PHYS 120 FINAL EXAMINATION

Date: 11 December, 1996
Time: 3 hours
Calculator and one formula sheet are permitted

Name_____
Signature_____
Student #_____

Conversion: 1 eV = 1.6×10^{-19} J

1. (10 marks) Circle one answer to each of the following five questions:

(i) Order the following reactions from slowest to fastest (Δ^{++} has quark content *uuu*)

reaction X: $\pi \rightarrow \gamma + \gamma$
reaction Y: $\Delta^{++} \rightarrow p^{+} + \pi^{+}$
reaction Z: $n \rightarrow p + e + \nu$

(a) XYZ (b) ZYX (c) YXZ (d) ZXY (e) none of [a]-[d]

(ii) An oven at a temperature of 150^{o} C resides in a kitchen with a temperature of 25^{o} C. What is the ratio of the photon number density in the oven's interior compared to the number density in the kitchen?

(a) 2.9 (b) 6^3 (c) 6^4 (d) 4.1 (e) none of [a]-[d]

(iii) Two targets have the same number density of scattering centres per unit area, but are made from different metals - zinc (**A** = 64) or aluminum (**A** = 27). What is the ratio of the scattering probability of the zinc target compared to the aluminum target for the scattering of a beam of strongly interacting particles?

(a) 1 (b) 4/3 (c) 64/27 (d) 16/9 (e) 27/64

(iv) The parallax of the star *Alpha* is θ. If the distance from Earth to the star *Beta* is twice as far as the distance from Earth to *Alpha*, what is the parallax of *Beta*?

(a) $\theta/2$ (b) 2θ (c) θ (d) 1 (e) $\theta/4$

(v) The Universe today is about 13 billion years old and has a mass density ρ. In another 13 billion years, what will be the mass density?

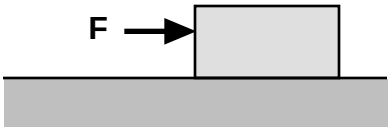
(a) 2ρ (b) $\rho / \sqrt{2}$ (c) $\rho / 2$ (d) $\sqrt{2}\,\rho$ (e) $\rho / 4$

2. (10 marks) Circle one answer to each of the following five questions:

(i) What is the cross product **A** x **B** of the vectors **A** = (1,0,1) and **B** = (-1,0,1)?

(a) (0,0,2) (b) (0,-1,0) (c) (0,2,0) (d) (0,-2,0) (e) none of [a]-[d]

(ii) The coefficients of friction between a 10 kg block and a table are μ_S = 0.8 and μ_K = 0.6. If a horizontal force **F** = 100 N is applied to the block, what is the net force that the block experiences? (Use **g** = 10 m/s^2)



(a) 20 N (b) 40 N (c) 60 N (d) 80 N (e) 100 N

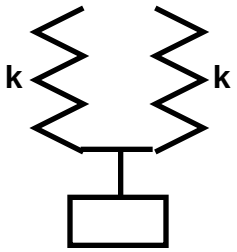
(iii) A girl is standing in an elevator traveling upwards at a constant speed **v**. She observes that it takes a time **t** for a penny to drop from her hand to the floor of the elevator. If the elevator were traveling downwards at a constant speed of 2**v**, how long would it take for the penny to drop?

(a) **t** (b) 2**t** (c) 4**t** (d) **t**/2 (e) none of [a]-[d]

(iv) Two thin coins are made from identically the same metal, but one coin has triple the diameter of the other. What is the ratio of the moment of inertia of the large coin compared to the small coin? Take the axis of rotation to be perpendicular to the coin and through its centre; assume that the coins have the same thickness.

(a) 243 (b) 81 (c) 27 (d) 9 (e) 3

(v) Two identical springs, each with force constant **k**, are attached in parallel. What is the effective force constant of the springs, taken together?



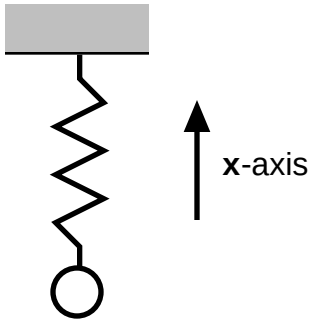
(a) 2**k** (b) 4**k** (c) **k** (d) **k**/4 (e) **k**/2

3. (10 marks) Circle one answer to each of the following five questions:

(i) Three objects, a ring (R), a solid disk (D), and a sphere (s) all have the same mass and radius. If they roll without slipping down an incline plane, what is their relative speed at any given time (list the speeds from slowest to fastest)?

(a) RDS (b) SRD (c) DSR (d) RSD (e) none of [a]-[d]

(ii) A mass hanging from a spring is pulled down from its equilibrium position through a distance **A** and then released at **t** = 0. It oscillates with a frequency **f**. What is its displacement as a function of time, **x**(**t**)?



(a) **A** sin(2π**ft**) (b) -**A** sin(2π**ft**) (c) **A** cos(2π**ft**) (d) -**A** cos(2π**ft**) (e) **A** sin(ω**t**)

(iii) Radio station CBC-am broadcasts at a frequency of about 700 x 10^3 Hz, while CBC-fm broadcasts at about 100 x 10^6 Hz. If the amplitude of the radio waves leaving the broadcast towers were the same for both stations, what would be the ratio of the power for CBC-am compared to CBC-fm?

(a) 2.0 x 10^4 (b)7 x 10^{-3} (c) 4.9 x 10^{-5} (d) 143 (e) none of [a]-[d]

(iv) An astronaut takes a simple pendulum with her on a voyage to the Moon. The acceleration due to gravity on the surface of the Moon is 1/6 of that on the Earth. What is the ratio of the frequency of the pendulum as measured on the Moon compared to the frequency on Earth?

(a) 1 (b) 6 (c) 1/6 (d) √6 (e) 1 / √6

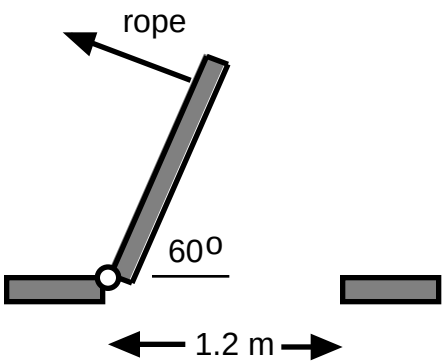
(v) When plucked, a guitar string under a tension **T** vibrates with a frequency **f**. If you wish to double the frequency at which the string vibrates, under what tension must you place the string?

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

SOLVE EACH OF THE FOLLOWING PROBLEMS. DEFINE YOUR SYMBOLS AND SHOW A COMPLETE SOLUTION

4. (12 marks) A thin rod of mass **M** and length **L** pivots around a point **L**/3 from one end of the rod.
(a) What is the moment of inertia about the pivot point?
(b) What is the frequency of oscillation if **L** = 2 m?

5. (18 marks) A trap door which is 1.2 m to the side has a mass of 25 kg. The door is attached to the floor by a hinge, and is pulled up by a rope perpendicular to the surface of the door. If the door is held at an angle of 60^o with respect to the horizontal:
(a) what is the tension **S** in the rope?
(b) what is the force on the hinge from the door and rope?
In (a) and (b), quote the magnitude of the force and direction with respect to the floor.



6. (15 marks) A mouse of mass 20 grams walks around the edge of a horizontal turntable, which may be viewed as uniform disk of mass 200 grams. If both the turntable and mouse are initially at rest, how much does the turntable move relative to the ground while the mouse makes one complete circle on the turntable?

7. (15 marks) Suppose that the potential energy experienced by a particle has the form

$$\mathbf{U}(\mathbf{x}) = \mathbf{U}_O[\,(\mathbf{x}/\mathbf{a})^4 - (\mathbf{x}/\mathbf{a})^2\,]$$

where **a** is a length scale and $\mathbf{U}_O$ is an energy scale.

(a) At what values of **x** ($-\infty < \mathbf{x} < \infty$) does the force on the particle vanish?
(b) What is the value(s) of **U** when the force vanishes?
(c) Classify each zero-force position as stable or unstable. The position is stable if the particle is always subject to a restoring force when it is displaced slightly from the position.

8. (10 marks) Emergency exit signs are sometimes powered by the decay of radioactive tritium, which has a half-life of 12.3 years and emits an electron with a kinetic energy of 0.0186 MeV. Light is emitted when the electron is captured by the surrounding plastic in the sign. Suppose that you want to construct a radioactive Christmas tree light with tritium. How many tritium atoms would you need for the light to shine with a power of 5 watts?

Answers:

1. (i) ZXY; (ii) 2.9; (iii) 16/9; (iv) $\theta/2$; (v) $\rho/4$.
2. (i) [0, -2, 0]; (ii) 40 N; (iii) t; (iv) 81; (v) $2k$.
3. (i) RDS; (ii) $-A\cos[2\pi ft]$; (iii) 4.9×10^{-5}; (iv) $1/\sqrt{6}$; (v) $4T$.
4. (i) $ML^2/9$; (ii) 0.43 s^{-1}.
5. (i) S = 61.3 N at 30° above horizontal (to left)
   (ii) F = 221 N at 76° below horizontal (to left).
6. $\theta = \pi/3$.
7. (i) $-a/\sqrt{2}$, 0, $a/\sqrt{2}$
   (ii) $-U_o/4$, 0, $-U_o/4$
   (iii) stable, unstable, stable.
8. 9.4×10^{23} atoms.