Physics 123 - Analytical Physics
FINAL EXAM
Monday, December 20, 2010
Professor R.A. Bartynski

Answers

Your name sticker with **exam code. SIGN HERE:**

1. The exam will last from 4:00 p.m to 7:00 p.m. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts..
2. In the section labeled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit RUID Number.
4. Enter 123 under COURSE, and your section number (see label above) under SEC.
5. Under CODE enter the exam code given above.
6. During the exam, you may use pencils, a calculator, and two 8.5 x 11 inch sheets with formulas and notes.
7. There are 30 multiple-choice questions on the exam. For each question, mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. **At the end of the exam, hand in the answer sheet and the cover page.** Retain this question paper for future reference and study.
8. When you are asked to open the exam, make sure that your copy contains all 30 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
9. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.
10. If needed, the acceleration due to gravity on earth may be take as $g = 9.81\ m/s^2$.

1. A student throws a set of keys vertically upward to her sorority sister in a window 4.0 m above. The keys are caught 1.5 s later by the sister's outstretched hand. With what initial velocity were the keys thrown?

a) 8.94 m/s
b) 4.47 m/s
c) Cannot be determined
d) 3.33 m/s
→ e) 10.0 m/s

$y = v_0 t - \frac{1}{2} g t^2$, $y = 4.0$, $t = 1.5$

$v_0 = \frac{y + \frac{1}{2} g t^2}{t} = 10.0 \frac{m}{s}$

2. A force of 11.0 N holds a spring with a 22.0 N/m spring constant in compression. The potential energy stored in the spring is:

a) 11.0 J
→ b) 2.75 J
c) 5.50 J
d) 22.0 J
e) 5.00 J

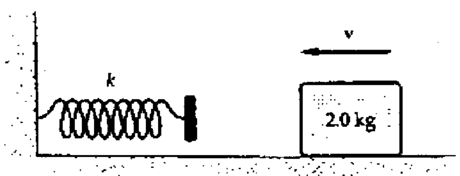
$F = kx$ where $F = 11.0\,N$, $k = 22.0 \frac{N}{m}$

$\Rightarrow x = \frac{F}{k} = 0.50\ m$

$U_{spring} = \frac{1}{2} k x^2 = 2.75\ J$

3. The horizontal surface on which the 2.0 kg block in the figure slides is frictionless. The speed of the block before it touches the spring is 6.0 m/s. How fast is the block moving at the instant the spring has been compressed 15 cm? The spring constant of the spring is 2.0 kN/m.

→ a) 3.7 m/s
b) 4.4 m/s
c) 4.9 m/s
d) 5.4 m/s
e) 14 m/s



tot E = a constant $= \frac{1}{2} m v_i^2$, $m = 2.0\ kg$, $v_i = 6.0 \frac{m}{s}$

When spring is compressed by $x = 15$ cm,

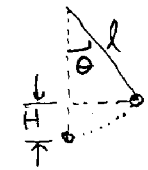
$\frac{1}{2} m v_i^2 = \frac{1}{2} m v^2 + \frac{1}{2} k x^2$ (v: velocity of block)

$v = \sqrt{\frac{m v_i^2 - k x^2}{m}} = \sqrt{\frac{2.0 \times (6.0)^2 - 2.0 \times 10^3 \times (0.15)^2}{2.0}}$

$= 3.7 \frac{m}{s}$

4. A pendulum is made by letting a 2.0 kg object swing at the end of a string of length 1.5 m. The maximum angle that the strings makes with the vertical as the pendulum swings is 30°. What is the speed of the object as it goes through the lowest point on its trajectory?

→ a) 2.0 m/s
b) 1.0 m/s
c) 3.5 m/s
d) 3.8 m/s
e) 5.4 m/s



tot E = constant.

$mgH + 0 = 0 + \frac{1}{2} m v^2$

$\Rightarrow v = \sqrt{2gH}$, $H = \ell(1 - \cos\theta)$, $\ell = 1.50\ m$, $\theta = 30°$

$v = 2.0 \frac{m}{s}$

5. Which one of the following statements is correct for an object released from rest at a height of 2.3 m?

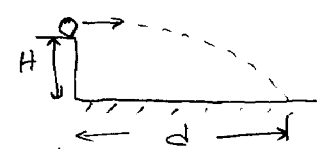
→ a) the average velocity during the first second is 4.9 m/s
b) during each second the object falls 9.8 m ($v \neq$ constant)
c) the acceleration changes by 9.8 m/s every second ($a = g$ — constant)
d) the object falls ~~9.8 m~~ 4.9 m during the first second of time
e) the acceleration of the object is proportional to its weight ($a = g$ independent of w)

$\bar{v} = \frac{x_f - x_i}{\Delta t} = \frac{4.9 - 0}{1}$

6. Identical guns fire identical bullets horizontally at the same speed from the same height above level planes, one on the earth and one on the moon. Which of the following three statements is/are true?

- I. The horizontal distance traveled by the bullet is greater for the moon.
- II. The flight time is less for the bullet on the earth.
- III. The velocity of the bullets at impact are the same.

a) III only
→ b) I and II only
c) I and III only
d) II and III only
e) I, II, III



$H = \frac{1}{2} a t^2 \Rightarrow t = \sqrt{\frac{2H}{a}}$

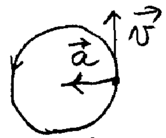
$d = v_0 t$

$t_{moon} > t_e$

$v_{impact} = \sqrt{v_0^2 + (at)^2}$ → depends on a

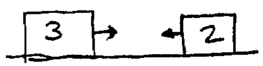
7. A particle moves at constant speed in a circular path. The instantaneous velocity and instantaneous acceleration vectors are:

a) both tangent to the circular path
b) both perpendicular to the circular path
→ c) perpendicular to each other
d) opposite to each other
e) none of the above



$\vec{a}$ points towards center of circle.

8. A 3.0-kg and a 2.0-kg cart approach each other on a horizontal air track in such a way that their center of mass has a speed of 4.0 m/s. They collide and stick together. After the collision their total kinetic energy is:



a) 16 J
b) 2.0 J
c) 24 J
→ d) 40 J
e) can't tell from the given data

$\vec{P}_i = (m_1 + m_2)\vec{v}_{cm}$

$P_f = P_i$

$K.E. = \frac{P^2}{2M} = \frac{(m_1+m_2)^2 v_{CM}^2}{2(m_1+m_2)}$

$= \frac{5 \times (4.0)^2}{2} = 40 \text{ J}$

9. You and a friend are sitting opposite each other at a large circular table in a restaurant. Your friend is in need of a packet of sugar. On the center of the table is a circular rotating tray (a Lazy Susan) that is 2.0 m in diameter and its surface has a coefficient of static friction $\mu_s = 0.25$. You place a packet of sugar on the edge of the rotating tray and then, starting from rest, give it a constant acceleration, α, such that the sugar packet overcomes the force of static friction and flies off the tray just when it reaches your friend. The angular acceleration, α,(in rad/s^2) that you have given the tray is:

→ a) 0.39
b) 9.8
c) 2.5
d) 0.20
e) 1.3

When static frictional force and centripetal acceleration match,

$m\mu_s g = m\frac{v^2}{R} = m\omega^2 R$

$\omega = \sqrt{\frac{\mu_s g}{R}}$

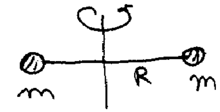
But $\omega = \alpha t$ and $\theta = \frac{1}{2}\alpha t^2 = \pi$

$\Rightarrow t = \sqrt{\frac{2\pi}{\alpha}}$

$\Rightarrow \sqrt{\frac{\mu_s g}{R}} = \sqrt{2\pi\alpha} \Rightarrow \alpha = \frac{\mu_s g}{2\pi R} = 0.39$

10. A dumbbell consists of two 15-kg masses on a rod of negligible mass and length 0.50 m. The moment of inertia for rotation of the dumbbell around an axis perpendicular to the rod, passing through the center of mass, is

→ a) 1.9 kg m^2
b) 7.5 kg m^2
c) 1.75 kg m^2
d) 0.94 kg m^2
e) 3.75 kg m^2



$2R = 0.50 \text{ m}$

$I = 2 \times m R^2$

$= 2 \times 15 \times (0.25)^2$

$= 1.9 \text{ kg m}^2$

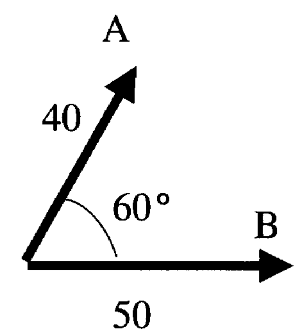
11. A car of mass m_1 traveling at velocity v passes a car of mass m_2 parked at the side of the road. The momentum of the system of two cars is

a) 0.
→ b) $m_1 v$.
c) $(m_1 - m_2)v$.
d) $\frac{m_1 v}{m_1 + m_2}$
e) $(m_1 + m_2)v$.

tot $P = P_1 + P_2 = m_1 v + m_2 \cdot 0$

$= m_1 v$

12. Vectors $\vec{A}$ and $\vec{B}$ with their magnitudes are shown. What is the magnitude of a vector $\vec{C}$, if $\vec{C} = \vec{A} - \vec{B}$?



→ a) 46
b) 10
c) 30
d) 78
e) 90

$\vec{C} = (40\cos 60° \hat{i} + 40 \sin 60° \hat{j})$

$- 50 \hat{i}$

$= -30 \hat{i} + 35 \hat{j}$

$|\vec{C}| = \sqrt{30^2 + 35^2} = 46$

13. A bicycle wheel, a hollow sphere, and a solid sphere each has the same mass and radius. They are all rolling straight on a flat horizontal surface without slipping such that the total kinetic energies are all equal. Which has the greatest magnitude of angular velocity and which has the least?

$I_{sphere} < I_{hollow} < I_{bicycle\ wheel}$

a) The wheel has the greatest; the solid sphere has the least.
b) The wheel has the greatest; the hollow sphere has the least.
c) They all have the same magnitude of angular velocity.
→ d) The solid sphere has the greatest; the wheel has the least.
e) The solid sphere has the greatest; the hollow sphere has the least.

$K.E. = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{m}{R^2} + I\right)\omega^2$

$\Rightarrow \omega^2 = 2K.E./\left(\frac{m}{R^2} + I\right)$

14. A 20-g bullet is fired into a 2.0-kg block of wood placed on a horizontal surface. The bullet stops in the block. The impact moves the block (+ bullet) a distance of 5.0 m before it comes to rest. If the coefficient of kinetic friction between the block and surface is 0.25, calculate the speed of the block (+ bullet) system immediately after impact.

a) 20 m/s
b) 3.5 m/s
c) 25 m/s
→ d) 5.0 m/s
e) 2.2 m/s

$p = (m+M)v$

$\frac{p^2}{2(m+M)} = f \cdot d \qquad f = \mu_k (m+M)g \qquad d = 5.0$

$v = \frac{2f \cdot d}{m+M} = \frac{2 \times 0.25 \times 2.02 \times 9.8}{2.02} = 5.0\ \frac{m}{s}$

15. The speed of a 4.0-kg object is given by $v = (2t)$ m/s^2, where t is in s. At what rate is the resultant force on this object doing work at $t = 1$ s?

a) 48 W
b) 40 W
c) 32 W
d) 56 W
→ e) 16 W

$\text{Power} = F \cdot v$

$= (ma) \cdot v, \quad a = \frac{dv}{dt} = 2$

$= 4.0 \times 2 \times 2$

$= 16$ W.

16. A boy launches a rock straight up with an elastic slingshot by pulling it a certain distance x from the unstretched position. The rock reaches a maximum height h above the point of launch, where h is much greater than x. If the boy then launches the same rock by stretching the slingshot by $2x$, the maximum height will be nearest

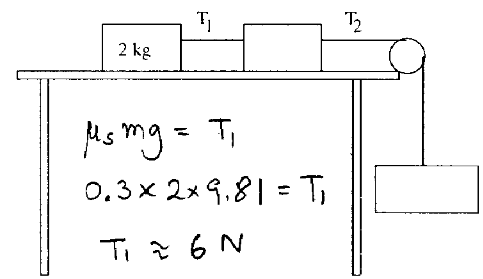
a) h
b) $\sqrt{2}h$
c) $2h$
→ d) $4h$
e) (need mass of rock, spring constant of slingshot)

$mgh = \frac{1}{2}kx^2$

$x \to 2x$

$mgh \to 4\left(\frac{1}{2}kx^2\right)$

17. If the coefficient of friction between the blocks and table shown in the figure is 0.3, and the system is moving with constant velocity, the tension T_1 is



a) need to know the other masses
b) 2 N
c) 4 N
→ d) 6 N
e) 8 N

$\mu_s mg = T_1$

$0.3 \times 2 \times 9.81 = T_1$

$T_1 \approx 6$ N

18. The turntable of a record player has an angular velocity of 8.0 rad/s at the moment when it is turned off. The turntable comes to rest 2.5 s after being turned off. Through how many radians does the turntable rotate after being turned off? Assume constant angular acceleration.

a) 12 rad
b) 8.0 rad
→ c) 10 rad
d) 16 rad
e) 6.8 rad

$\omega = \omega_0 + \alpha t$

$0 = 8.0 + \alpha \times 2.5 \Rightarrow \alpha = -3.2\ \frac{rad}{s^2}$

$\theta = \frac{1}{2}\alpha t^2 = -\frac{1}{2}(3.2) \times (2.5)^2$

$= 10$ rad

19. For a particle moving under the influence of a conservative force, which of the following is **false**?

a) The net work done by the force on the particle is zero if it follows a closed path.

b) The work done on the particle in moving from one point to another is always positive.

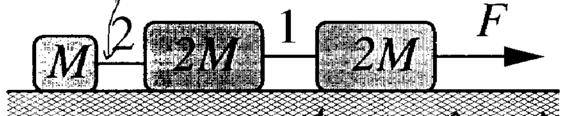
c) The magnitude of the change in kinetic energy of the particle is equal to the magnitude of the change in potential energy of the particle.

d) It is possible for the force to do no work on the particle during its motion.

e) The work done on the particle in moving from one point to another can be positive or negative (or zero).

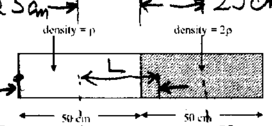
20. The horizontal surface on which the objects slide is frictionless. If M = 2.0 kg, the tension in string 1 is 12 N. Determine F.

a) 25 N
b) 20 N
c) 12 N
d) 35 N
e) 24 N



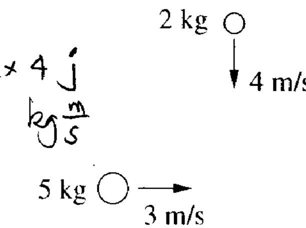
21. The left 50 cm of a meter stick is made of a uniform plastic of density ρ. The other 50 cm is made of a uniform plastic of density 2ρ. If the origin of the meter stick is at the left end, how far is the center of mass of the meter stick from the origin?

a) 33 cm
b) 50 cm
c) 58 cm
d) 42 cm
e) none of these.



22. A mass of 2.0 kg is moving south with a speed of 4.0 m/s while a mass of 5.0 kg is moving east at 3.0 m/s. They collide at the origin and stick together. What is the magnitude of the momentum of the combined mass (in kg m/s)?

a) 11
b) 13
c) 17
d) 19
e) 20



23. A 2.0-kg mass is projected vertically upward from ground level with an initial speed of 30 m/s. The mass rises to a maximum height of 35 m above ground level. How much work is done on the mass by air resistance between the point of projection and the point of maximum height?

a) −0.21 kJ
b) +0.21 kJ
c) −0.42 kJ
d) +0.42 kJ
e) −0.69 kJ

24. A baseball outfielder throws a baseball of mass 0.15 kg at a speed of 40 m/s and initial angle of 30° above horizontal. What is the kinetic energy of the baseball at the highest point of the trajectory?

a) 6.0 J
b) 240 J
c) 90 J
d) 5.25 J
e) 120 J

25. A 12-g bullet is fired into a 3.0-kg ballistic pendulum initially at rest and becomes embedded in it. The pendulum subsequently rises a vertical distance of 12 cm. What was the initial speed of the bullet?

→ a) 0.38 km/s
b) 0.44 km/s
c) 0.50 km/s
d) 0.54 km/s
e) 0.024 km/s

$mv = (m+M)V$

$V = \left(\frac{m}{m+M}\right)v, \quad \frac{1}{2}(m+M)V^2 = (m+M)gH$

$\frac{1}{2}\left(\frac{m}{m+M}\right)^2 v^2 = gH \Rightarrow v = \frac{\sqrt{2gH}(m+M)}{m} = 385\ \frac{m}{s}$

26. An escalator is 30 m long and slants at an angle of 30° relative to the horizontal. If it moves at 1.0 m/s, at what rate does it do work in lifting a 50 kg man from the bottom to the top of the escalator?

a) 49 W
b) 98 W
c) 294 W
d) 490 W
→ e) 245 W

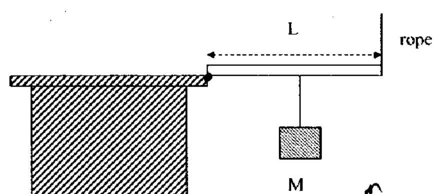
$P = \frac{dW}{dt} = mg\frac{dh}{dt} = mgv\sin\theta$

$= 50 \times 9.81 \times 1.0 \sin 30°$

$\simeq 245\ J/s$

27. A block of mass M is hanging from the middle of a horizontal bar of length L as shown in the figure. One end of the bar is held on the edge of a desk and the other end is held up by a rope vertically. What is the magnitude of the torque exerted by the rope about the edge of the desk? Assume that the mass of the bar is negligible.

a) MgL
b) 2MgL
→ c) MgL/2
d) MgL/4
e) The answer depends on the length of the rope.



net $\tau = 0$

$\tau_1 = \tau_2$

$Mg \cdot \frac{L}{2} = \tau_2$

28. A torque of 42 Nm gives a large wheel an angular acceleration of 0.78 rad/s^2. What is the moment of inertia in units of (kg m^2) of the wheel?

a) 32 b) 12 c) 5.1 d) 54 ↑ e) 0.98

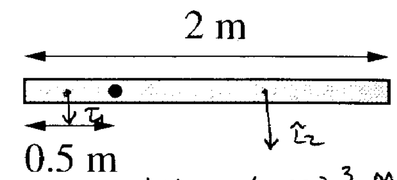
$\tau = I\alpha$

$42 = I \cdot 0.78$

$I = 54\ kg\ m^2$

29. A uniform rod of length 2.0 m is mounted so as to rotate freely about a horizontal axis that is perpendicular to the rod and that passes through the rod at a point 0.5 m from one end. If this rod is released from rest in the horizontal position, what is the initial magnitude of angular acceleration of the rod? The moment of inertia of a uniform rod of mass M and length L about its center of mass is $\frac{1}{12}ML^2$. Note, though, that the pivot point is not at the center of mass.

→ a) 8.4 rad/s^2
b) 7.4 rad/s^2
c) 4.9 rad/s^2
d) 6.4 rad/s^2
e) 3.1 rad/s^2



$\tau = I\alpha \quad \tau = \tau_2 - \tau_1 = -(0.25)\frac{1}{4}Mg + (0.75)\frac{3}{4}Mg = 0.5Mg$

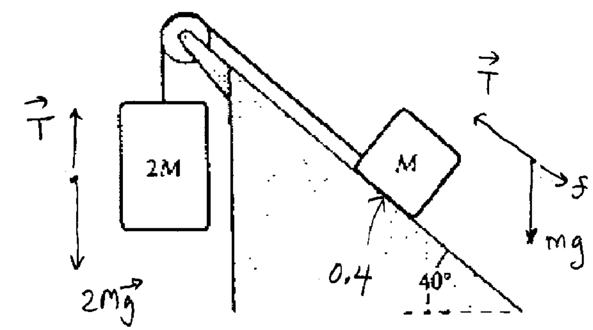
By parallel axis theorem:

$I = I_{cm} + Md^2 = \frac{1}{12}ML^2 + M\frac{L^2}{16} = .58M, \quad d = \frac{L}{4}$

$\alpha = \frac{\tau}{I} = \frac{0.5Mg}{0.58M} = 8.4\ \frac{rad}{s}$

30. In the figure shown, the coefficient of kinetic friction between the block of mass M and the incline is 0.40. What is the magnitude of the acceleration of the suspended block (of mass 2M) as it falls? Disregard the mass of the pulley and any friction in the pulley.

→ a) 3.4 m/s^2
b) 4.7 m/s^2
c) 4.2 m/s^2
d) 3.9 m/s^2
e) 5.4 m/s^2



2M: $2Mg - T = 2Ma \Rightarrow T = 2M(g-a)$

$T - \mu Mg\cos\theta - Mg\sin\theta = Ma$

$2M(g-a) - Mg(\mu\cos\theta + \sin\theta) = Ma$

$2g - g(\mu\cos\theta + \sin\theta) = 3a$

$a = \frac{g}{3}[2 - (\mu\cos\theta + \sin\theta)]$, with $\cos\theta = 0.77$, $\sin\theta = 0.64$

$= 3.4\ m/s^2$