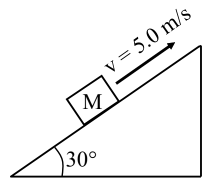
(1) $1.0 \times 10^{-3} m^3$
(2) $8.0 \times 10^{-4} m^3$
(3) $2.0 \times 10^{-4} m^3$
(4) $3.0 \times 10^{-4} m^3$
(5) $5.0 \times 10^{-4} m^3$

23. A block is connected to a light string attached to the bottom of a large container of water. The tension in the string is 3.0 N. The gravitational force from the earth on the block is 2.0 N. What is the block's volume?



(1) $5.0 \times 10^{-4}\text{m}^3$
(2) $8.0 \times 10^{-4}\text{m}^3$
(3) $2.0 \times 10^{-4}\text{m}^3$
(4) $3.0 \times 10^{-4}\text{m}^3$
(5) $1.0 \times 10^{-3}\text{m}^3$

24. A person pushes a block of mass M = 6.0 kg with a constant speed of 5.0 m/s straight up a flat surface inclined 30.0° above the horizontal. The coefficient of kinetic friction between the block and the surface is $\mu = 0.40$. What is the net force acting on the block?



(1) 0 N (2) 21 N (3) 30 N (4) 51 N (5) 76 N

25. The period of motion of an object-spring system is 0.256 s when a 31.57 g object is attached to the spring. What is the force constant of the spring?

(1) 19.0 N/m (2) 8.08 N/m (3) 48.9 N/m (4) 0.99 N/m (5) 119 N/m

26. A 1200 kg satellite orbits Planet X in a circular orbit with a constant speed of 5.00×10^3 m/s. The radius of orbit is 7.50×10^7m. What is the magnitude of the gravitational force exerted on the satellite by Planet X?

(1) 400 N (2) 200 N (3) 0.080 N (4) 100 N (5) More information is required to answer this question.

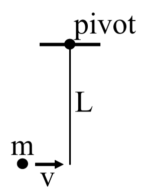
27. A 600 kg satellite orbits Planet X in a circular orbit with a constant speed of 7.00×10^3 m/s. The radius of orbit is 1.50×10^8m. What is the magnitude of the gravitational force exerted on the satellite by Planet X?

(1) 200 N (2) 400 N (3) 0.080 N (4) 100 N (5) More information is required to answer this question.

28. A 150 kg satellite orbits Planet X in a circular orbit with a constant speed of 5.00×10^3 m/s. The radius of orbit is 3.80×10^7m. What is the magnitude of the gravitational force exerted on the satellite by Planet X?

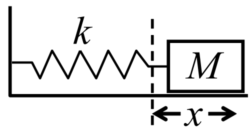
(1) 100 N (2) 200 N (3) 0.080 N (4) 400 N (5) More information is required to answer this question.

29. A point particle of mass m collides with a thin rod pivoted at one end. The rod has mass M = 2m, length L, and moment of inertia $I = \frac{1}{3}ML^2$. The particle moves horizontally with speed V when it hits the bottom of the rod and sticks to it. What is the speed of the particle immediately after collision?



(1) $\frac{3}{5}$ V (2) $\frac{1}{3}$ V (3) $\frac{1}{\sqrt{3}}$ V (4) $\frac{3}{4}$ V (5) $\frac{\sqrt{3}}{2}$ V

30. A block of mass M on a horizontal surface is connected to the end of a massless spring of spring constant k. The block is pulled a distance x from equilibrium and when released from rest, the block moves toward equilibrium. What minimum coefficient of kinetic friction between the surface and the block would prevent the block from returning to equilibrium with non-zero speed?



(1) $\frac{kx}{2Mg}$ (2) $\frac{kx^2}{2Mg}$ (3) $\frac{kx}{Mg}$ (4) $\frac{Mg}{2kx}$ (5) $\frac{k}{4Mgx}$

31. In a circus performance, a large 5.0 kg hoop of radius 3.0 m rolls without slipping. If the hoop is given an angular speed of 3.2 rad/s while rolling on the horizontal and allowed to roll up a ramp inclined at 15° with the horizontal, how far (measured along the incline) does the hoop roll?

(1) 36.3 m (2) 20.9 m (3) 15.8 m (4) 27.8 m (5) 31.0 m

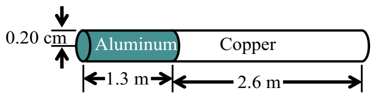
32. In a circus performance, a large 5.0 kg hoop of radius 3.0 m rolls without slipping. If the hoop is given an angular speed of 3.4 rad/s while rolling on the horizontal and allowed to roll up a ramp inclined at 20° with the horizontal, how far (measured along the incline) does the hoop roll?

(1) 31.0 m (2) 20.9 m (3) 15.8 m (4) 27.8 m (5) 36.3 m

33. In a circus performance, a large 5.0 kg hoop of radius 3.0 m rolls without slipping. If the hoop is given an angular speed of 3.1 rad/s while rolling on the horizontal and allowed to roll up a ramp inclined at 25° with the horizontal, how far (measured along the incline) does the hoop roll?

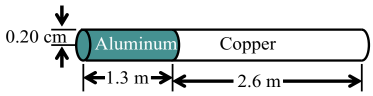
(1) 20.9 m (2) 15.8 m (3) 27.8 m (4) 31.0 m (5) 36.3 m

34. Determine the elongation of the rod in the figure below if it is under a tension of 6.7×10^3 N. The radius and lengths are given in the figure.



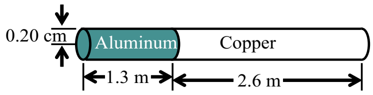
(1) 2.25 cm (2) 1.51 cm (3) 1.85 cm (4) 1.34 cm (5) 2.05 cm

35. Determine the elongation of the rod in the figure below if it is under a tension of 6.1×10^3 N. The radius and lengths are given in the figure.



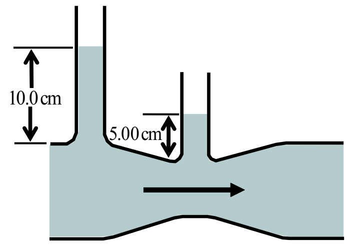
(1) 2.05 cm (2) 1.51 cm (3) 1.85 cm (4) 1.34 cm (5) 2.25 cm

36. Determine the elongation of the rod in the figure below if it is under a tension of 4.5×10^3 N. The radius and lengths are given in the figure.



(1) 1.51 cm (2) 1.85 cm (3) 1.34 cm (4) 2.25 cm (5) 2.05 cm

37. The inside diameters of the larger portions of the horizontal pipe depicted in the figure below are 2.40 cm. Water flows to the right at a rate of $2.10 \times 10^{-4} m^3/s$. Determine the inside diameter of the constriction.



(1) 1.56 cm
(2) 1.46 cm
(3) 1.43 cm
(4) 1.29 cm
(5) 1.38 cm

38. At rest, a car's horn sounds at a frequency of 480 Hz. The horn is sounded while the car is moving down the street. A bicyclist moving in the same direction with one-third the car's speed hears a frequency of 422 Hz. What is the speed of the car? $T_{\text{air}} = 24°$.

(1) 76.4 m/s (2) 28.3 m/s (3) 54.1 m/s (4) 16.4 m/s (5) 47.0 m/s

39. At rest, a car's horn sounds at a frequency of 375 Hz. The horn is sounded while the car is moving down the street. A bicyclist moving in the same direction with one-third the car's speed hears a frequency of 345 Hz. What is the speed of the car? $T_{\text{air}} = 24°$.

(1) 47.0 m/s (2) 28.3 m/s (3) 54.1 m/s (4) 16.4 m/s (5) 76.4 m/s

40. At rest, a car's horn sounds at a frequency of 495 Hz. The horn is sounded while the car is moving down the street. A bicyclist moving in the same direction with one-third the car's speed hears a frequency of 470 Hz. What is the speed of the car? $T_{\text{air}} = 24°$.

(1) 28.3 m/s (2) 54.1 m/s (3) 16.4 m/s (4) 76.4 m/s (5) 47.0 m/s

FOLLOWING GROUPS OF QUESTIONS WILL BE SELECTED AS ONE GROUP FROM EACH TYPE
TYPE 1
Q# S 2
Q# S 3
Q# S 4
TYPE 2
Q# S 7
Q# S 8
Q# S 9
TYPE 3
Q# S 11
Q# S 12
Q# S 13
TYPE 4
Q# S 15
Q# S 16
Q# S 17
TYPE 5
Q# S 21
Q# S 22
Q# S 23
TYPE 6
Q# S 26
Q# S 27
Q# S 28
TYPE 7
Q# S 31
Q# S 32
Q# S 33
TYPE 8
Q# S 34
Q# S 35

(2) $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

$\Rightarrow 0.1 \times 30 + m_2 \times 0 = 0.1 \times 20 + m_2 v_{2f}$

$\Rightarrow m_2 v_{2f} = 1$

if $v_{2f} = 2$ m/s, $m_2 = 0.5$ kg

if $v_{2f} = 1$ m/s, $m_2 = 1.0$ kg

if $v_{2f} = 5$ m/s, $m_2 = 0.2$ kg

(7) Speed of light $= 3 \times 10^8$ m/s

$\frac{2d}{3 \times 10^8} = t \Rightarrow$

if $t = 72$h 48m, $d = 3.9 \times 10^{13}$ m

if $t = 35$h 12m, $d = 1.9 \times 10^{13}$ m

if $t = 53$h 42m, $d = 2.9 \times 10^{13}$ m

(10) $v_{iy} = v \sin 37°$, $v_{fy} = 0$, $\Delta y = 12.3$ ft $= 3.75$ m

$\Rightarrow 0^2 = v^2 \sin^2 37° - 2 \times 9.8 \times 3.75 \Rightarrow v = 14.2$ m/s

(11) Power of bulb $= P$

No. of years $= Y$

No. of hours $= 365 \times 24 \times Y$

price $= p$

if $P = 100$W $= 0.1$kW, $Y = 1$, $p = \$0.1$,
Total $= P \times Y \times 365 \times 24 \times p = \$87.6 \approx \$100$

if $P = 0.06$kW, $Y = 2.5$ months, $p = \$0.08$
Total $\approx \$10$

if $P = 0.6$kW, $Y = 1$, $p = \$0.16$, Total $= \$1000$

(14) $P = \frac{F}{A}$

$\Rightarrow [P] = \frac{MLT^{-2}}{L^2} = \frac{M}{LT^2}$

(15) $\omega = 2\pi/60 = 0.105$ rad/s

(16) $\omega = \frac{2\pi}{60 \times 60} = 1.745 \times 10^{-3}$ rad/s

(17) $\omega = \frac{2\pi}{12 \times 60 \times 60} = 1.454 \times 10^{-4}$ rad/s

(18) displacement $= d$

$$t_{downstream} = \frac{d}{v_{BR} + v_{RE}}$$

$$t_{upstream} = \frac{d}{v_{BR} - v_{RE}}$$

$$\Rightarrow t = \frac{d}{v_{BR} - v_{RE}} + \frac{d}{v_{BR} + v_{RE}}$$

$$= \frac{d v_{BR} + d v_{RE} + d v_{BR} - d v_{RE}}{v_{BR}^2 - v_{RE}^2}$$

$$= \frac{2 d v_{BR}}{v_{BR}^2 - v_{RE}^2}$$

if $d = 260\,m$, $v_{BR} = 10\,m/s$, $v_{RE} = 1.1\,m/s$
then $t = 52.6\,s$

if $d = 260\,m$, $v_{BR} = 13\,m/s$, $v_{RE} = 1.9\,m/s$
then $t = 40.9\,s$

if $d = 235\,m$, $v_{BR} = 8\,m/s$, $v_{RE} = 1.5\,m/s$
then $t = 60.9\,s$

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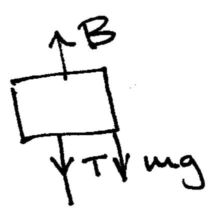
(19) Density of water $= 1 \times 10^3\ kg/m^3$



$$\Rightarrow B = T + mg = \rho_{fluid} V_{fluid}\, g$$
$$= \rho_{fluid} V_{object}\, g.$$

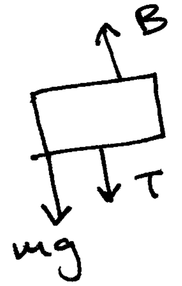
$$\Rightarrow V_{object} = \frac{T + mg}{\rho_{fluid}\, g}$$

if $T = 3\,N$, $mg = 5\,N$, $V_{object} = 8 \times 10^{-4}\ m^3$

if $T = 5\,N$, $mg = 5\,N$, $V_{object} = 1 \times 10^{-3}\ m^3$

if $T = 3\,N$, $mg = 2\,N$, $V_{object} = 5 \times 10^{-4}\ m^3$

(21)



$$B = mg + T$$

$$\Rightarrow \rho_\omega V_\omega g = mg + T$$

$$\Rightarrow \rho_\omega V_{obj}\, g = mg + T$$

$$\Rightarrow V_{obj} = \frac{mg + T}{\rho_\omega g}$$

if $mg = 5\ N$, $T = 3\ N$, $V_{obj} = 8 \times 10^{-4}\ m^3$

if $mg = 5N$, $T = 5N$, $V_{obj} = 1 \times 10^{-3}\ m^3$

if $mg = 2N$, $T = 3N$, $V_{obj} = 5 \times 10^{-4}\ m^3$

(24) $a = 0 \Rightarrow$ Net force $= 0$

(25) $$T = 2\pi\sqrt{\frac{m}{k}}$$

$$\Rightarrow k = \frac{4\pi^2 m}{T^2} = 19\ N/m$$

(26) $$a_c = \frac{mv^2}{r} = F_g$$

if $m = 1200\ kg$, $v = 5\times10^3\ m/s$, $r = 7.5\times10^7\ m$

$F_g = 400\ N$

if $m = 600\ kg$, $v = 7\times10^3\ m/s$, $r = 1.5\times10^8\ m$

if $m = 150\ kg$, $v = 5\times10^3\ m/s$, $F_g = 196\ N \approx 200\ N$

$r = 3.8\times10^7 m$, $F_g = 100\ N$

(29)

$$L_i = mL^2\omega_i = \frac{mL^2 V}{L} = mLV$$

$$L_f = \left(mL^2 + \frac{1}{3}2mL^2\right)\omega_f = \frac{5}{3}mL^2\omega_f = L_i$$

$$\Rightarrow \frac{5}{3}mL^2\omega_f = mLV$$

$$\Rightarrow \omega_f = \frac{3V}{5L} = \frac{V_f}{L} \Rightarrow V_f = \frac{3}{5}V$$

(30) All the $PE = \frac{1}{2}kx^2$ is lost to friction

$$\Rightarrow \mu_k N x = \frac{1}{2}kx^2 \Rightarrow \mu_k Mg x = \frac{1}{2}kx^2$$

$$\Rightarrow \mu_k = \frac{kx}{2Mg}$$

(31) Total initial Energy $= \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$

$$= \frac{1}{2}Mv^2 + \frac{1}{2}MR^2\frac{v^2}{R^2} = MV^2$$

Total final energy $= Mgh = Mgd\sin\theta$

$\Rightarrow Mgd\sin\theta = MV^2$

$$\Rightarrow d = \frac{v^2}{g\sin\theta} = \frac{R^2\omega^2}{g\sin\theta}$$

if $\omega = 3.2$ rad/s, $R = 3$ m, $\theta = 15° \Rightarrow d = 36.3$ m

if $\omega = 3.4$ rad/s, $R = 3$m, $\theta = 20°$, $\Rightarrow d = 31.0$ m

if $\omega = 3.1$ rad/s, $R = 3$m, $\theta = 25°$, $\Rightarrow d = 20.9$ m

(34) $$Y_{Al} = \frac{T/A}{\Delta L_1/L_1} \Rightarrow Y_{Al} = \frac{TL_1}{A\Delta L_1} \Rightarrow \Delta L_1 = \frac{TL_1}{AY_{AL}}$$

& $$\Delta L_2 = \frac{TL_2}{AY_{cu}}$$

$$\Delta L = \Delta L_1 + \Delta L_2 = \frac{T}{A}\left(\frac{L_1}{Y_{Al}} + \frac{L_2}{Y_{cu}}\right)$$

if $T = 6.7 \times 10^3$ N $\Rightarrow \Delta L = 2.25$ cm

if $T = 6.1 \times 10^3$ N $\Rightarrow \Delta L = 2.05$ cm

if $T = 4.5 \times 10^3$ N $\Rightarrow \Delta L = 1.51$ cm

(37)

$$A_1 v_1 = A_2 v_2 = \text{flow rate}$$

$$\Rightarrow v_1 = \frac{\text{flow rate}}{A_1} = \frac{\text{flow rate}}{\pi d_1^2/4} = \frac{4(\text{flow rate})}{\pi d_1^2}$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$\Rightarrow P_{atm} + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_{atm} + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

$$\Rightarrow g(h_1 - h_2) + \frac{v_1^2}{2} = \frac{v_2^2}{2}$$

$$\Rightarrow v_2 = \sqrt{2g(h_1-h_2) + v_1^2}$$

$$\Rightarrow A_2 = \frac{\text{flow rate}}{v_2} = \frac{\pi d_2^2}{4}$$

$$\Rightarrow d_2 = \sqrt{\frac{4(\text{flow rate})}{\pi v_2}} = \sqrt{\frac{4(\text{flow rate})}{\pi\sqrt{2g(h_1-h_2) + \frac{16(\text{flow rate})^2}{\pi^2 d_1^4}}}}$$

$$\Rightarrow d_2 = 1.56 \text{ cm}$$

(38)

$$v = 331\sqrt{\frac{T}{273}} = 331\sqrt{\frac{24+273}{273}} = 345 \text{ m/s}$$

$$f_o = f_s\left(\frac{v + v_o}{v - v_s}\right) = f_s\left(\frac{345 + v_{car}/3}{345 - (-v_{car})}\right)$$

$$\Rightarrow f_o \times 345 + v_{car} f_o = 345 f_s + f_s v_{car}/3$$

$$\Rightarrow v_{car} = \frac{345(f_s - f_o)}{f_o - f_s/3}$$

if $f_s = 480$ Hz, $f_o = 422$ Hz, $v_{car} = 76.4$ m/s

if $f_s = 375$ Hz, $f_o = 345$ Hz, $v_{car} = 47.0$ m/s

if $f_s = 495$ Hz, $f_o = 470$ Hz, $v_{car} = 28.3$ m/s