

PHYS 151 SPRING 2006

Final Exam Cover Sheet

Exam time limit: 120 minutes.

You may use a calculator and both sides of TWO sheets of notes, *handwritten only*.

Closed book; no collaboration.

Complete *ALL* questions.

For all multiple-choice questions, choose the ONE best answer. There is no penalty for guessing.

Ignore friction/air resistance in all problems, unless told otherwise.

On your BUBBLE SHEETS, complete:

- **NAME (last name first)**
- **ROSTER NUMBER for "IDENTIFICATION NUMBER"**

... that's all. No other info is needed.

Final Exam, Part A

Exam time limit: 120 minutes. You may use calculators and both sides of 2 sheets of notes, handwritten only. Closed book; no collaboration. For all multiple-choice questions, choose the ONE best answer. There is no penalty for guessing.

Physical constants:

$$g = 9.81 \text{ m/s}^2$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$G = 6.673 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$$

$$k_B = 1.38 \times 10^{-23} \text{ J/K}$$

$$R = 0.0821 \text{ L}\cdot\text{atm}/(\text{mol}\cdot\text{K}) = 8.315 \text{ J}/(\text{mol}\cdot\text{K})$$

Useful conversions:

$$1 \text{ year} = 3.156 \times 10^7 \text{ s}$$

$$1 \text{ cal} = 4.186 \text{ J}$$

$$1 \text{ m}^3 = 1000 \text{ L}$$

$$0 \text{ }^\circ\text{C} = 273.15 \text{ K}$$

$$1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$$

masses

$$M_{\text{Sun}} = 1.99 \times 10^{30} \text{ kg}$$

$$M_{\text{Earth}} = 5.97 \times 10^{24} \text{ kg}$$

$$M_{\text{Moon}} = 7.35 \times 10^{22} \text{ kg}$$

radii

$$R_{\text{Sun}} = 6.96 \times 10^8 \text{ m}$$

$$R_{\text{Earth}} = 6.38 \times 10^6 \text{ m}$$

$$R_{\text{Moon}} = 1.74 \times 10^6 \text{ m}$$

orbital distances

$$r_{\text{Earth-Sun}} = 1.50 \times 10^{11} \text{ m}$$

$$r_{\text{Earth-Moon}} = 3.84 \times 10^8 \text{ m}$$

orbital periods

$$T_{\text{Earth}} = 1.00 \text{ year}$$

$$T_{\text{Moon}} = 27.4 \text{ days}$$

(2 pts. each) **Convert** the following quantities into the specified units:

- $3.8 \times 10^5 \text{ km} =$ _____ μm
A. $3.8 \times 10^{-10} \mu\text{m}$ D. $3.8 \times 10^{14} \mu\text{m}$
B. $3.8 \times 10^{-7} \mu\text{m}$ E. $3.8 \times 10^{17} \mu\text{m}$
C. $3.8 \times 10^{11} \mu\text{m}$
- $90. \text{ atm} =$ _____ kPa
A. 0.91 kPa D. 910 kPa
B. 9.1 kPa E. 9100 kPa
C. 91 kPa
- $22.4 \text{ L} =$ _____ cm^3
A. 224 cm^3 D. $224,000 \text{ cm}^3$
B. 2240 cm^3 E. $2,240,000 \text{ cm}^3$
C. $22,400 \text{ cm}^3$
- $3.3 \text{ g}\cdot\text{cm}^2 =$ _____ $\text{kg}\cdot\text{m}^2$
A. $3.3 \times 10^{-7} \text{ kg}\cdot\text{m}^2$ D. $33 \text{ kg}\cdot\text{m}^2$
B. $3.3 \times 10^{-3} \text{ kg}\cdot\text{m}^2$ E. $3.3 \times 10^7 \text{ kg}\cdot\text{m}^2$
C. $0.33 \text{ kg}\cdot\text{m}^2$

5. (1 pt.) If an object's *kinetic energy doubles* (without changing its mass), its **velocity** must have increased by a factor of:

- A. 1.5 D. $2\sqrt{2}$
B. $\sqrt{2}$ E. 4
C. 2

During the “Hustle Up the Hyatt” race in Waikiki, contestants run up the stairs from the ground floor to the roof of the Hyatt hotel: a net rise of 140 meters (41 floors).

6. (2 pts.) If the winner’s mass is 62 kg, how much total **work** did he perform in raising his body 140 meters?

- A. 580 J
- B. 5.0 kJ
- C. 15 kJ
- D. 51 kJ
- E. 85 kJ

7. (2 pts.) If the winner’s time was 3 minutes and 18 seconds, what was his average **power** output?

- A. 13 W
- B. 54 W
- C. 120 W
- D. 430 W
- E. 2.3 kW

Two identical masses of 10. kg are both moving to the right on a frictionless horizontal track: mass *A* at 6.0 m/s, which gradually gains on mass *B* at 2.0 m/s. Eventually the two collide and *stick together*.

8. (2 pts.) The pair of masses will have a **final velocity** of:

- A. 1.5 m/s
- B. 2.0 m/s
- C. 3.0 m/s
- D. 3.5 m/s
- E. 4.0 m/s

9. (1 pt.) The above collision is:

- A. **elastic**
- B. **inelastic**

10. (2 pts.) If the **net torque** on a rigid object is *greater than zero*, the result will be:

- A. changing angular velocity
- B. constant angular momentum
- C. zero angular acceleration
- D. constant angular displacement
- E. increasing moment of inertia

11. (2 pts.) You want to hang three masses along a 100-cm-long rod so that the rod balances exactly at its center. A 400-gram mass is located at one end ($x = 0.0$ cm), and a 600-gram mass is located 10 cm from the other end ($x = 90$. cm). **Where** should you position the final 800-gram mass? (Neglect the mass of the rod itself.)

- A. $x = 40$. cm
- B. $x = 42$ cm
- C. $x = 45$ cm
- D. $x = 55$ cm
- E. $x = 60$. cm

12. (2 pts.) What is the **acceleration due to gravity** (i.e., the local value of g) at the Moon's distance from the center of the Earth? (Use values as needed from the list of astronomical data at the start of the exam.)

- A. 0.0027 m/s^2
- B. 0.0084 m/s^2
- C. 0.067 m/s^2
- D. 0.35 m/s^2
- E. 1.1 m/s^2

13. (1 pt.) Assuming that the Moon orbits in uniform circular motion, which **one** of the following is **TRUE** for the Moon? (a_{cp} = centripetal acceleration; α = angular acceleration)

- A. $a_{\text{cp}} = 0$ and $\alpha = 0$
- B. $a_{\text{cp}} = 0$ but $\alpha > 0$
- C. $a_{\text{cp}} > 0$ but $\alpha = 0$
- D. $a_{\text{cp}} > 0$ and $\alpha > 0$

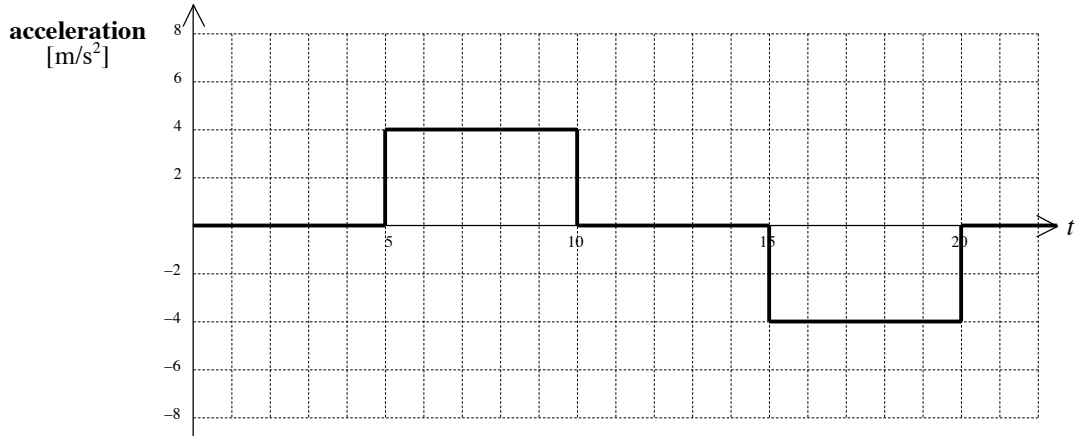
14. (2 pts.) Which **one** of the following statements about the Moon's orbit is **TRUE**?

- A. The shape of the Moon's orbit is in fact a perfect circle, but the Earth is located off-center.
- B. The Moon moves slowest along its orbit when closest to Earth, and fastest when farthest from Earth.
- C. If the Moon were 10% farther from Earth, it would still orbit Earth with the same period.
- D. If the Moon were 10% more massive than it is now, it would still orbit Earth with the same period.
- E. Too many Moon questions make you a lunatic.

15. (2 pts.) *This one might require some extra thought:* The orbital radius of the Moon is slowly drifting farther and farther from the Earth, over millions of years. (The reasons for this are too complicated to discuss here... but it's true!) Assume for simplicity that the Moon's orbit remains circular, but that the radius of the orbit slowly grows over time. As this happens, which **one or more** of the following quantities slowly **increase(s)**?

- A. The Moon's orbital moment of inertia
- B. The Moon's orbital period
- C. The Moon's orbital angular momentum
- D. both A & B
- E. A, B, & C

The **acceleration** of an elevator during a 24-second interval is shown in the following graph (taking the $+y$ -direction to be *upward*):



Suppose that a student in the elevator has a mass of 60.0 kg. She is standing on a bathroom scale (recall that bathroom scales read the *normal force* of the floor on the person).

16. (2 pts.) What **scale reading** would the student observe during the time interval $t = 0$ to 5 s?

- A. 0 N
- B. 60.0 N
- C. 240. N
- D. 300. N
- E. 589 N

17. (2 pts.) What **scale reading** would the student observe during the time interval $t = 5$ to 10 s?

- A. 240. N
- B. 300. N
- C. 349 N
- D. 589 N
- E. 829 N

18. (2 pts.) What **scale reading** would the student observe during the time interval $t = 15$ to 20 s?

- A. 240. N
- B. 300. N
- C. 349 N
- D. 589 N
- E. 829 N

Suppose that the elevator started at rest at time $t = 0$.

19. (2 pts.) What is the student's **velocity** at $t = 8.0$ s?

- A. 4.0 m/s
- B. 4.9 m/s
- C. 6.9 m/s
- D. 12 m/s
- E. 14 m/s

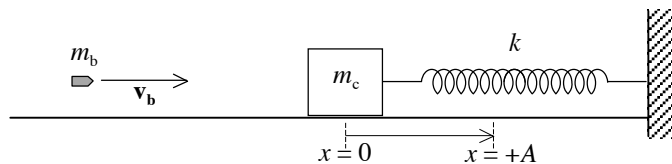
20. (2 pts.) What is the student's **velocity** at $t = 20.0$ s?

- A. 0 m/s
- B. -20.0 m/s
- C. -40.0 m/s
- D. 20.0 m/s
- E. 40.0 m/s

Suppose also that the elevator started at position $y = 0$ at time $t = 0$.

21. (2 pts.) What is the student's **position** at $t = 8.0$ s?

- A. 8.0 m
- B. 18 m
- C. 28 m
- D. 38 m
- E. 48 m



A bullet of mass m_b and initial velocity v_b strikes and becomes lodged in a large wooden cube of mass m_c . The wooden cube is initially at rest, on a level frictionless surface, and attached to a massless ideal spring (constant = k).

22. (2 pts.) While the bullet collides with the cube...

- A. The *force* felt by the cube is equal in magnitude to the force felt by the bullet.
- B. The *impulse* received by the cube is equal in magnitude to the impulse received by the bullet.
- C. The *acceleration* of the cube is equal in magnitude to the acceleration of the bullet.
- D. both A & B
- E. A, B, & C

23. (2 pts.) What is the **velocity** v' of the cube+bullet immediately *after* collision?

- A. $\frac{m_b}{m_c} v_b$
- B. $\frac{m_c}{m_b} v_b$
- C. $\sqrt{\frac{m_c}{m_b}} v_b$
- D. $\frac{m_b + m_c}{m_b} v_b$
- E. $\frac{m_b}{m_b + m_c} v_b$

24. (2 pts.) After impact, what is the **maximum compression** A of the spring by the cube+bullet (in terms of v')?

- A. $\sqrt{\frac{m_b + m_c}{k}} v'$
- B. $\frac{m_b + m_c}{k} v'$
- C. $\left(\frac{m_b + m_c}{k}\right)^2 v'$
- D. $\sqrt{\frac{k}{m_b + m_c}} v'$
- E. $\frac{k}{m_b + m_c} v'$

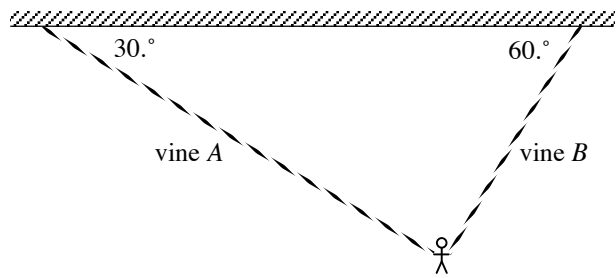
25. (2 pts.) What is the **period** of the resulting oscillations of the spring?

- A. $2\pi\sqrt{\frac{m_b + m_c}{k}}$
- B. $2\pi\frac{m_b + m_c}{k}$
- C. $2\pi\left(\frac{m_b + m_c}{k}\right)^2$
- D. $2\pi\sqrt{\frac{k}{m_b + m_c}}$
- E. $2\pi\frac{k}{m_b + m_c}$

26. (2 pts.) On the diagram above, the $+x$ -direction is to the right. As the spring oscillates, the cube's **acceleration** has its **largest negative value** at the same time as which one of the following occurs?

- A. $x = +A$
- B. $x = 0$
- C. $x = -A$
- D. $v = +v_{\max}$
- E. $v = -v_{\max}$

A 6.0-kg monkey hangs at rest simultaneously from two vines, A and B. Each of the vines has negligible mass.



27. (2 pts.) What is the **tension** in vine A?

- A. 20. N D. 51 N
 B. 29 N E. 59 N
 C. 39 N

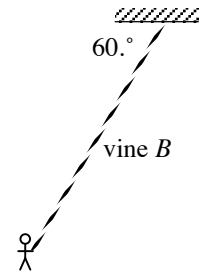
28. (2 pts.) What is the **tension** in vine B?

- A. 20. N D. 51 N
 B. 29 N E. 59 N
 C. 39 N

The monkey now releases vine A and swings back-and-forth on vine B, which is 5.0 meters long. Neglect air resistance.

29. (2 pts.) What is the monkey's maximum **speed** as it passes through the lowest point of its swing? (Note that the vine starts at an initial angular displacement as shown at right.) *Hint: Use trig & conservation of energy.*

- A. 3.6 m/s D. 4.8 m/s
 B. 4.0 m/s E. 5.2 m/s
 C. 4.4 m/s



30. (2 pts.) What is the **period** of the monkey's swings?

- A. 1.1 s D. 5.8 s
 B. 3.2 s E. 6.9 s
 C. 4.5 s

31. (1 pt.) At a moment that vine B is *exactly vertical* during one of its swings, the **tension** in the vine is:

- A. zero C. equal to the monkey's weight
 B. less than the monkey's weight D. greater than the monkey's weight

(1 pt. each) Suppose that Mowgli, a young man whose mass is 60. kg (much larger than the monkey), had been hanging from the same vines at the start of this problem instead of the monkey.

32. Mowgli's **tensions** in both vines while hanging at rest would be...

- A. less than the monkey's B. the same as the monkey's C. greater than the monkey's

33. Mowgli's **speed at the bottom of the swing** would be...

- A. less than the monkey's B. the same as the monkey's C. greater than the monkey's

34. Mowgli's **period** while swinging would be...

- A. shorter than the monkey's B. the same as the monkey's C. longer than the monkey's

35. The **height** that Mowgli reaches at the right-hand extreme of each swing would be...

- A. higher than the monkey's B. the same as the monkey's C. lower than the monkey's

36. (1 pt.) Suppose that **air resistance** actually is present as the vine swings back and forth. Mowgli finds that his swings gradually exhibit...

- A. decreasing amplitude and shortening period D. unchanging amplitude and shortening period
 B. decreasing amplitude and unchanging period E. unchanging amplitude and lengthening period
 C. decreasing amplitude and lengthening period

37. (2 pts.) Which one **weighs** the most? (*Recall:* $1 \text{ m}^3 = 1000 \text{ L}$ and $\rho_{\text{water}} = 1000 \text{ kg/m}^3$)
- A. 1 newton of water
 - B. 100 grams of water
 - C. 1 liter of water
 - D. 100 cm^3 of water

38. (1 pt.) An unknown quantity of oil is added to an unknown quantity of water in a container. If the oil is seen to **float** on top of the water, we can deduce that the oil has...
- A. less weight than the water
 - B. less mass than the water
 - C. lower density than water
 - D. less volume than the water
 - E. lower temperature than the water

A small submarine is used for a dive to the ocean floor. Assume that the density of seawater is 1025 kg/m^3 , regardless of pressure. At the submarine's present depth, the water pressure is 350. atm.

39. (2 pts.) What is the **depth** of the submarine?
- A. 352 m
 - B. 705 m
 - C. 1.06 km
 - D. 3.52 km
 - E. 5.70 km

40. (2 pts.) If the submarine's total surface area is 15.0 m^2 , what is the **total force** of the seawater on the outside of the submarine? (Assume that the ocean pressure is essentially uniform over the submarine's entire surface.)
- A. $3.52 \times 10^4 \text{ N}$
 - B. $5.23 \times 10^5 \text{ N}$
 - C. $2.53 \times 10^6 \text{ N}$
 - D. $3.25 \times 10^7 \text{ N}$
 - E. $5.32 \times 10^8 \text{ N}$

(1 pt. each) For each of the following 4 descriptions, choose the name of the most closely related **phenomenon**:

41. A police officer uses a "radar gun" to aim radio waves at an oncoming car. The reflected waves have a higher frequency than the original waves, and the frequency shift depends on the car's speed.

42. Two musical instruments play pitches that differ by only a few hertz. You hear both pitches, but the total sound oscillates between loud and soft several times each second. As one of the musicians tunes his instrument to match the other's pitch, this loud-soft oscillation slows down and eventually stops.

43. As a boat is lowered into the water, it will stop when it has displaced an amount of water whose weight is equal to the weight of the boat.

44. As wind blows past the outside of a house, the fast-moving air has lower pressure, while the stationary air inside the house has higher pressure. This helps to draw air up and out of chimneys and stovepipes, but also causes rooftops to fly off during windstorms.

- A. Archimedes' Principle
- B. Beats
- C. Bernoulli's Principle
- D. Doppler Effect
- E. Pascal's Principle

You play the lowest note on a piano, and you hear a 25-Hz sound.

45. (2 pts.) If the speed of sound in air is 340 m/s, what is the **wavelength** of the sound waves you hear?

- A. 2.9 mm
- B. 4.0 cm
- C. 7.4 cm
- D. 85 cm
- E. 14 m

46. (2 pts.) The vibrating string inside the piano is 1.5 m long and is fixed at both ends. If its fundamental mode oscillates at 25 Hz, what is the **speed** of the waves along this particular string?

- A. 0.67 m/s
- B. 8.3 m/s
- C. 17 m/s
- D. 38 m/s
- E. 75 m/s

47. (2 pts.) The **frequency** of the string's 4th overtone is:

- A. 5.0 Hz
- B. 20. Hz
- C. 31 Hz
- D. 75 Hz
- E. 125 Hz

48. (2 pts.) Increasing the **tension** in the string will...

- A. increase the speed of waves along the string
- B. increase the frequency of the fundamental mode
- C. increase the wavelength of the fundamental mode
- D. both A & B
- E. A, B, & C

49. (1 pts.) The standing wave modes *on the string* are:

- A. **longitudinal** oscillations
- B. **transverse** oscillations

A flute can be approximated as a simple tube with one closed end and one open end. Blowing very gently into the flute excites the fundamental mode; blowing harder excites the 1st overtone; still harder excites the 2nd overtone; etc.

50. (1 pt.) *All* of the flute's modes of oscillation must have:

- A. a node at each end
- B. an antinode at each end
- C. a node at the closed end, and an antinode at the open end
- D. a node at the open end, and an antinode at the closed end
- E. none of the above patterns is true for *all* modes

51. (2 pts.) The flute is 33.0 centimeters long, and the speed of sound in air is 340. m/s. What is the **frequency** of the flute's 1st overtone?

- A. 103 Hz
- B. 309 Hz
- C. 430. Hz
- D. 568 Hz
- E. 773 Hz

52. (2 pts.) The amount of **heat** needed to raise the temperature of exactly 100 mL of water by exactly 10 °C is:

($c_{\text{water}} = 4186 \text{ J}/(\text{kg}\cdot^{\circ}\text{C})$; $\rho_{\text{water}} = 1000. \text{ kg}/\text{m}^3$)

- A. 4.186 J
- B. 41.86 J
- C. 418.6 J
- D. 4.186 kJ
- E. 41.86 kJ

(1 pt. each) The phase diagram of an unknown substance is shown at right:

53. This substance *cannot* exist as liquid at 0.75 atm.

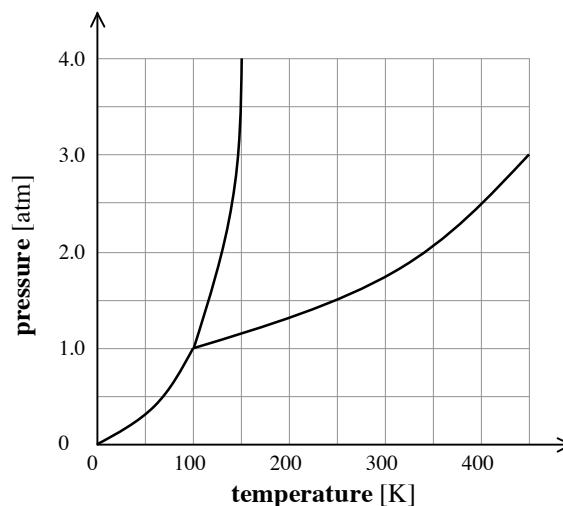
- A. **True**
- B. **False**

54. This substance is solid at 75 K at *all* pressures.

- A. **True**
- B. **False**

55. The boiling point at 2.0 atm pressure is 125 K.

- A. **True**
- B. **False**



An ideal gas in a sealed, rigid (constant volume) container starts at a temperature of 33 °C and a pressure of 1.0 atm.

56. (2 pts.) If the gas is heated until its pressure increases to 2.5 atm, its new **temperature** is:

- A. 68 °C
- B. 180 °C
- C. 300 °C
- D. 340 °C
- E. 490 °C

(1 pt. each) During the thermodynamic process described above, ...

57. ... the gas did **NO work** on its surroundings/container.

- A. **True**
- B. **False**

58. ... the **internal energy** (U) of the gas increased.

- A. **True**
- B. **False**

59. ... the process was **adiabatic**.

- A. **True**
- B. **False**

A heat engine takes in 120. J of energy every second, but expels 85.0 J of it as waste heat every second.

60. (2 pts.) What is the engine's **efficiency**?

- A. 29.2%
- B. 44.2%
- C. 53.8%
- D. 68.3%
- E. 73.8%

61. (2 pts.) If the same engine draws its input heat from a reservoir at 575 °C, what is its **exhaust temperature**?

- A. 172 °C
- B. 226 °C
- C. 328 °C
- D. 410. °C
- E. 661 °C