PHYSICS 120 FINAL EXAMINATION

Date: 17 April, 2000
Time: 3 hours
Calculator and one formula sheet are permitted.

Name_____
Signature_____
Student #_____

This examination has 8 questions. Please show complete solutions to questions 4-8.

Masses: Earth = 5.98×10^{24} kg Jupiter = 1.90×10^{27} kg Sun = 1.99×10^{30} kg
Distances: Earth-Sun = 1.50×10^{8} km Jupiter-Sun = 7.78×10^{8} km
radius of Earth = 6.37×10^{3} km

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

(i) Order the following decays from slowest to fastest (Δ^+ has quark content *uud*)

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

(a) XYZ (b) ZYX (c) YZX (d) XZY (e) none of [a]-[d]

(ii) Particle **A** decays at rest into two identical particles **B**. If one of the **B** particles has kinetic energy $m_A c^2 / 3$, what is its momentum?

(a) $\sqrt{10}\, m_A c / 6$ (b) $\sqrt{2}\, m_A c / 3$ (c) $m_A c / 3$ (d) $m_A c / 2$ (e) $m_A c / 6$

(iii) How many protons are there in nucleus X produced in the reaction

$^4He + {}^4He \rightarrow X + e^+ + \nu$?

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

(iv) The "third-life" is the time it takes for a sample to decay to 1/3 of its original activity (not too useful, we'll admit). What is the "third-life" in terms of the decay constant λ?

(a) $\ln 3 / \lambda$ (b) $\lambda/3$ (c) $\ln 2 / 3\lambda$ (d) $3 / \lambda$ (e) $\ln(1/3) / \lambda$

(v) What is the approximate ratio of the energy density of relic microwave radiation from the early universe (T = 3K) compared to infrared radiation at room temperature?

(a) 10^{8} (b) 10^{-2} (c) 10^{6} (d) 10^{-8} (e) 10^{-6}

2. Circle the correct answer for each of the following questions (2 marks each; no part marks):

(i) A jogger changes her speed several times during the first four minutes of her run: 50 m/min for the first 30 seconds, 70 m/min for the next 1.5 minutes, and 90 m/min for the last two minutes. What is her average speed in m/min?

(a) 70 (b) 78 (c) 80 (d) 73 (e) 75

(ii) An automobile is moving towards the east at 50 km/hr, and the wind is from the north at 50 km/hr. Which vector represents the wind velocity as observed by a passenger in the car, where the first component points to the east and the second component to the north?

[a] (50, -50) [b] (-50, 50) [c] (50, 50) [d] (100, 0) [e] (-50, -50)

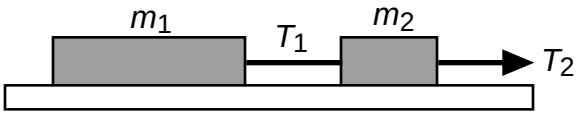
(iii) An 80 kg man on ice skates pushes a 40 kg boy, also on skates, away from him with a force of 100 N. What is the force exerted by the boy on the man?

(a) 200 N (b) 100 N (c) 50 N (d) 40 N (e) 0

(iv) The radius of the planet Xion is three times that of the Earth, although the densities of the planets are the same. What is the acceleration due to gravity on the surface of Xion?

(a) 27g (b) g (c) 3g (d) g / 3 (e) g / 9

(v) Two masses (m_1 and m_2) are connected by a massless string and accelerated uniformly on a frictionless surface, as shown. The ratio of the tensions T_1/T_2 is given by:



(a) m_1/m_2 (b) m_2/m_1 (c) $(m_1+m_2)/m_2$ (d) $m_1/(m_1+m_2)$ (e) $m_2/(m_1+m_2)$

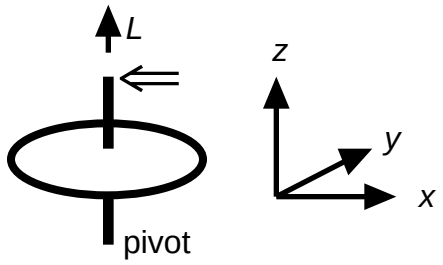
3. Circle the correct answer for each of the following questions (2 marks each; no part marks):

(i) A turntable rotates through 6 radians in 3 seconds as it accelerates uniformly from rest. What is its angular acceleration in radians per square second?

(a) 1 (b) 6 (c) 2 (d) 1/3 (e) 4/3

(ii)

A spinning bike wheel has its angular momentum vector pointing in the +*z* direction. If you press gently on the axle in the -*x* direction, as shown in the diagram, in what direction does the axle move?



(a) +x (b) -x (c) +y (d) -y (e) none of (a) - (d)

(iii) What is the moment of inertia of a thin ring of mass *M* and radius *R* if the axis of rotation is in the plane of the ring and passes through its centre?

(a) $MR^2/2$ (b) $MR^2/4$ (c) $MR^2/3$ (d) 0 (e) MR^2

(iv) A uniform thin rod of mass *m* and length 4*x* pivots about a point a distance *x* from one of its ends. What is the moment of inertia about this point?

(a) $mx^2/12$ (b) $13mx^2/12$ (c) $4mx^2/3$ (d) $7mx^2/3$ (e) mx^2

(v) The angular displacement of a bar in a torsion pendulum is $\theta(t) = 3 \cos 5t$, where *t* is in seconds. What is the magnitude of the rate of change of θ when $\theta = 1.5$ radians [*units are quoted in* s^{-1} *below*]?

(a) 7.5 (b) 3.0 (c) 13 (d) 15 (e) 5

4. It takes 120 days for a radioactive source to decay to 1/4 of its initial activity. What is the decay rate of the whole source (in Becquerels) if it contains 10^{20} radioactive nuclei?
(9 marks)

5. (a) Find the centre-of-mass position of the Earth-Jupiter-Sun system in the two configurations shown in the diagram. Choose the centre of the Sun as the coordinate system origin. The centres of the objects lie on a straight line.
(b) Comparing configurations I and II, how much does the position of the Sun change relative to the centre-of-mass of each configuration?

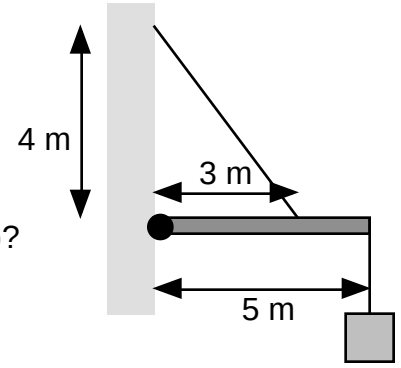
Config I	**E ------- S ------- J**
Config 2	**J ------- E -------- S**

(10 marks)

6. The Earth rotates about its axis and also revolves around the Sun.
(a) What is the angular momentum of the Earth due to its rotation about its axis?
(b) What is the angular momentum of the Earth due to its motion around the Sun?
(c) If the Earth suddenly reversed its direction of rotation, what would be the fractional change in the length of an Earth year? Assume that the force causing this reversal acts only between the Earth and the Sun.
(18 marks)

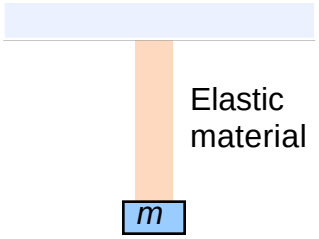
7.

One end of a uniform 50 kg beam 5 m in length is attached to a vertical wall by a hinge. It is held horizontally by a flexible cable which connects to the beam 3 m from the wall. A 200 kg weight is attached to the beam.
(a) What is the tension *T* in the cable (8 marks)?
(b) What force *F* does the hinge exert on the beam (8 marks)?



(16 marks)

8.
A strip of elastic material with mass 5.00 g has an unstretched length of 50.0 cm and a force constant of 200 N/m. The top of the elastic is hung from a fixed point and a mass *m* is hung from the bottom of the band. The band is plucked in the middle to make it vibrate.



a) What is the lowest frequency transverse vibration when $m = 2.0$ kg? By how much does this frequency change when the 2.0 kg mass is replaced by a 3.0 kg mass?
b) Does the transverse vibration have the same frequency as the longitudinal vibration?
(17 marks)

Answers:

1. (i) c, (ii) b, (iii) c, (iv) a, (v) d.
2. (i) b, (ii) e, (iii) b, (iv) c, (v) d.
3. (i) e, (ii) d, (iii) a, (iv) d, (v) c.
4. 1.34×10^{13} s^{-1}.
5. (a) 7.42×10^{5} km, -7.42×10^{5} km;
   (b) 1.48×10^{6} km.
6. (a) 7.06×10^{33} kg•m^2/s; (b) 2.69×10^{40} kg•m^2/s; (c) 5.25×10^{-7}.
7. (a) 4590 N; (b) 3010 N.
8. (a) transverse: 40.5 s^{-1} and 47.7 s^{-1}; (b) longitudinal: 1.59 s^{-1} for 2 kg mass.