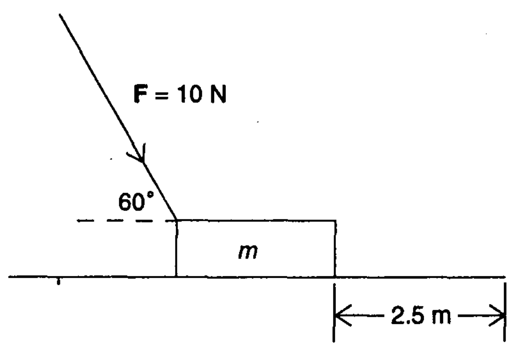
Practice Test 2

SECTION I: MULTIPLE-CHOICE

Time: 90 minutes
50 questions

DIRECTIONS: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one (or two where indicated) that is best in each case. You have 90 minutes to complete this portion of the test. You may use a calculator and the information sheets provided in the appendix.



1. A block ($m = 1.5$ kg) is pushed along a frictionless surface for a distance of 2.5 meters, as shown above. How much work has been done if a force of 10 newtons makes an angle of 60 degrees with the horizontal?

   (A) Zero
   (B) 12.5 J
   (C) 21.6 J
   (D) 25 J

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2. What is the instantaneous power due to the gravitational force acting on a 3-kilogram projectile the instant the projectile is traveling with a velocity of 10 meters per second at an angle of 30 degrees above the horizontal?

(A) 300 W
(B) 150 W
(C) –150 W
(D) –300 W

3. A hockey puck of an unknown mass is sliding along ice that can be considered frictionless with a velocity of 10 meters per second. The puck then crosses over onto a rough floor that has a coefficient of kinetic friction equal to 0.2. How far will the puck travel before friction stops it?

(A) 2.5 m
(B) 5 m
(C) 25 m
(D) Depends on the mass

4. A dart is placed onto a spring. The spring is stretched a distance x. By what factor must the spring's elongation be changed so that the maximum kinetic energy given to the dart is doubled?

(A) 1/2
(B) 2
(C) 4
(D) $\sqrt{2}$

QUESTIONS 5 AND 6 ARE BASED ON THE FOLLOWING INFORMATION:

A 10-kilogram projectile is launched at a 60° angle to the ground with a velocity of 200 m/s. Neglect air resistance.

5. Compare this projectile with a 5-kilogram projectile launched under the same conditions but at a 30° angle. The 5-kilogram projectile will

(A) go higher up and farther along the ground
(B) go equally high and equally far along the ground
(C) neither go as high nor as far along the ground
(D) not go as high but go equally far along the ground

6. As the launch angle is lowered to 45°, the maximum horizontal distance traveled by the projectile will

(A) decrease only
(B) increase only
(C) increase and then decrease
(D) decrease and then increase

7. An object of mass m rests on top of a spring that has been compressed by x meters. The force constant for this spring is k. The mass is not attached to the spring and will shoot upward when the spring is uncompressed. When released, how high will the mass rise?

(A) $mg - kx$
(B) kx^2/mg
(C) $(kx^2/2mg) - x$
(D) $(k/m)^{1/2}x$

8. Which of the following is the best method for finding a spring's force constant k?

(A) Hanging a known mass on the spring and dividing the weight by the length of spring
(B) Hanging several known masses on the spring, taking the average value of the mass, and dividing by the average length of the spring
(C) Hanging several known masses on the spring and finding the area under the curve after plotting force versus extension
(D) Hanging several known masses on the spring and finding the slope of the graph after plotting force versus extension

9. How much of a braking force is applied to a 2,500-kilogram car on the moon ($g = 1.6\ m/s^2$) that has an initial velocity of 30 meters per second if the car is brought to a stop in 15 seconds?

(A) 5,000 N
(B) 6,000 N
(C) 8,000 N
(D) 25,000 N

10. A 1-kilogram object is moving to the right with a velocity of 6 meters per second. It collides with and sticks to a 2-kilogram mass, which is also moving to the right, with a velocity of 3 meters per second. What happens to the total kinetic energy during this collision?

(A) The kinetic energy is conserved because the collision is elastic.
(B) The kinetic energy is conserved even though the collision is not elastic.
(C) Some kinetic energy is lost during the collision even though total momentum is conserved.
(D) Some kinetic energy is lost during the collision because of the elastic nature of the collision.

11. A ball with a mass of 0.2 kilogram strikes a wall with a velocity of 3 meters per second. It bounces straight back with a velocity of 1 meter per second. What was the magnitude of the impulse delivered to this ball?

(A) 0.2 kg · m/s
(B) 0.4 kg · m/s
(C) 0.6 kg · m/s
(D) 0.8 kg · m/s

12. Which of the following is an equivalent expression for the maximum velocity attained by a mass m oscillating horizontally along a frictionless surface? The mass is attached to a spring with a force constant k and has an amplitude of A.

(A) Ak/m
(B) $A(k/m)^{½}$
(C) mg/kA
(D) $A2k/m$

13. A 0.5-kilogram mass is attached to a spring with a force constant of 50 newtons per meter. What is the total energy stored in the mass-spring system if the mass travels a distance of 8 cm in one cycle?

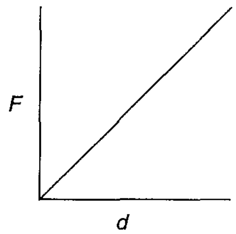
(A) 0.5 J
(B) 0.01 J
(C) 0.04 J
(D) 0.08 J

14. Which of the following expressions is equivalent to the magnitude of the escape velocity in terms of the magnitude of the orbital velocity v for a spacecraft?

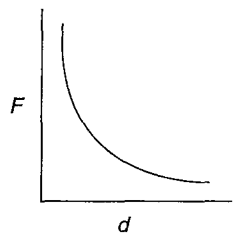
(A) $2v$
(B) v
(C) $4v$
(D) $\sqrt{2}v$

15. Which of the following graphs correctly shows the relationship between magnitude of gravitational force and distance between two masses?

(A)



(B)



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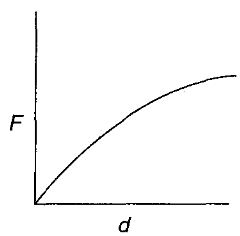
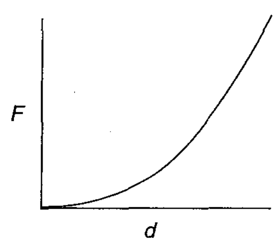


(D)



16. Standing wave nodes in a string occur every 20 cm. If the velocity of the incident waves is equal to 5 m/s and the length of the string is 80 cm, what is the frequency of the waves equal to?

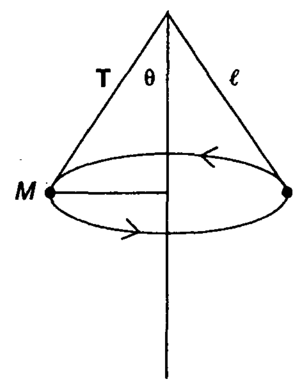
(A) 25 Hz
(B) 6.25 Hz
(C) 12.5 Hz
(D) 3.125 Hz

17. Is it possible to make two wires of equal electrical resistance if one is made out of a much more conductive material?

(A) No. The more conductive material will always have a lower resistance.
(B) No. The less conductive material will always require a greater voltage to produce an equal current.
(C) Yes. The less conductive wire must be made with a larger cross-sectional area.
(D) Yes. The more conductive wire must be shorter.

18. A projectile is launched at a 30° angle to the ground with a velocity of 200 m/s. What is its speed at its maximum height?

(A) 9.8 m/s
(B) 100 m/s
(C) 173 m/s
(D) 200 m/s



19. A conical pendulum consists of a mass m attached to a light string of length L. The mass swings around in a horizontal circle, making an angle θ with the vertical as shown above. What is the magnitude of tension, T, in the string?

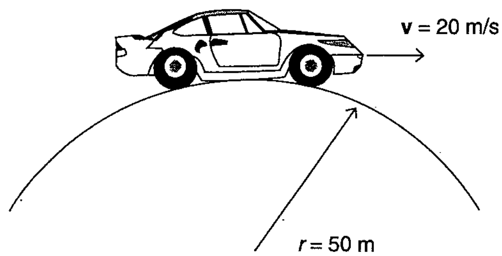
(A) $mg/\cos\theta$
(B) $mg\cos\theta$
(C) $mg/\sin\theta$
(D) $mg\sin\theta$

20. The magnitude of the one-dimensional momentum of a 2-kilogram particle obeys the relationship $p = 2t + 3$. What was the velocity of the particle at $t = 1$ second?

(A) 5 m/s
(B) 2 m/s
(C) 1 m/s
(D) 2.5 m/s

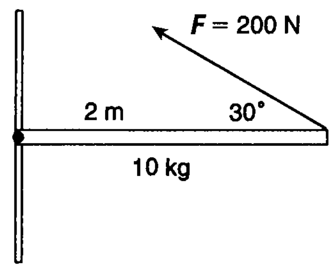
21. An object is experiencing a nonzero net force. Which of the following statements is most accurate?

(A) The linear and angular momentums of the object are both definitely changing.
(B) Although the linear momentum of the object is definitely changing, the angular momentum may not be.
(C) Although the angular momentum of the object is definitely changing, the linear momentum may not be.
(D) Neither the linear momentum nor the angular momentum is definitely changing.



22. A car with a 500-newton driver goes over a hill that has a radius of 50 meters as shown above. The velocity of the car is 20 meters per second. What are the approximate force and the direction that the car exerts on the driver?

(A) 900 N, up
(B) 400 N, down
(C) 100 N, up
(D) 500 N, up



23. What is the net torque acting on the pivot supporting a 10-kilogram beam 2 meters long as shown above?

(A) 198 N · m
(B) −198 N · m
(C) −102 N · m
(D) 102 N · m

24. A trumpet player notices a string on a harp is beginning to vibrate when he plays a certain note on his trumpet. What is this an example of?

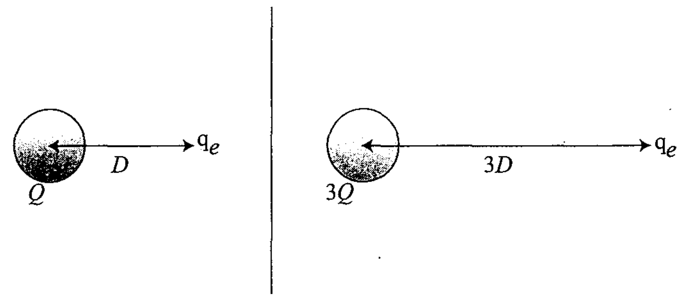
(A) Constructive interference
(B) Destructive interference
(C) Refraction
(D) Resonance

25. What is the ratio of the equivalent resistance of 2 resistors R in series to the same 2 resistors in parallel?

(A) 0.5
(B) 1
(C) 2
(D) 4

26. A 12-volt battery is advertised as a "40 amp hour" battery. The manufacturer is expressing that the battery has a capacity of

(A) 144,000 C
(B) 144,000 J
(C) 1,728,000 J
(D) 1,728,000 W



27. Compare the force experienced by an electron in the two situations shown above. In the situation on the left, the electron is a distance D from a positive charge Q. In the situation on the right, the electron is 3 times farther ($3D$) from 3 times as much positive charge ($3Q$) as in the scenario on the left. The force of electrical attraction in the scenario on the right will

(A) remain the same as the situation on the left
(B) be 3 times stronger than the situation on the left
(C) be 3 times weaker than the situation on the left
(D) be 9 times weaker than the situation on the left

28. An old record player could bring a disk up to its 45 RPM speed in less than a second. If the same size disk can also be brought up to a speed of 75 RPM in about the same amount of time on another player, compare the two torques.

(A) The torques would be the same as the moment of inertia of the two disks are the same.
(B) The torques would be the same because of the conservation of angular momentum.
(C) The torque would be larger in the second case as it requires a greater angular acceleration.
(D) The torque would be larger in the second case as it entails both a larger force and a larger lever arm.

QUESTIONS 29–31 REFER TO THE FOLLOWING INFORMATION:

Two small, identical metal spheres are projected at the same time from the same height by two identical spring guns. Each gun provides the same push on its sphere. However, one sphere is projected vertically upward while the other sphere is projected horizontally. The speed of each projectile as it emerges from the gun is the same. Frictional losses are negligible.

29. How does the speed of the vertically launched sphere compare to the speed of the horizontally launched sphere as they each hit the floor?

(A) It is the same.
(B) It is twice as great.
(C) It is greater but not necessarily twice as great.
(D) It is less.

30. How does the time required for the vertically projected sphere to hit the floor compare with that for the horizontally projected sphere?

(A) It is the same.
(B) It is twice as great.
(C) It is greater but not necessarily twice as great.
(D) It is less.

31. How does the work done by gravity to the vertically launched sphere compare to the work done by gravity to the horizontally launched sphere?

(A) It is the same.
(B) It is twice as great.
(C) It is greater but not necessarily twice as great.
(D) It is less.

QUESTIONS 32 AND 33 REFER TO THE FOLLOWING INFORMATION:

A racing car is speeding around a flat, circular track whose radius is 250 m. The car's speed is a constant 50 m/s, and the car has a mass of 2,000 kg.

32. The centripetal force necessary to keep the car in its circular path is provided by

(A) the engine
(B) the brakes
(C) friction
(D) the steering wheel

33. The magnitude of the car's centripetal force is equal to

(A) 10 N
(B) 400 N
(C) 4,000 N
(D) 20,000 N

QUESTIONS 34 AND 35 REFER TO THE FOLLOWING INFORMATION:

Two small masses, *X* and *Y*, are *d* meters apart. The mass of *X* is 4 times as great as the mass of *Y*. Mass *X* attracts mass *Y* with a gravitational force of 16 N.

34. The force with which *Y* attracts *X* is equal to

(A) 4 N
(B) 16 N
(C) 32 N
(D) 64 N

35. If the distance between X and Y is doubled, then X will attract Y with a force of

(A) 4 N
(B) 8 N
(C) 16 N
(D) 32 N

36. A projectile is launched at an angle such that it undergoes projectile motion. In the absence of any air resistance, which of the following statements is correct?

(A) The horizontal velocity increases during the flight.
(B) The horizontal velocity remains constant during the flight.
(C) The horizontal velocity decreases during the flight.
(D) The vertical acceleration changes during the flight.

37. Which of the following charges is NOT possible?

(A) 4.8×10^{-19} C
(B) 4.8×10^{-18} C
(C) 4.8×10^{-20} C
(D) -4.8×10^{-19} C

38. The sound of a moving siren from the west of you that is traveling toward you is transmitted through the air to your ear and is

(A) vibrating in a north-south direction
(B) vibrating in a west-east direction
(C) vibrating up and down
(D) vibrating in a corkscrew fashion

39. The sound of a moving siren from the west of you that is traveling toward you is transmitted through the air to your ear and is

(A) moving faster than the usual speed of sound
(B) heard at a lower frequency than usual
(C) heard at a higher frequency than usual
(D) heard at a lower amplitude than usual

40. A woman standing on a scale in an elevator notices that the scale reads her true weight. From this, she may conclude that

(A) the elevator must be at rest
(B) the elevator must be accelerating precisely at 9.8 m/s^2
(C) the elevator must be moving upward
(D) the elevator must not be accelerating

41. A planet has half the mass of Earth and half the radius. Compared with the acceleration due to gravity at the surface of Earth, the acceleration due to gravity at the surface of this planet is

(A) the same
(B) halved
(C) doubled
(D) quadrupled

42. Complete the analogy.

Force is to torque as _______ is to moment of inertia.

(A) momentum
(B) angular momentum
(C) angular acceleration
(D) mass

43. While standing on a moving train, you are suddenly thrown forward as the train stops. This effect can be best explained using Newton's law of

(A) inertia
(B) acceleration
(C) action and reaction
(D) universal gravity

44. For a falling object to reach terminal velocity (a constant downward speed), the magnitude of the force due to air friction must be

(A) negligible
(B) less than mg
(C) equal to mg
(D) greater than mg

45. An object is in free fall for T seconds. Compare its change in velocity during the first $T/2$ seconds with its change in velocity during the final $T/2$ seconds.

(A) They are the same.
(B) They are larger during the first interval.
(C) They are smaller during the first interval by a factor of ½.
(D) They are less than ½ as small during the first interval.

46. Which of the following must be zero if an object is spinning at a constant rate? Select two answers.

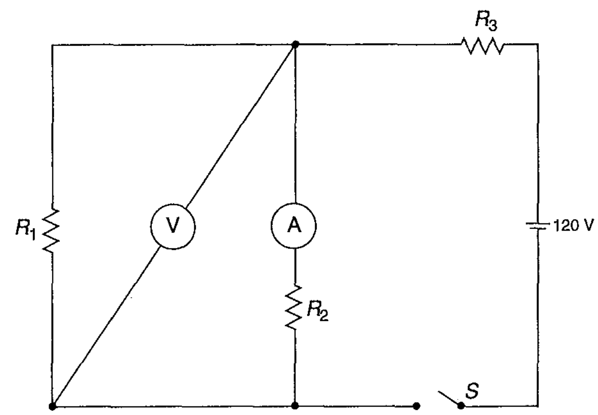
(A) Net torque
(B) Moment of inertia
(C) Angular momentum
(D) Angular acceleration

47. Which of the following could be used to calculate the time in flight for a horizontally launched projectile on Earth? Ignore friction. Select two answers.

(A) The launch speed
(B) The final vertical velocity
(C) The final horizontal velocity
(D) The initial height

48. As an ice skater draws her arms inward during a spin, which of the following remain constant? Select two answers.
   (A) Her moment of inertia
   (B) Her angular momentum
   (C) Her angular velocity
   (D) Her center of mass

49. A total of three forces, each with a magnitude of 5 N, are exerted on an object with a mass of 15 kg. Which of the following statements are true? Select two answers.
   (A) The object may be accelerating at 1 m/s^2.
   (B) The object might not be accelerating.
   (C) The object might be accelerating at 2 m/s^2.
   (D) The sum of the components of the object's acceleration must add up to the magnitude of its acceleration ($a_x + a_y = |\mathbf{a}|$).



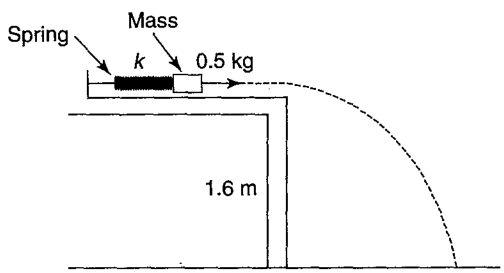
50. In the circuit above, with the switch closed, what will voltmeter V read? (A is an ammeter.) Select two answers.
   (A) The voltage drop across R_1
   (B) The voltage drop across ammeter A
   (C) The voltage drop across R_2
   (D) Zero

SECTION II: FREE-RESPONSE

Time: 90 minutes
5 questions

DIRECTIONS: You have 90 minutes to complete this portion of the test. You may use a calculator and the information sheets provided in the appendix.

1. A group of students have been asked to determine the spring constant k of the following setup. They have a known mass and a very smooth tabletop. The only additional equipment they have is metersticks and rulers.



(a) Describe an experimental procedure to determine the spring constant k. You may wish to label the diagram above further to help in your description. Indicate what measurements you would take and how you would take them. Include enough detail so that another student could carry out your procedure.

(b) What are the expected results of the experiment? Determine your independent and dependent variables. Sketch out the expected graph. Derive the relationship you would expect to find.

(c) What common sources of error in your procedure might happen during this investigation? What steps could you take to minimize these errors?

(d) A group of students collected the following data; x is for the spring and D is along the ground. The students found a discontinuity in the behavior of the graph. Graph the data and determine a value for k. Offer a possible explanation for the discontinuity.

x (cm)	D (m)
1	0.21
2	0.41
3	0.59
4	0.8
5	0.99
6	1.19
7	1.22
8	1.28
9	1.34
10	1.46

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2. An elevator ride consists of the following portions.

   a. Initially, the elevator is on the ground floor and quickly speeds up in the upward direction on its way to the top floor.
   b. Most of the trip upward is at a constant velocity.
   c. Suddenly, near the top floor, the elevator comes to a stop just in time for the top floor.
   d. Now the button for the first floor is pressed, and the elevator speeds downward suddenly.
   e. Most of the trip downward is spent at constant velocity.
   f. Suddenly, at the very bottom, the elevator comes to a stop.

   (a) Draw a qualitative free-body diagram (showing the relative vector sizes) for each portion of the elevator ride as experienced by a passenger. Next to each, describe how the person would feel (normal, heavier than usual, lighter than usual, etc.).
   (b) Explain the difference among the passenger's mass, gravitational weight, and apparent weight throughout the trip. When (if ever) are these the same, and when (if ever) are they different? Which quantities change during the trip, and which ones do not?
   (c) Describe what would happen if, on the way up (during step (b)), the cables were to break. Ignore any frictional effect between the elevator itself and the elevator shaft. Be sure to include a discussion of the relative motion of the elevator car and the passenger. Your answer should include a discussion or sketch of the height above ground, the velocity, and the acceleration experienced by the passenger from the time of the break until the end of the motion.
   (d) Sketch the expected behavior of the person's height as a function of time for situation (c) above. Also sketch the person's V_y as a function of time as well.

3. A long-distance, unmanned probe is sent to another planet. To keep it oriented correctly, the probe is given a lot of spin during the early part of the trip. However, when the probe is getting close to its destination, the spin is no longer desired. Two very long cables with mass at the end of each are extended while the probe is still in deep space. Once extended, the cables are released and the probe begins its landing sequence.
   (a) Explain qualitatively why the spinning will help the probe oriented correctly. Describe the underlying physics concepts using equations and diagrams as needed.
   (b) Explain what is accomplished by the action of extending and releasing the cables near the end of the probe's flight. Describe the underlying physics concepts using equations and diagrams as needed. Do the masses need to be a significant portion of the probe's mass for this procedure to be effective?
   (c) What happens to all of the probe's linear momentum when it lands on its destination planet? Describe qualitatively in terms of physics principles what happens during the landing.

4. Two cars are separated by 25 meters. Both are initially at rest. Then the car in front begins to accelerate uniformly at x meters per second squared. The second car, which is behind, begins to accelerate uniformly at y meters per second squared.
   (a) If the second car must catch up with the car in front within 10 seconds, what type of relationship must exist between y and x? Is there a maximum or minimum difference between the two accelerations? Explain using words and equations.
   (b) Given that the conditions in question (a) are being met (that is, the second car will catch up to the first within 10 seconds), is there any instant in time that the cars will have the same velocity? Will there be any interval of time over which both cars will have the same average velocity? Support your answers with graphs.
   (c) Given that the conditions in question (a) are being met (i.e., the second car will catch up to the first within 10 seconds) and that both cars are continuing to drive with constant velocity for an additional 10 seconds at their instantaneous speeds at the moment the second car has caught up with the first, which car will be ahead and by how much by the end of the trip? Answer this question qualitatively and algebraically. Specially determine the minimum and maximum differences in displacement if they can be found.
   (d) If both cars are on track to meet the conditions in question (a) (that is, the second car will catch up to the first within 10 seconds) but both cars are stopped after traveling 50 meters, which one will have expended the most energy? Assume both cars are identical in mass and fuel efficiency. Choose one of the following options, and justify your choice:
   _____ The first car expended more energy.
   _____ Both cars expended equal energy.
   _____ The second car expended more energy.
   _____ Which car expended more energy requires more knowledge of when exactly the second car catches up to the first car.

5. (a) A fellow student argues that you cannot use the formula $\frac{1}{2}gt^2$ to find the height of a very tall cliff (200 meters or so) when dropping a stone from the top and counting the seconds until impact at the bottom. He says that because of Newton's law of universal gravity, the acceleration is not constant during the fall. Using equations and calculations, both support and refute his argument. Would his argument have had greater, lesser, or the same power to persuade you if he was talking about a cliff on the Moon? Why or why not?

(b) Two masses, M and $9M$, are separated by a distance of d. At what distance and in what direction from the smaller mass should a third mass be placed such that the net gravitational force on this third mass is zero? There are two solutions. Find both.

ANSWER KEY

1. **B**	14. **D**	27. **C**	40. **D**
2. **C**	15. **B**	28. **C**	41. **C**
3. **C**	16. **C**	29. **A**	42. **D**
4. **D**	17. **C**	30. **C**	43. **A**
5. **D**	18. **C**	31. **A**	44. **C**
6. **B**	19. **A**	32. **C**	45. **A**
7. **C**	20. **D**	33. **D**	46. **A, D**
8. **D**	21. **B**	34. **B**	47. **B, D**
9. **A**	22. **C**	35. **A**	48. **B, D**
10. **C**	23. **C**	36. **B**	49. **A, B**
11. **D**	24. **D**	37. **C**	50. **A, C**
12. **B**	25. **D**	38. **B**	
13. **B**	26. **C**	39. **C**	

ANSWERS EXPLAINED

Section I: Multiple-Choice

1. **(B)** Work $= fd\cos 60° = (10\text{ N})(2.5)(0.5) = 12.5\text{ J}$

2. **(C)**

$$\text{Power} = \text{work/time} = (fd\cos 120°)/T = (mg\cos 120°)(D/T)$$
$$= (3)(10)(-0.5)(10\text{ m/s}) = -150\text{ W}$$

3. **(C)**

$$W = \Delta\text{KE}$$
$$\mu ND\cos 180° = 0 - \frac{1}{2}mv^2$$
$$(\mu mgD)(-1) = -\frac{1}{2}mv^2$$
$$D = v^2/2\mu g = 100/(2\times 0.2\times 10) = 25\text{ m}$$

4. **(D)** Conservation of energy:

$$\text{KE} = \text{EPE} = \frac{1}{2}kx^2$$

Since we need x^2 to double, increase x by $(2)^{1/2} = \sqrt{2}$.

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5. **(D)** The 30° and 60° angles will have equal ranges but with the roles of V_x and V_y reversed. Therefore, the projectile launched at a 30° angle will not go as high. Note that mass does not enter into projectile motion problems.

6. **(B)** 45° gives the maximum range for a projectile as it is splitting the initial velocity evenly between vertical (giving you time in flight) and horizontal (giving you speed downrange). Angles above or below will have shorter ranges. Approaching the 45° angle will increase the range:

$$\text{Range} = (v_0^2/R)\sin 2q$$

7. **(C)**

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

$h = kx^2/2mg$ above the starting point. Since the release point is a distance x above the starting point, we must subtract x from the answer.

8. **(D)** $F = kx$. So when graphing f versus x, k will be the slope. The extension of the spring is x when F is the force applied to the spring.

9. **(A)**

$$\mathbf{F}\Delta t = \Delta\mathbf{p}$$

$$(\mathbf{F})(15\text{ s}) = 0 - (2{,}500)(30) = -75{,}000\text{ kg}\cdot\text{m/s}$$

$$\mathbf{F} = -5{,}000\text{ N}$$

The negative sign indicates an opposing force. Note that weight is not needed in this calculation, so the value of g is irrelevant.

10. **(C)** Momentum is always conserved. However, kinetic energy is lost unless the collision is elastic, in which case the kinetic energy is also conserved:

$$\mathbf{p}_i = 1(+6) + 2(+3) = 12\text{ kg m/s} = \mathbf{p}_f = 3\mathbf{v}_f$$

$$\mathbf{v}_f = 4\text{ m/s}$$

Initial KE:

$$\left(\frac{1}{2}\right)(1)(6)^2 + \left(\frac{1}{2}\right)(2)(3)^2 = 27\text{ J}$$

Final KE:

$$\left(\frac{1}{2}\right)(3)(4)^2 = 24\text{ J}$$

3 joules are lost.

AP PHYSICS 1—TEST 2

11. **(D)** Impulse = $\Delta \mathbf{p} = \mathbf{p}_f - \mathbf{p}_i = 0.2(-1) - (0.2)(3) = -0.8$ kg · m/s

12. **(B)**

$$\frac{1}{2}kA^2 = \text{total energy when } x = A \text{ (all PE, no KE)}$$

$$\frac{1}{2}mv_{\max}{}^2 = \text{total energy when } x = 0 \text{ (all KE, no PE)}$$

Conservation of energy:

$$\frac{1}{2}kA^2 = \frac{1}{2}mv_{\max}{}^2$$

$$v_{\max} = (k/m)^{1/2}A$$

13. **(B)** In one cycle, the mass travels 4 amplitudes:

$$A = 0.02 \text{ m}$$

$$\text{Energy} = \frac{1}{2}kA^2 = \frac{1}{2}(50)(0.02)^2 = 0.01 \text{ J}$$

14. **(D)** Orbital velocity:

$$F_g = \text{centripetal force} = mv^2/R$$

$$GMm/R^2 = mv^2/R$$

$$v = (GM/R)^{1/2}$$

Escape velocity:

$$E_{\text{total}} > 0$$

$$\text{KE} + \text{PE} > 0$$

$$\frac{1}{2}mv^2 - GMm/R > 0 \text{ (using universal gravitational PE)}$$

$$v > (2GM/R)^{1/2}$$

15. **(B)** The gravitational force between two masses has a $1/R^2$ relationship (where R is the distance from center to center). Graph B shows the correct inverse relationship.

16. **(C)** Since node to node is half a wavelength:

$$\lambda = 0.4 \text{ m}$$

$$f = v/\lambda = 5/0.4 = 12.5 \text{ Hz}$$

17. **(C)** Resistivity is only part of the resistance of a wire:

$$R = \rho L / A$$

Therefore, a less conductive material (lower ρ) can be made equal in resistance to a more conductive material by making the less conductive material shorter and/or fatter (lower L or larger A).

18. **(C)** At maximum height, all speed is from V_x:

$$V_x = 200\cos 30° = 173 \text{ m/s}$$

19. **(A)** Vertical forces must cancel:

$$T\cos\theta - mg = 0$$

$$T = mg/\cos\theta$$

20. **(D)** $\mathbf{v} = \mathbf{p}/m = (2 \times 1 + 3)/2 = 2.5$ m/s

21. **(B)** Since $\mathbf{F}\Delta t = \Delta\mathbf{p}$, a net force will change the linear momentum. However, torque also involves the lever arm ($\tau = RF\sin\theta$). So despite having a nonzero net force, the net torque might still be zero.

22. **(C)** Circular motion:

$$F_{\text{net}} = mv^2/R$$

$$mg - N = mv^2/R$$

N is the force the car exerts on the driver:

$$mg - mv^2/R = (500 - 50)(20^2)/50 = 500 - 400 = 100 \text{ N}$$

Note that the correct answer can be found by simply knowing that the net force must be down and that the car must be pushing upward on the passenger.

23. **(C)** Take the center of mass to be 1 meter from the pivot:

$$\text{Net torque} = +mg(1)\sin 90° - 200(2)\sin 30°$$
$$= 98 - 200 = -102 \text{ N}\cdot\text{m}$$

24. **(D)** Resonance is the sympathetic vibration of an object when impacted by a wave with the same frequency as its own fundamental frequency of oscillation.

25. **(D)**

$$\text{Resistors in series} = 2R$$

$$\text{Resistors in parallel} = R/2$$

$$\text{Difference} = 1.5R$$

$$\text{Ratio} = 2R/(R/2) = 4$$

26. **(C)** Batteries store energy, which is measured in joules:

$$\text{Energy} = \text{power} \times \text{time} = I \times V \times \text{time} = (40\text{ A})(12\text{ V})(3{,}600\text{ s})$$
$$= 1{,}728{,}000\text{ J}$$

27. **(C)** Coulomb's law is kQ_1Q_2/R^2. Tripling Q_1 triples the force. Tripling R makes the force 9 times weaker. Net effect:

$$3 \times 1/9 = 1/3$$

28. **(C)**

$$\text{Torque} = I\alpha$$

$$\alpha = \text{angular acceleration} = \Delta\omega \,/\, \Delta t$$

Our only data provided are that the angular acceleration must be larger for the 75 RPM record and that the moment of inertia has not changed (same disk). Therefore, the torque supplied must be larger.

29. **(A)** Remember conservation of energy. Since both start at the same height (same PE) with the same kinetic energy, they will both hit the ground with same joules of energy (all KE). The same KE means the same speed since their masses are the same. Note that this does not imply that both components of velocity are the same. They are not. This implies that only the magnitudes of the final velocity vectors are the same.

30. **(C)** The vertically projected sphere will spend much more time in the air as it goes much higher. Without knowing the exact speed of the launch, it is not possible to say by what factor the time in flight is extended.

31. **(A)** The change in gravitational potential energy is the same for both. Therefore the work done by gravity is the same.

32. **(C)** Friction is the only force that is directed inward toward the center of the circle. By definition, all centripetal forces must be directed inward. To confirm this, imagine the path the car would take on a firictionless stretch of track.

33. **(D)** $mv^2/r = (2{,}000 \times 50^2)/250 = 20{,}000$ N

34. **(B)** Remember Newton's third law. The forces are equal and opposite.

35. **(A)** Universal gravity is a $1/R^2$ law. Doubling R makes the force 4 times weaker.

36. **(B)** No horizontal acceleration means no change in horizontal velocity.

37. **(C)** Charge is quantized (comes in integer multiples only) in units of $\pm 1.6 \times 10^{-19}$ C.

38. **(B)** Sound is a longitudinal wave.

39. **(C)** The Doppler shift of waves that occurs when the source and receiver are moving toward each other causes a shorter wavelength and hence a higher frequency.

40. **(D)** The elevator must be traveling at constant velocity to insure the normal force (reading on the scale) is the same as her true weight. However, this velocity value can be any number: positive, zero, or negative.

41. **(C)** Remember that $g = Gm/R^2$. Half the mass means half the g. Half the R means $4 \times g$. Collect the changes:

$$\frac{1}{2} \times 4 = 2$$

42. **(D)** Forces cause mass to accelerate linearly. Torques cause moments of inertia to acceleration angularly.

43. **(A)** Inertia is the tendency of an object to continue its motion in the absence of other forces. As the train stops, the passengers continue forward until a force is brought to bear directly on them.

44. **(C)** Constant velocity means no acceleration. No acceleration means no net force. The friction opposing weight must be equal in magnitude to that weight.

45. **(A)** Constant acceleration means precisely that. For the same time interval, the change in velocity will be the same.

46. **(A) and (D)** Constant angular velocity means zero angular acceleration, which means no net torque.

47. **(B) and (D)** Since the vertical velocity is zero, only height is needed to determine the drop time:

$$H = \frac{1}{2}gt^2$$

Knowing the final vertical velocity would also allow one to determine the time since:

$$V_{yf} = 0 - gt$$

48. **(B) and (D)** The skater's center of mass must remain above her skates. Since no external torques are involved in drawing her arms inward, her momentum is conserved. Note that her moment of inertia decreases and her angular velocity increases.

49. **(A) and (B)** If the 3 forces are in the same direction, $F_{net} = 15$ N, which is the maximum possible force. In this situation, the acceleration is 1 m/s^2. If the 3 forces are 120° apart from each other in direction, they would add up to zero and produce no acceleration.

50. **(A) and (C)** Both R_1 and R_2 are connected in parallel to the same two points that the voltmeter is measuring the potential difference between. Therefore, the voltmeter reading is that same voltage drop for both R_1 and R_2. Note that an ideal ammeter has no resistance and thus experiences no voltage drop itself.

Section II: Free-Response

1. (a) For various measured compressions of the spring (x), measure horizontal range for the mass (R). Range should be measured along the floor from beneath the edge of the table to where the mass first hits the ground. Multiple trials for each compression x should be taken so that the average range of values can be determined.

   (b) The independent variable is the one the experimenter controls and manipulates directly. In this case, the independent variable is the compression x. The dependent variable is the one measured as a result of changes in the independent variable. In this case, the dependent variable is the range. Independent variables are graphed on the horizontal axis. Theoretical prediction:

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

$$v = (k/m)^{1/2}x$$

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This velocity is the horizontal projectile's velocity. The time in flight is found from the height of the table:

$$H = \frac{1}{2}gt^2$$

$$1.6 \text{ m} = 4.9t^2$$

$$t = 0.57 \text{ s}$$

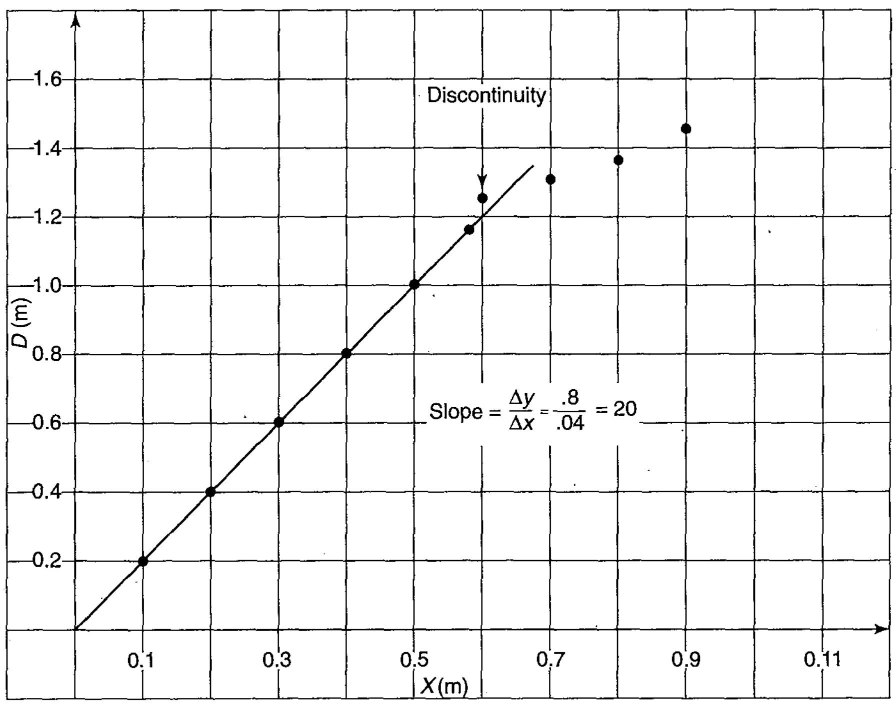
$$R = vt = (k/m)^{1/2}xt = .57(k/m)^{1/2}x$$

Using the fixed values for m and t:

$$R = 0.806k^{1/2}x$$

(c) The major source of error is friction of the tabletop between the end of the spring and the edge of the table. Ensuring that this distance is small and that the surfaces involved are smooth will minimize this error.

(d)



The discontinuity is probably caused by exceeding the limit of elasticity for this spring. Hooke's law assumes that the material is perfectly elastic and resumes its shape after being stretched or compressed:

$$\text{Slope} = 20 = 0.806k^{1/2} \text{ (from part (b))}$$

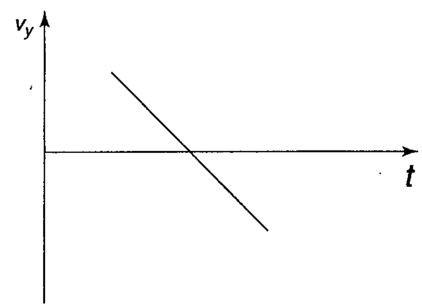
Solving for k:

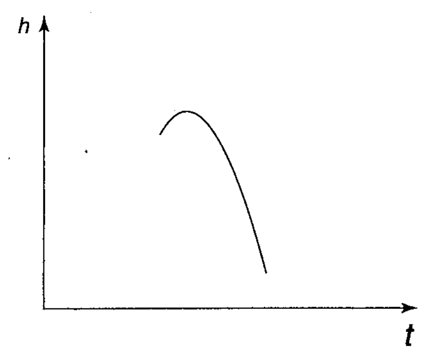
$$k = 616 \text{ N/m}$$

(b) A person's mass is a measure of his or her inertia. This value does not change due to acceleration or changes in location. Gravitational weight is a force due to the interaction of the person's mass and the planet on which he or she is standing (including the distance between their centers). Although technically this value is slightly smaller as you get higher above sea level, the differences within a building on Earth are negligible. Apparent weight is the contact forces your body experiences, which give you your subjective experience of "weight." In this case, the normal force and the changing values of the normal force explain the changes the person would experience on the elevator ride.

(c) The elevator and passenger would experience free fall. The only force would be the downward *mg*, and the normal force would be zero. Hence, the person would feel weightless. Since the car was on the way up when the cables broke, both passenger and elevator would maintain the same relative velocity to each other as both continued upward, slowed down, and then reversed direction and continued to speed up while falling. The entire time, the passenger would feel weightless.

(d)

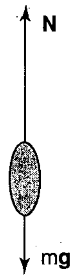




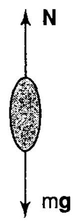
3. (a) The spinning probe acts as a gyroscope since angular momentum is both a vector and conserved. The direction of the angular momentum requires an external torque to be changed. Therefore, barring some outside force, the probe will maintain the orientation it has when the angular velocity is given to its moment of inertia:

$$\mathbf{L} = I\omega$$

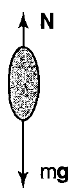
2. (a)

a. 

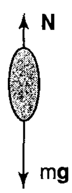
Upward acceleration, feel heavy

b. 

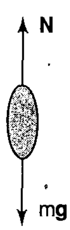
No acceleration, feel normal

c. 

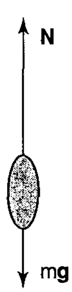
Downward acceleration, feel light

d. 

Downward acceleration, feel light

e. 

No acceleration, feel normal

f. 

Upward acceleration, feel heavy

(b) By extending the masses outward from the probe's body, the moment of inertia of the spinning probe can be greatly increased. Note that the masses need not be that great in order to change the moment of inertia substantially as the distance, R, from the axis of rotation can be made quite large by using a long cable and the R term is squared in the moment of inertia calculation:

$$I = mR^2$$

Increasing the moment of inertia serves to slow the spin rate of the probe by decreasing the angular velocity in order to conserve angular momentum:

$$\mathbf{L} = I_{small}\omega_{large} = I_{large}\omega_{small}$$

(c) Linear momentum ($m\mathbf{v}$) of the probe-planet system must be conserved. Equal and opposite impulses ($\mathbf{F}\Delta t$) are delivered to the probe and the planet during impact. However, because of their vastly different masses, what is a major impulse to the probe turns out to be a moderate impulse to the entire planet and has almost no perceptible effect on the planet's motion:

$$M_{probe}\Delta\mathbf{V}_{big} - M_{big}\Delta\mathbf{V}_{small} = 0$$

4. (a) When the cars meet, the position of each car, relative to a common origin, must be the same. Since each car is starting from rest and accelerating uniformly:

$$d_1 = d_2$$

$$\frac{1}{2}xt^2 + 25 = \frac{1}{2}yt^2$$

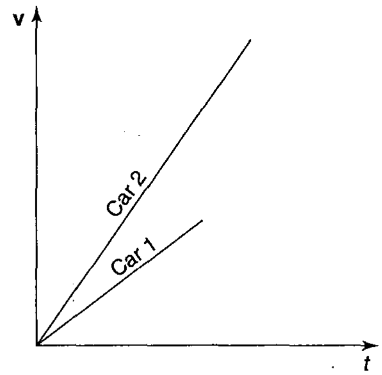
$$y - x = 50/t^2$$

Clearly, the second car must have a larger acceleration ($y > x$). The difference between the two accelerations must increase as time to catch up (t) gets smaller. So there is no upper limit on how much faster car y must accelerate than car x to catch up within 10 seconds. There is, however, a lower limit on the difference. This can be found by examining the case when the second car takes the full 10 seconds:

$$y - x = 50/t^2 = 50/100 = 0.5$$

Thus we see that for the second car to catch up with the lead car within the first 10 seconds, the second car must accelerate at least 0.5 m/s^2 faster than the first car.

(b) No, they will never have either the same instantaneous speed or the same average speed. The second car is always faster:



The second car has a slope of y on this graph, while the first car has a slope of x. Since $y > x$, one can see that neither the instantaneous nor the average slopes of either of these plots is ever the same.

(c) The second car will be ahead as it will have the higher speed when the two meet Therefore, for the rest of the trip, the second car will cover more ground and come out ahead. To find out by how much, we can compare their speed when they meet:

$$v_1 = xt \qquad v_2 = yt$$

where t is the exact time (within the first 10 seconds) when they meet.

$$\Delta d = v_2(10) - v_1(10) = 10(yt - xt) = (y - x)10t$$

Substitute our algebraic expression from part (a):

$$\Delta d = 500/t$$

Once again, there is no upper bound on the difference in distance. However, there is a lower bound that can be found by setting t equal to 10 seconds:

$$\Delta d > 50 \text{ m}$$

(d) __X__ The second car expended more energy.

No matter the details, more work was done in moving the second car as it had the greater acceleration. Greater acceleration (with the same mass) means greater force. Since the displacements are the same, the greater force means more work:

$$W = Fd$$

AP PHYSICS 1—TEST 2

5. (a) First, technically your fellow student is correct. As the top of the cliff is 200 meters farther from the center of Earth, the gravitational field experienced by the rock at the top of the cliff is technically weaker:

$$g_{top} = GM_{Earth}/(R + 200)^2 \quad \text{versus} \quad g_{bottom} = GM_{Earth}/(R)^2$$

Since the radius of Earth is 6.38×10^6 m, adding a mere 200 m does not make much of a difference:

$$200/(6.38 \times 10^6) = 3 \times 10^{-5}$$

Therefore for all practical purposes, the difference in gravitational field strength is so minimal that treating g as a constant acceleration is fairly reasonable.

On the moon, one would expect a greater deviance since 200 meters is a greater fraction of the Moon's radius (1.7×10^6). However, any decrease in the moon's gravitational effects would also be negligible;

$$200/(1.7 \times 10^6) = 1 \times 10^{-4}$$

(b) Somewhere along a line between M and $9M$ but closer to M should be a position such that the force of attraction for M will cancel the force of attraction for $9M$. Let the distance between the third mass (m) and M be x:

$$GmM/x^2 = Gm(9M)/(d - x)^2$$

Cancel and simplify:

$$9x^2 = (d - x)^2$$

Take the square root of both sides:

$$\pm 3x = d - x$$

This leads us to two solutions:

$$x = d/4$$

which is the expected solution between the masses and

$$x = -d/2$$

which is an unexpected solution on the outside of mass M along the same line. Note that in both solutions, the new mass m is 3 times farther away from $9M$ than it is from M.