PHYS 101 Final Examination

April 13, 2002 Name_____

Time: 3 hours Student number_____

Calculator and one formula sheet permitted. For questions 4 to 8, please show complete solutions and explain your reasoning, stating any principles that you have used.

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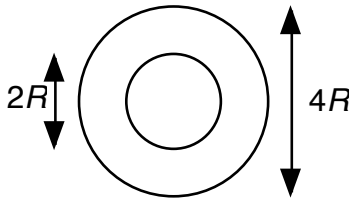
1. For each of the following questions, circle one correct answer only. (10 marks)

(i) Two cars are travelling in concentric circles of radius R and $2R$, as in the diagram.



Each car completes its own circle in the same time T. What is the centripetal acceleration of the outer car divided by that of the inner car?

(a) 1 (b) 2 (c) 1/2 (d) $4\pi^2$ (e) $8\pi^2$

(ii) An object of mass m is hung from the lower end of a vertical rope of negligible mass. What is the tension in the rope if the object has a downward acceleration a on the surface of the Earth?

(a) $m(g - a)$ (b) $g + a$ (c) ma (d) $g-a$ (e) $m(g + a)$

(iii) The power required to keep a particular car moving at a constant speed v against drag at low speeds is P. What is the power required to move the car at $2v$?

(a) P (b) $2P$ (c) $4P$ (d) $8P$ (e) none of [a-d]

(iv) A car of mass m and a truck of mass $2m$ travel at the same speed v but opposite directions: the car heads east while the truck heads west. What is the velocity of their centre-of-mass?

(a) v/3 east (b) v west (c) v/2 west (d) v/3 west (e) v/2 east

(v) A spring under a compression x has a potential energy V_o. When the compression is doubled $2x$, the potential energy stored in the spring is

(a) V_o (b) $2V_o$ (c) $3V_o$ (d) $8V_o$ (e) None of [a-d] is correct.

2. For each of the following questions, circle one correct answer only. (10 marks)

(i) For angular motion, if **R** lies along the *x*-axis with a length of 1 m, and **v** points in the negative *z* direction with a magnitude of 1 m/s, what is the angular velocity in rad / s?
(a) (0,1,0) (b) (0,-1,0) (c) (0,-2π,0) (d) (0,2π,0) (e) none of [a-d]

(ii) A solid sphere of mass M and radius R rolls without slipping along a table at speed v. What is its kinetic energy?
(a) $Mv^2/2$ (b) Mv^2 (c) $7Mv^2/10$ (d) $Mv^2/5$ (e) $3Mv^2/2$

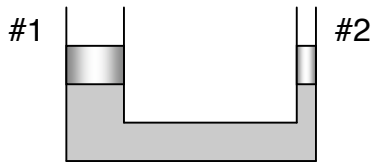
(iii) A mass attached to a spring vibrates with a period of 0.5 s. When the mass passes through its equilibrium position, it is moving with a velocity of 0.2 m/s. What is the amplitude of the motion?
(a) 0.016 m (b) 0.032 m (c) 0.1 m (d) 0.4 m (e) 1.25 m

(iv) A string under tension carries transverse waves travelling at speed v. If the same string is under four times the tension, what is the wave speed?
(a) v (b) $v/4$ (c) $v/2$ (d) $4v$ (e) $2v$

(v) The standing waves on a string of length L that is fixed at both ends have a speed v. The three lowest frequencies of vibration are
(a) v/L, $2v/L$, and $3v/L$ (b) $v/2L$, v/L, and $3v/2L$ (c) $\lambda/2$, λ, and $3\lambda/2$

3. For each of the following questions, circle one correct answer only. (10 marks)

(i) Pistons in the hydraulic press have radii $2R$ and R, respectively. If the fluid in the press is incompressible, what distance does piston #2 move if piston #1 moves by h?
(a) $h/4$ (b) $h/2$ (c) $4h$
(d) $16h$ (e) $2h$



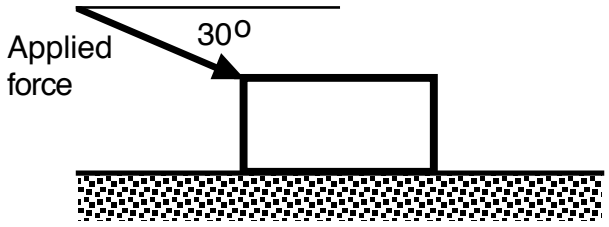
(ii) Blood flows from a large artery of radius 0.3 cm, where its speed is 8 cm/s, into a region where the radius has been reduced to 0.2 cm because of thickening of the walls. Assuming the blood to be incompressible, what is its speed in the narrower region in cm/second?
(a) 18 (b) 0.06 (c) 12 (d) 5.3 (e) 3.6

(iii) A solid cube has length L to the side. If the length of a side increases by 1% upon heating, what is the relative change in volume?
(a) 1% (b) 10^{-1} (c) 30% (d) 10^{-6} (e) 3×10^{-2}.

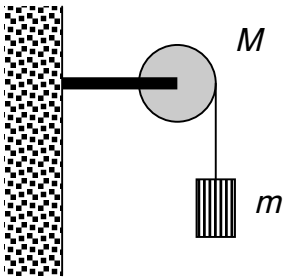
(iv) A light bulb contains a fine tungsten wire that is heated to 3000K by electric current. At this temperature, the emissivity of tungsten is 0.34. The surface area of the tungsten wire is 1.0cm^2. The room temperature is 300K. What is the radiated power of the light bulb in watts? (Note: The Stefan-Boltzmann constant is 5.67×10^{-8} J/(s-m^2-K^4)
(a) 1.56 (b) 0.00567 (c) 56.7 (d) 0.0156 (e) 156

(v) (Continue the previous question) What is the power that the light bulb absorbs from its surroundings?
(a) 1.56 (b) 0.00567 (c) 56.7 (d) 0.0156 (e) 156

4. A force *F* of 100 N is applied to a box of mass 5 kg resting on the floor as shown in the diagram. Both coefficients of friction (static and dynamic) between the box and the floor are 0.5.
(a) What is the magnitude and direction of the frictional force between the box and the floor? (Use $g = 10$ m/s^2)
(b) What is the acceleration of the block? (10 marks)



5. An object of mass *m* is tied to a light string wound around a uniform solid cylindrical wheel of mass *M* and radius *R*. The wheel is free to rotate. The object is released, making the wheel turn. Draw the applicable free-body diagrams and **derive** an algebraic expression for the angular acceleration α of the wheel as a function of *m*, *M*, *R* and *g*. (15 marks)



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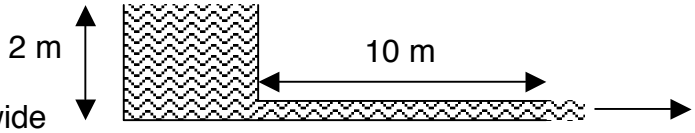
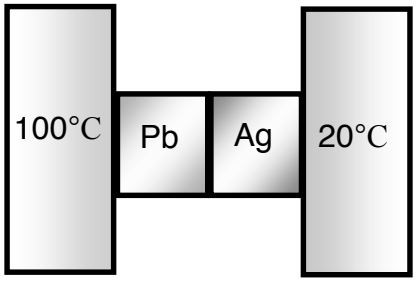
6. A 200 gram mass vibrates in the x-direction without friction at the end of a massless horizontal spring for which k = 7.2 N/m. The mass is displaced 5.0 cm from equilibrium and released.
(a) Find the period of the vibration.
(b) Find maximum speed of the mass.
(c) Find the speed of the mass when it is 4.0 cm from equilibrium (quote v in cm/s).
(d) Find the magnitude of the acceleration when the mass is 2.0 cm from equilibrium (quote a in cm/s^2). (20 marks)

7. A long garden hose is attached to the base of an open tank filled to the top with water. With a height of 2 meters, the tank is sufficiently wide



that water flows through it without dissipation. The hose, however, is both long (10 meters) and narrow (radius = 0.5 cm).
(a) What is the pressure at the bottom of the tank arising from the weight of the water?
(b) What is the speed of the water as it sprays from the hose? Take the viscosity of water to be 10^{-3} kg / m•s, and ignore the difference in air pressure between the top and bottom of the tank. (Use g = 10 m/s^2) (10 marks)

8. Two metal cubes, with 2-cm sides, are held between two walls, one with a temperature of 100°C and the other at 20°C. The cubes are lead (Pb) and silver (Ag), whose thermal conductivities are 353 W/m•K and 429 W/m•K, respectively.



(a) Find the temperature at the lead-silver junction.
(b) Find the energy transfer through the cubes in 1.0 s.
(15 marks)

Answers:

1. b, a, c, d, e
2. a, c, a, e, b
3. c, a, e, e, d
4. (a) $F_x = -50$ N, $F_y = 0$; 7.3 m/s^2.
5. $a = mg / [(m + M/2)R]$
6. (a) π/3 s (b) 30 cm/s (c) 18 cm/s (d) 72 cm/s^2.
7. (a) 2 x 10^4 N/m^2 (b) 6.2 m/s.
8. (a) 56 °C (b) 310 J.