Physics 120 Final Examination

6 August, 1999 Name_____
Time: 3 hours Signature_____
Calculator and one formula sheet allowed Student number _____

Show complete solutions to questions 4 to 7.
This examination has 7 questions.

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Some useful data:

$c = 3.0 \times 10^8$ m/s $k_B = 1.38 \times 10^{-23}$ J/K

1 pc = 3.26 l.y. 1 l.y. = 9.46×10^{15} m

$I_{sphere} = (2/5)MR^2$ $I_{disk} = (1/2)MR^2$ (axes through the centre)

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1. (12 marks) Circle one answer for each of the following questions:

(i) The radius of a nucleus scales with mass number like $A^{1/3}$. If the mass number of a nucleus is doubled, by what factor does the density change?

(a) no change (b) 2 (c) 8 (d) 1/8 (e) 1/2

(ii) What is the approximate cross section for the reaction p + γ → p + γ?

(a) 1 fm^2 (b) 10^{-42} m^2 (c) 10^{-24} m^2 (d) 10^{-36} m^2 (e) 10^{-16} m^2

(iii) What is the kinetic energy of a particle of mass m and momentum mc?

(a) $(\sqrt{2} - 1)mc^2$ (b) mc^2 (c) $mc^2/2$ (d) $\sqrt{2}\,mc^2$ (e) $(\sqrt{2} + 1)mc^2$

(iv) How many neutrons are there in the beryllium nucleus produced in the reaction
^{4}He + ^{4}He -> Be + n?

(a) 7 (b) 8 (c) 3 (d) 4 (e) none of [a]-[d]

(v) By what factor does the photon energy density increase when the interior of a furnace rises from 400 K to 800 K?

(a) 2 (b) 32 (c) 8 (d) 16 (e) none of [a]-[d]

(vi) What was the value of the Hubble parameter when the universe was 1/4 of the age that it is today (in terms of today's value of H)?

(a) 4H (b) H (c) H/4 (d) H^{-1} (e) 2H

2. (14 marks) Circle one answer for each of the following questions:

(i) Starting at rest, an object falls a height h in time t. Assuming that the only force on the object is its gravitational attraction to the Earth, how far does the object fall in an elapsed time of $3t$, starting from rest?

(a) $3h$ (b) $9h$ (c) $27h$ (d) $6h$ (e) $h/3$

(ii) A car travels at constant speed on a circular test track of radius R, completing each lap around the track in time T. The centripetal acceleration of the car, a_C, is at the limit where the tires start to skid. If the test track were three times as large (i.e., had a radius of $3R$), what would be the shortest period in which the car could complete a lap without its acceleration exceeding the same a_C as for the smaller track?

(a) $3T$ (b) $9T$ (c) $T / 3$ (d) $\sqrt{3}\, T$ (e) none of (a - d)

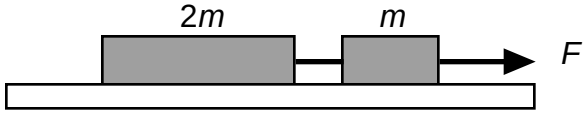
(iii) The acceleration due to gravity on the Moon is only 1/6 that on the Earth. An object with a weight of 60 N on Earth is transported to the Moon. What is its mass as measured on the Moon? Use $g = 10$ m/s^2 on Earth.

(a) 6 kg (b) 1 kg (c) 0.6 kg (d) 60 kg (e) 10 kg

(iv) A projectile is fired at an angle of 35^o above the horizontal. At the highest point in its trajectory, its speed is 200 m/s. If air resistance is neglected, what is the initial horizontal component of the projectile's velocity (in m/s)?

(a) 0 (b) 200 cos35^o (c) 200 sin35^o (d) 200/cos35^o (e) 200

(v) Two masses (m and $2m$) are attached to one another by a string as illustrated. A force F acts on mass m to accelerate the whole system. What is the magnitude of the force on mass $2m$?



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

(vi) Two objects have the same mass m and velocities $(v,0)$ and $(0,v)$. What is the magnitude of their centre-of-mass velocity?

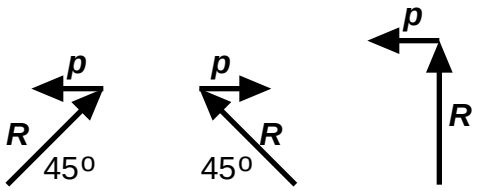
(a) $v/2$ (b) 0 (c) $\sqrt{2}v$ (d) $2v$ (e) $v/\sqrt{2}$

(vii) Object A with mass m is travelling in the positive x direction when it collides inelastically with a body of mass $2m$ and comes to a complete stop. If object A has an initial velocity v, what is the kinetic energy of object B?

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

3. (12 marks) Circle one answer in each of the following questions:

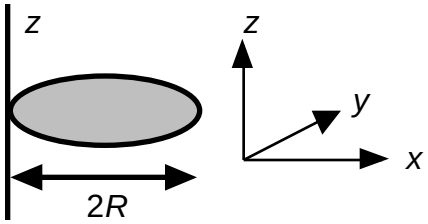
(i) Which of the following configurations has the largest angular momentum for a given R and p?



[a] [b] [c] [d] [e] all [a]-[d] are the same

(ii)

A solid disk has a mass M and radius R. What is the moment of inertia along an axis which is perpendicular to the disk and passes through its edge?



(a) MR^2 (b) $2MR^2$ (c) $MR^2/2$ (d) $(2/5)MR^2$ (e) $(3/2)MR^2$

(iii) What is the kinetic energy of a solid cylinder of mass m which rolls without slipping on a level surface with velocity v?

(a) 0 (b) $mv^2/4$ (c) $mv^2/2$ (d) $3\,mv^2/4$ (e) mv^2

(iv)

A mass m hanging from a spring of force constant k oscillates with a period T_o. If the same mass were hung from a spring with force constant $3k$, what would be its period of oscillation?

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

(v) A mass m is hung from a stiff massless rod, hinged at the top so that the rod acts like a pendulum with period T_o. If the mass is doubled, what is the new period in terms of the original period T_o?

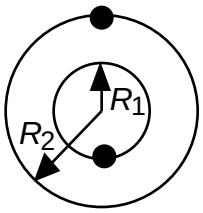
(a) $2T_o$ (b) $\sqrt{2}\,T_o$ (c) T_o (d) $T_o/\sqrt{2}$ (e) $T_o/2$

(vi) A wave travels along a string under tension at a speed v. If the mass per unit length of the string were twice as large, but the tension on the string is the same, how fast would the wave travel in terms of its original speed?

(a) $2v$ (b) $\sqrt{2}\,v$ (c) v (d) $v/\sqrt{2}$ (e) $v/2$

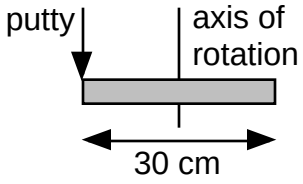
4. A galaxy in Ursa Major is 215 Mpc away, and its light shows a 5% fractional change in wavelength towards the red.
(a) Find the velocity of the galaxy relative to the Earth in km/sec.
(b) Deduce a value of the Hubble parameter from this observation.
(10 marks)

5. In a binary star system, two stars with masses m_1 and m_2 rotate about their common

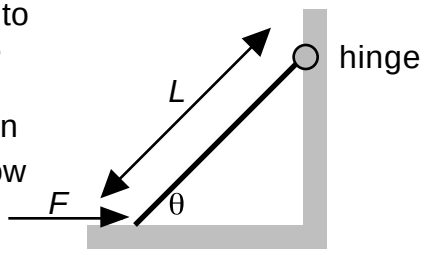


centre of mass. Assume that the orbits are circular, with radii R_1 and R_2, such that the distance $D = R_1 + R_2$ between the stars is constant.
(i) Establish that $R_1 = Gm_2T^2 / (4\pi^2D^2)$, where T is the period of the orbit.
(ii) Find the sum of the masses $m_1 + m_2$ in terms of D and T.
(14 marks)

6. A record and turntable are rotating without friction at 0.6 revolutions per second. A piece of putty is dropped onto the edge of the record, where it sticks. What is the angular speed of the turntable after the putty sticks? The mass of the putty is 0.100 kg, and the mass of the record and turntable combined is 0.500 kg. Assume that there is no motor attached to the turntable. (14 marks)



7.
A thin massless rod is attached to a wall by a hinge and rests on a frictionless floor at an angle θ with respect to the horizontal. A force F is applied horizontally to the rod at the point where it touches the floor.
(a) What is the magnitude of the total reaction force on the rod at the hinge as a function of F and θ only (show a free-body diagram; 12 marks).
(b) For a given F, what is the minimum reaction force and for what angle θ does it occur? (2 marks)



Answers:

1. (i) no change; (ii) 10^{-36} m^2; (iii) $(\sqrt{2} - 1)mc^2$; (iv) 3; (v) 16; (vi) $4H$.
2. (i) $9h$; (ii) $\sqrt{3}\ T$; (iii) 6 kg; (iv) 200; (v) $2F/3$; (vi) $v/\sqrt{2}$; (vii) $mv^2\ /4$.
3. (i) RP; (ii) $(3/2)MR^2$; (iii) $3\ mv^2/4$; (iv) $T_o/\sqrt{3}$; (v) T_o; (vi) $v\ /\sqrt{2}$.
4. (i) 1.5×10^4 km/s; (ii) 70 km / (s-Mpc).
5. (i) proof; (ii) $m_1 + m_2 = 4\pi^2 D^3 / GT^2$.
6. 2.68 rad/sec.
7. (i) $R = F/\cos\theta$; (ii) $R = F$.