PHYSICS 101 FINAL EXAMINATION - A

Tuesday, 17 April, 2001
Time: 3 hours
Calculator and one formula sheet permitted

NAME (PRINT)________________________
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STUDENT NUMBER___________________

This examination has eight questions. Please show complete solutions to questions 4 to 8. As an exam strategy, do your mathematics first, then make sure your reasoning is clearly explained; name any principles that you use.

1 atmosphere = 1.01 x 10^5 Pa

$I = MR^2/2$ (disk, axis through centre) $I = ML^2/3$ (rod, axis through end)

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1. Circle the correct answer for each question (2 marks each; no part marks):

(i) The heat flow per unit time through a rectangular slab of material is *H*. If the slab is made twice as thick, but the area and temperature difference are unchanged, what is the rate of heat flow?

(a) *H*   (b) 2*H*   (c) *H* /2   (d) 4*H*   (e) *H* /4

(ii) In an ideal gas, what is the ratio of the mean speed of a nitrogen molecule compared to an unbound nitrogen atom?

(a) 2   (b) √2   (c) 1   (d) 1/2   (e) 1/ √2

(iii) Two stars, *Alpha* and *Beta*, produce the same amount of energy per unit time, but have different radii: *Alpha* is twice as large as *Beta*. What is the ratio of their surface temperatures, $T_{\text{Alpha}} / T_{\text{Beta}}$?

(a) $2^{1/2}$ (b) $2^{-1/4}$ (c) $2^{1/4}$ (d) $2^{-1/2}$ (e) none of [a-d]

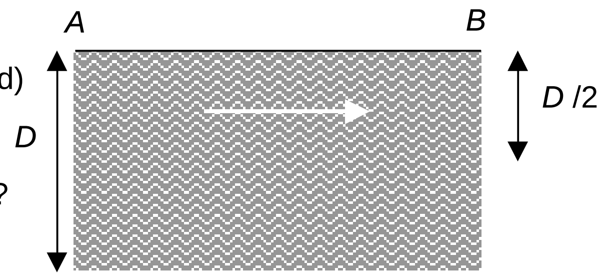
(iv) As it forages for food, a particular species of animal randomly explores an area of radius *R* in the daylight hours of a winter's day. In the summer, when there are twice as many hours of daylight, what is the radius of the region that the animal can explore, all other things being equal?

(a) 2*R*   (b) *R*   (c) 4*R*   (d) *R*/2   (e) √2 *R*

(v) When inspecting the heating system of an old building, an engineer notices that many small pipes flow in parallel towards the furnace. She proposes that the small pipes be replaced by a larger pipe of twice the diameter. How many small pipes can the large one replace, and still maintain the same flow of fluid? Assume that the fluid is viscous, and that the pressure drop per unit length of pipe is the same in both cases.

(a) 16   (b) 8   (c) 4   (d) 32   (e) 2

(vi) Water flows along a canal of depth D with a flow rate Q (volume per second) at point A. If the depth of the canal changes to $D/2$ at point B, what is the new flow rate in terms of the original Q? Treat the water as incompressible.



(a) $Q/2$ (b) Q (c) $2Q$ (d) 0 (e) $4Q$

2. Circle the correct answer for each question (2 marks each; no part marks):

(i) The displacement $y(x,t)$ of a particular travelling wave has the form

$$y(x,t) = A \sin(x + \pi t/2).$$

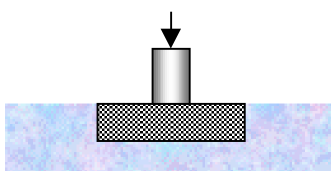
What is the speed of this wave, ignoring its direction?

(a) $\pi/2$ (b) 2π (c) 4 (d) 8π (e) none of [a-d]

(ii) A grandfather clock uses the swing of a large pendulum to measure time. Suppose that such a clock is transported to a small planet where the local acceleration due to gravity is 1/9 that on Earth. How many Earth hours would it take for the clock to complete 12 hours as measured by the hands of the clock?

(a) 12 (b) 36 (c) 4 (d) 4/3 (e) 72

(iii) A rectangular block of mass m is placed in a fluid and held by a rod such that the top face of the block lies at the surface of the fluid. If the density of the block is 1/3 that of the fluid, what force must the rod exert on the block, ignoring direction?



(a) $3mg$ (b) $mg/3$ (c) $2mg/3$ (d) $3mg/2$ (e) $2mg$

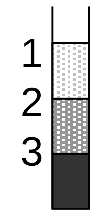
(iv) A mass is hung vertically from a spring of force constant k_{sp}. When given an amplitude of oscillation A, the mass has a maximum speed v during its motion. If the spring constant is tripled to $3k_{sp}$, what amplitude is needed to give the mass the same maximum velocity?

(a) $A/\sqrt{3}$ (b) $3A$ (c) $A/3$ (d) $\sqrt{3}\,A$ (e) A

(v) A wire is stretched between two fixed points separated by a distance L. What is the longest wavelength that a standing wave can have on this wire?

(a) L (b) $2L$ (c) $L/2$ (d) 0 (e) no limit

(vi) Water, mercury and oil have densities 1.0 x 10^3, 13.6 x 10^3 and 0.9 x 10^3 kg/m^3, respectively. Knowing that these fluids do not mix with each other, what is their order (1-2-3) if equal amounts are placed in a cylinder?



(a) water-merc-oil (b) oil-merc-water
(c) oil-water-merc (d) merc-water-oil (e) merc-oil-water

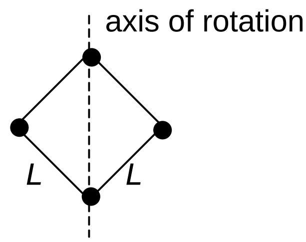
3. Circle the correct answer for each question (2 marks each; no part marks):

(i) The total linear momentum of a system of particles will be conserved if:
(a) the positions of the particles do not change with respect to each other
(b) one particle is at rest
(c) no external force acts on the system
(d) the internal forces equal the external forces
(e) the particles do not rotate about their axes.

(ii) Find the vector **C** in the cross product **C** = **A** x **B**, if **A** = (0,1,0) and **B** = (1,0,0).
(a) (1,1,0) (b) (0,0,1) (c) (0,0, -1) (d) (1, -1,0) (e) (0,0,1)

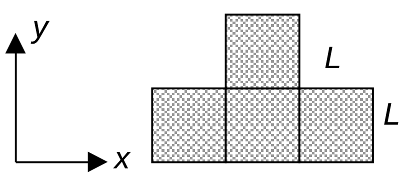
(iii) A vertical rope is attached to an object of mass M. What is the tension in the rope in order to give the mass an upward acceleration of 3g?
(a) 3g (b) 4g (c) Mg (d) 3Mg (e) 4Mg

(iv) Consider four objects arranged at the corners of a square having dimensions L x L. What is the moment of inertia of this configuration with respect to an axis lying in the plane of the objects, as shown. Each mass is equal to M and is concentrated at a point.



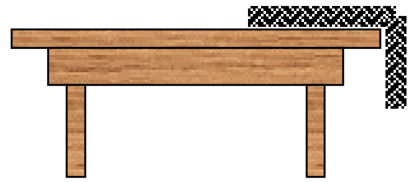
(a) 4ML^2 (b) 2ML^2 (c) ML^2 (d) ML^2/2 (e) none of [a-d]

(v) Four squares of equal mass and dimension L x L are arranged as shown. What is the y-component of their centre-of-mass?



(a) L/2 (b) 3L/2 (c) L (d) 3L/4 (e) L/4

4. A thin rope of mass M hangs over the edge of a table. The fraction of its total length L lying on the table experiences a frictional force with the table governed by a coefficient of friction μ. For a given value of μ, what is the minimum fraction f of the rope that can lie on the table without slipping over the edge? Assume that the edge is smooth and does not contribute to the frictional force. (12 marks)

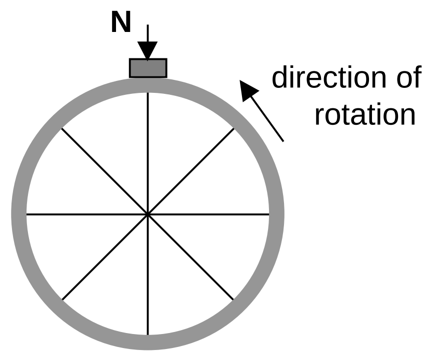


5. A thin bike wheel of radius 0.2 m and mass 2.0 kg is spinning at 5 revs/second. A block is pushed against the top of the wheel with a force **N** of 10 N. The coefficient of kinetic friction between the block and the wheel is 0.9.

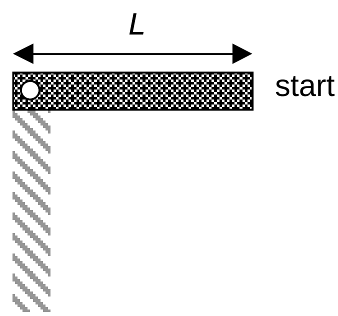
(a) What is the angular momentum of the wheel before the block is applied (include the sign)?

(b) What torque does the block exert on the wheel (include the sign)?

(c) How long does it take for the wheel to stop? (21 marks)

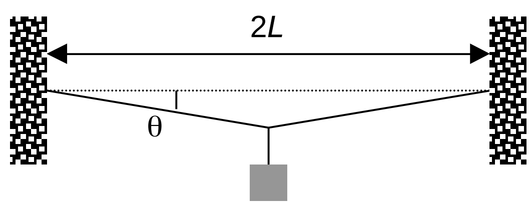


6. A rod of uniform mass of mass M and length L is free to pivot about a hole drilled through one end, as in the diagram. Initially at rest, it is released from a horizontal position. What is its angular frequency as it swings through the vertical position, in terms of g and the characteristics of the rod? (11 marks)



7. A bubble rises from the bottom of a glass of water (density = 1.0×10^3 kg/m^3) from a depth of 12 cm below the surface. At the bottom, the initial volume of the bubble is V_{bot}, growing to V_{top} just as it reaches the surface. Treating the bubble as an ideal gas, what is V_{top}/V_{bot}? The external pressure on the fluid is one standard atmosphere. (12 marks)

8. Let's revisit the demonstration done in class where a horizontal wire of length $2L$ has a small weight hung from it. Upon heating, the wire expands and the weight drops, as in the diagram. For small displacements, establish that $\theta = (2\alpha\,\Delta T)^{1/2}$, where α is the linear expansion coefficient and ΔT is the temperature difference. You may use without proof the small x approximations $\sin x$ x, $\cos x$ $1 - x^2/2$ and $1/(1+x)$ $1-x$. (10 marks)



Answers:

1. (i) c, (ii) e, (iii) d, (iv) e, (v) a, (vi) b.
2. (i) a, (ii) b, (iii) e, (iv) a, (v) b, (vi) c.
3. (i) c, (ii) c, (iii) e, (iv) c, (v) d.
4. 1 / (1+μ)
5. (a) 2.51 kg•m^2/2 (b) -1.8 kg•m^2/s^2 (c) 1.4 s
6. $(3g/L)^{1/2}$
7. V_{top}/V_{bottom} = 1.012