PHYSICS MID-YEAR EXAMINATION
JANUARY, 2008

General Instructions and Information

This examination consists of three parts:

Part I – 40 multiple choice questions worth 2 points each.
You must answer all 40 questions.
Please fill in your answers in the appropriate spaces on the NCS answer form.
Use only a #2 pencil. Fill in the space completely.
If you wish to erase an answer, you must erase it completely.
Make no stray marks on the form.
Choose the best answer.

Part II – Two required free response questions worth 6 points each.
Show your work and answers on the answer sheet provided on the last page of this exam.
Separate the answer sheet from the rest of the exam.

Part III – Choice of one of three free response questions worth 8 points.
Show your work and answers on the answer sheet provided on the reverse side of the Part II answer sheet.

CAREFULLY REMOVE THIS TOP SHEET FROM THE REST OF THE EXAM. REFERENCE TABLES TO BE USED WITH THE EXAM ARE FOUND ON THE REVERSE SIDE OF THIS INSTRUCTION FORM.

CAREFULLY REMOVE THE LAST SHEET FROM THE REST OF THE EXAM. THIS WILL BE USED TO ANSWER PART II AND PART III.

PLEASE REMEMBER TO SIGN THE DECLARATION ON THE BOTTOM OF THE LAST PAGE.
### List of Physical Constants

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universal gravitational Constant</td>
<td>$G$</td>
<td>$6.67 \times 10^{-11}$ $\text{Nm}^2\text{kg}^{-2}$</td>
</tr>
<tr>
<td>Acceleration due to gravity</td>
<td>$g$</td>
<td>$9.81 \text{ m/s}^2$</td>
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<tr>
<td>Speed of light in a vacuum</td>
<td>$c$</td>
<td>$3.00 \times 10^8 \text{ m/s}$</td>
</tr>
<tr>
<td>Speed of sound in air at STP</td>
<td>$v$</td>
<td>$3.31 \times 10^3 \text{ m/s}$</td>
</tr>
<tr>
<td>Mass of Earth</td>
<td></td>
<td>$5.98 \times 10^{24} \text{ kg}$</td>
</tr>
<tr>
<td>Mass of the Moon</td>
<td></td>
<td>$7.35 \times 10^{22} \text{ kg}$</td>
</tr>
<tr>
<td>Mean radius of the Earth</td>
<td></td>
<td>$6.37 \times 10^6 \text{ m}$</td>
</tr>
<tr>
<td>Mean radius of the Moon</td>
<td></td>
<td>$1.74 \times 10^8 \text{ m}$</td>
</tr>
<tr>
<td>Mean distance - Earth to the Moon</td>
<td></td>
<td>$3.84 \times 10^8 \text{ m}$</td>
</tr>
<tr>
<td>Mean distance - Earth to the Sun</td>
<td></td>
<td>$1.50 \times 10^{11} \text{ m}$</td>
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<tr>
<td>Rest mass of the electron</td>
<td>$m_e$</td>
<td>$9.11 \times 10^{-28} \text{ kg}$</td>
</tr>
<tr>
<td>Rest mass of the proton</td>
<td>$m_p$</td>
<td>$1.67 \times 10^{-27} \text{ kg}$</td>
</tr>
<tr>
<td>Rest mass of the neutron</td>
<td>$m_n$</td>
<td>$1.67 \times 10^{-27} \text{ kg}$</td>
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</table>

### Prefixes for Powers of 10

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tera</td>
<td>T</td>
<td>$10^{12}$</td>
</tr>
<tr>
<td>Giga</td>
<td>G</td>
<td>$10^9$</td>
</tr>
<tr>
<td>Mega</td>
<td>M</td>
<td>$10^6$</td>
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<tr>
<td>Kilo</td>
<td>K</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Deci</td>
<td>d</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>Centi</td>
<td>c</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Milli</td>
<td>m</td>
<td>$10^{-3}$</td>
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<td>Micro</td>
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<td>$10^{-6}$</td>
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<tr>
<td>Nano</td>
<td>n</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>Pico</td>
<td>p</td>
<td>$10^{-12}$</td>
</tr>
</tbody>
</table>

### Approximate Coefficients of Friction

| Rubber on concrete (dry)   | Kinetic | 0.68 | Static | 0.90 |
| Rubber on concrete (wet)   |         | 0.58 |        |      |
| Rubber on asphalt (dry)    |         | 0.67 | 0.85   |      |
| Rubber on asphalt (wet)    |         | 0.53 |        |      |
| Rubber on ice              |         | 0.15 |        |      |
| Waxled ski on snow         |         | 0.05 | 0.14   |      |
| Wood on wood               |         | 0.30 | 0.42   |      |
| Steel on steel             |         | 0.57 | 0.74   |      |
| Copper on steel            |         | 0.36 | 0.53   |      |
| Teflon on Teflon           |         | 0.04 |        |      |

### Heat Constants

<table>
<thead>
<tr>
<th>Alcohol(ethyl)</th>
<th>Specific Heat (average)</th>
<th>Melting Point (°C)</th>
<th>Boiling Point (°C)</th>
<th>Heat of Fusion (kJ/kg)</th>
<th>Heat of Vaporization (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoholic(ethyl)</td>
<td>2.43 (lq.)</td>
<td>–117</td>
<td>79</td>
<td>109</td>
<td>855</td>
</tr>
<tr>
<td>Alcohol</td>
<td>0.90 (gel.)</td>
<td>660</td>
<td>267</td>
<td>396</td>
<td>1040</td>
</tr>
<tr>
<td>Ammonia</td>
<td>4.71 (lq.)</td>
<td>–78</td>
<td>–33</td>
<td>332</td>
<td>1370</td>
</tr>
<tr>
<td>Copper</td>
<td>0.39 (gel.)</td>
<td>1083</td>
<td>2567</td>
<td>205</td>
<td>4700</td>
</tr>
<tr>
<td>Iron</td>
<td>9.45 (sol.)</td>
<td>1535</td>
<td>2750</td>
<td>267</td>
<td>6290</td>
</tr>
<tr>
<td>Lead</td>
<td>0.13 (sol.)</td>
<td>328</td>
<td>1740</td>
<td>25</td>
<td>866</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.14 (sol.)</td>
<td>–39</td>
<td>357</td>
<td>11</td>
<td>295</td>
</tr>
<tr>
<td>Platinum</td>
<td>0.13 (sol.)</td>
<td>1772</td>
<td>3827</td>
<td>101</td>
<td>229</td>
</tr>
<tr>
<td>Silver</td>
<td>0.24 (sol.)</td>
<td>962</td>
<td>2212</td>
<td>105</td>
<td>2370</td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.33 (sol.)</td>
<td>3410</td>
<td>5660</td>
<td>192</td>
<td>4350</td>
</tr>
<tr>
<td>Ice</td>
<td>2.05 (sol.)</td>
<td>0</td>
<td>–334</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Water water</td>
<td>4.19 (iq.)</td>
<td>–100</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Steam</td>
<td>2.01 (gas.)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.39 (sol.)</td>
<td>420</td>
<td>907</td>
<td>113</td>
<td>1770</td>
</tr>
</tbody>
</table>

### Formulas

- $v = \frac{d}{t}$
- $a = \frac{\Delta v}{t}$
- $v_f = v_i + at$
- $d = \frac{1}{2} at^2$
- $v_f^2 = v_i^2 + 2ad$
- $A = A \sin \theta$
- $A = A \cos \theta$
- $F = \frac{F_{net}}{m}$
- $F_f = \mu F_N$
- $F_g = \frac{G m_1 m_2}{r^2}$
- $g = \frac{F_g}{m}$
- $P = Fv$
- $J = F_{net} = \Delta p$
- $F_e = kx$
- $PE_e = \frac{1}{2} kx^2$
- $F_e = ma$
- $a = \frac{v^2}{r}$
- $\Delta PE = mg \Delta h$
- $KE = \frac{1}{2} m v^2$
- $W = F d = \Delta E_i$
- $E_i = PE + KE + Q$
- $P = \frac{W}{t} = F \frac{v}{t} = F v$
- $Q = mc \Delta T_c$
- $Q_i = m H_i$
- $Q_i = m H_v$
- $a = \text{acceleration}$
- $a_c = \text{centripetal acceleration}$
- $A = \text{any vector quantity}$
- $d = \text{displacement/distance}$
- $E_i = \text{total energy}$
- $F = \text{force}$
- $F_c = \text{centripetal force}$
- $F_f = \text{force of friction}$
- $F_g = \text{weight/force due to gravity}$
- $F_n = \text{normal force}$
- $F_{net} = \text{net force}$
- $F_s = \text{force on a spring}$
- $g = \text{acceleration due to gravity or gravitational field strength}$
- $G = \text{universal gravitational constant}$
- $h = \text{height}$
- $J = \text{impulse}$
- $k = \text{spring constant}$
- $KE = \text{kinetic energy}$
- $m = \text{mass}$
- $p = \text{momentum}$
- $p = \text{power}$
- $PE = \text{potential energy}$
- $PE_{st} = \text{potential energy stored in a spring}$
- $F_s = \text{force on a spring}$
- $H_f = \text{heat of fusion}$
- $H_v = \text{heat of vaporization}$
- $T_c = \text{Celsius temperature}$
- $r = \text{radius/distance between centers}$
- $t = \text{time interval}$
- $v = \text{velocity/speed}$
- $W = \text{work}$
- $x = \text{change in spring length from the equilibrium position}$
- $\Delta = \text{change}$
- $\angle = \text{angle}$
- $\mu = \text{coefficient of friction}$
1. As the angle between two forces acting on the same point of an object is increased from 0° to 90°, the magnitude of the resultant force (1) decreases (2) increases (3) remains the same

2. A girl attempts to swim directly across a stream 15 meters wide. When she reaches the other side, she is 15 meters downstream. The magnitude of her displacement is closest to (1) 30 m (2) 21 m (3) 17 m (4) 15 m

3. The diagram below shows a person exerting a 300-N newton force on the handle of a shovel that makes an angle of 60° with the horizontal ground.

4. The component of the 300-N newton force that acts perpendicular to the ground is approximately (1) 150 N (2) 260 N (3) 300 N (4) 350 N

5. An object, initially at rest, falls freely near the Earth's surface. How long does it take the object to attain a speed of 98 meters per second? (1) 0.1 sec (2) 10 sec (3) 98 sec (4) 960 sec

6. Oil drips at 0.4-second intervals from a car that has an oil leak. Which pattern best represents the spacing of oil drops as the car accelerates uniformly from rest? (1) (2) (3) (4) ...

7. A group of bike riders took a 4.0-hour trip. During the first 3.0 hours, they traveled a total of 50 kilometers, but during the last hour they traveled only 10 kilometers. What was the group's average speed for the entire trip? (1) 15 km/hr (2) 30 km/hr (3) 40 km/hr (4) 60 km/hr

8. A car having an initial speed of 16 meters per second is uniformly brought to rest in 4.0 seconds. How far does the car travel during this 4.0-second interval? (1) 32 m (2) 82 m (3) 96 m (4) 4.0 m

9. Starting from rest, object A falls freely for 2.0 seconds, and object B falls freely for 4.0 seconds. Compared with object A, object B falls (1) one-half as far (2) twice as far (3) three times as far (4) four times as far

10. An object initially at rest accelerates at 5 meters per second² until it attains a speed of 30 meters per second. What distance does the object move while accelerating? (1) 30 m (2) 90 m (3) 3 m (4) 600 m

11. A ball is thrown horizontally at a speed of 20 meters per second from the top of a cliff. How long does the ball take to fall 19.6 meters to the ground? (1) 1.0 s (2) 2.0 s (3) 9.8 s (4) 4.0 s

12. A 2-kilogram block is dropped from the roof of a tall building at the same time a 6-kilogram ball is thrown horizontally from the same height. Which statement best describes the motion of the block and the motion of the ball? [Neglect air resistance.] (1) The 2-kg block hits the ground first because it has no horizontal velocity. (2) The 6-kg ball hits the ground first because it has more mass. (3) The 6-kg ball hits the ground first because it is round. (4) The block and the ball hit the ground at the same time because they have the same vertical acceleration.

13. An astronaut weighs 600 Newtons at the earth's surface. If he doubles his distance from the earth's center, his weight will be (1) 100 N (2) 150 N (3) 300 N (4) 400 N
14. The diagram below shows a projectile moving with speed v at the top of its trajectory.

Which vector best represents the acceleration of the projectile in the position shown?
(1) (3) 
(2) (4) 

Base your answers to questions 15 through 17 on the graph below which represents the relationship between velocity and time for a 2.0-kilogram cart that is initially at rest and starts moving northward.

15. What is the acceleration of the cart at t = 8 seconds?
(1) 0 m/s²  (3) 20 m/s²
(2) 10 m/s²  (4) -20 m/s²

16. In which direction is the cart traveling at t = 6 seconds?
(1) north  (3) south
(2) east  (4) west

17. At which value of t has the cart stopped moving?
(1) t = 3 s  (3) t = 6 s
(2) t = 5 s  (4) t = 8 s

18. If the kinetic energy of a 10-kilogram object is 2,000 joules, its velocity is
(1) 10 meters/sec.  (3) 100 meters/sec.
(2) 20 meters/sec.  (4) 400 meters/sec.

19. A different force is applied to each of four 1-kilogram blocks to slide them across a uniform steel surface at constant speed as shown below. In which diagram is the coefficient of friction between the block and steel smallest?
(1) 
(2) 
(3) 
(4) 

20. A 1.0 x 10⁴-kilogram box rests on the bed of a truck that is accelerating at a rate of 2.0 m/s². What is the magnitude of the force of friction on the box as it moves with the truck without slipping?
(1) 1.0 x 10³ N  (3) 5.0 x 10³ N
(2) 2.0 x 10² N  (4) 0.0 N

21. A 3.0-kilogram mass is traveling in a circle of 0.20-meter radius with a speed of 2.0 meters per second. What is its centripetal acceleration?
(1) 10. m/s²  (3) 60. m/s²
(2) 20. m/s²  (4) 6.0 m/s²

22. Which of the following objects has the greatest kinetic energy?
(1) a 1-kg object moving at 2 m/sec
(2) a 1-kg object moving at 3 m/sec
(3) a 1-kg object moving at 4 m/sec
(4) a 3-kg object moving at 2 m/sec

23. A 2-kilogram car and a 3-kilogram car are originally at rest on a horizontal frictionless surface as shown in the diagram below. A compressed spring is released causing the cars to separate. The 3-kilogram car reaches a maximum speed of 2 meters per second. What is the maximum speed of the 2-kilogram car?
(1) 1 m/s  (3) 3 m/s
(2) 2 m/s  (4) 6 m/s
24. As shown in the diagrams below, a lump of clay travels horizontally to the right toward a block at rest on a frictionless surface. Upon collision, the clay and the block stick together and move to the right.

![Clay and Block Diagrams](image)

Compared to the total momentum of the clay and the block before the collision, the momentum of the clay-block system after the collision is

1. less  
2. greater  
3. the same

25. A 0.60-kilogram softball initially at rest is hit with a bat. The ball is in contact with the bat for 0.20 second and leaves the bat with a speed of 25 meters per second. What is the magnitude of the average force exerted by the ball on the bat?

1. 8.3 N  
2. 15 N  
3. 3.0 N  
4. 75 N

26. The graph below shows the force exerted on a block as a function of the block's displacement in the direction of the force.

![Force vs Displacement Graph](image)

How much work did the force do in displacing the block 5.0 meters?

1. 0 J  
2. 20 J  
3. 0.80 J  
4. 4.0 J

27. When a machine does 250 joules of work in 10 seconds, the power developed by the machine will be

1. 2,500 watts  
2. 260 watts  
3. 240 watts  
4. 25 watts

28. If 700 watts of power is needed to keep a boat moving through the water at a constant speed of 10 meters per second, what is the magnitude of the force exerted by the water on the boat?

1. 0.01 N  
2. 70 N  
3. 700 N  
4. 7,000 N

29. The unstretched spring in the diagram below has a length of 0.40 meter and spring constant $k$. A weight is hung from the spring, causing it to stretch to a length of 0.60 meter.

![Spring Diagram](image)

How many joules of elastic potential energy are stored in this stretched spring?

1. $0.020 \times k$  
2. $0.080 \times k$  
3. $0.18 \times k$  
4. $2.0 \times k$

30. Which graph best represents the relationship between the elongation of a spring whose elastic limit has not been reached and the force applied to it?

1. ![Graph 1](image)  
2. ![Graph 2](image)  
3. ![Graph 3](image)  
4. ![Graph 4](image)

31. Base your answer to the following question on the diagram below which shows a 20-newton force pulling an object up a hill at a constant rate of 2 meters per second.

![Diagram](image)

The kinetic energy of the moving object is

1. 5 J  
2. 10 J  
3. 15 J  
4. 50 J
32. The wrecking crane shown below is moving toward a brick wall which is to be torn down.

At what point in the swing of the wrecking ball should the ball make contact with the wall to make a collision with the greatest kinetic energy?

(1) 1  (2) 2  (3) 3  (4) 4

33. A cart of mass $M$ on a frictionless track starts from rest at the top of a hill having height $h_1$, as shown in the diagram below.

What is the kinetic energy of the cart when it reaches the top of the next hill, having height $h_2$?

(1) $Mgh_1$  (2) $Mg(h_1-h_2)$  (3) $Mg(h_2-h_1)$  (4) 0

34. Which object weighs approximately 1 newton?

(1) planet  (2) paper clip  (3) physics student  (4) golf ball

35. The graph below shows the relationship between weight and mass for a series of objects on the Moon.

The acceleration due to gravity on the Moon is approximately

(1) $0.63 \text{ m/s}^2$  (2) $1.6 \text{ m/s}^2$  (3) $9.8 \text{ m/s}^2$  (4) $32 \text{ m/s}^2$

36. In the diagram below, a box is on a frictionless horizontal surface with forces $F_1$ and $F_2$ acting shown.

If the magnitude of $F_1$ is greater than the magnitude of $F_2$, then the box is

(1) moving at constant speed in the direction of $F_1$
(2) moving at constant speed in the direction of $F_2$
(3) accelerating in the direction of $F_1$
(4) accelerating in the direction of $F_2$

37. In an automobile collision, a 44-kilogram passenger moving at 15 meters per second is brought to rest by an air bag during a 0.10-second time interval. What is the magnitude of the average force exerted on the passenger during this time?

(1) 440 N  (2) 660 N  (3) 4400 N  (4) 6600 N

38. A 10-kilogram object and a 5.0-kilogram object are released simultaneously from a height of 50. meters above the ground. After falling freely for 2.0 seconds, the objects will have different

(1) accelerations  (2) speeds  (3) kinetic energies  (4) displacements

39. Base your answer to the following question on the diagram below which represents a 3.0-kilogram mass being moved at a constant speed by a force of 6.0 Newtons.

What is the change in the kinetic energy of the mass as it moves from point M to point N?

(1) 24 J  (2) 18 J  (3) 6 J  (4) 0 J

40. Which graph best represents the relationship between potential energy (PE) and height above ground $(h)$ for a youngster climbing a ladder.

(1)  (2)  (3)  (4)
41. Two forces, A and B are applied concurrently to the same point on an object. Force A has a magnitude of 6.0 N and is pointing due North. Force B has a magnitude of 5.0 N and is pointing in a direction of 40° South of East.
   a) Draw a labeled diagram of the two force vectors A and B, using a scale of 1 cm=1.0 N.  
   [2 points]
   b) Draw and label the resultant force vector R.  
   [2 points]
   c) Determine the magnitude and direction of the resultant force vector R, using a graphical method.  
   [1 point]
   d) Determine the magnitude and direction of a third force vector C which when applied concurrently with vectors A and B would produce a zero resultant.  
   [1 point]

42. A 2000 kg car accelerates uniformly from rest on a horizontal track reaching a speed of 20 m/s after a displacement of 50m, East.

For parts a) and b) of this problem, show all work including all formulas used, substitution with units, and answer with units
   a) Calculate the acceleration (including direction) of the car.  
   [2 points]
   b) Calculate the time it takes for the car to reach a speed of 20 m/s?  
   [2 points]
   c) What is the net force (including direction) acting on the car?  
   [1 point]
   d) If a 10,000 N force is pushing the car forward, what is the magnitude and direction of the force of friction acting on the car?  
   [1 point]
PART III
SELECT ONE OF THE FOLLOWING THREE QUESTIONS.
PLACE YOUR ANSWERS ON THE SHEET YOU USED FOR PART II AND CIRCLE
THE NUMBER OF THE QUESTION YOU SELECTED
(43, 44, OR 45).

43. A student adds heat energy to 2.0 kg of an unknown substance, and produces the following graph indicating the relationship between the temperature of the substance and the amount of heat added:

\[ T \text{ (°C)} \]

\[ \text{Heat Added (KJ)} \]

- a) How much heat was required to change the substance from a solid at its melting point to a liquid at the same temperature? [1 point]
- b) What is the phase of the substance at 800°C? [1 point]

For parts c) and d) show all work including all formulas used, substitution with units and answer with units.
- c) Calculate the Heat of Vaporization of this substance. [3 points]
- d) Calculate the Specific Heat of the substance in its liquid phase. [3 points]

44. For each part of this problem, show all work including all formulas used, substitution with units, and answer with units.

A force of 100N was required to push the 1 kg cart against the ideal spring compressing the spring 0.1 m as shown.

- a) Calculate the spring constant of the spring? [2 points]
- b) Calculate the amount of elastic potential energy that is stored in the spring? [2 points]

The cart is released from Point A and travels without friction to the top of the 0.1 m hill to Point B.
- c) Calculate the kinetic energy of the cart when it arrives at Point B? [2 points]
- d) If frictional forces were to reduce the kinetic energy of the cart at Point B to one half the value calculated in part c), how fast would the cart be moving at Point B? [2 points]

45. A 0.15 kg ball is thrown horizontally off the top of a building with an initial velocity of 10 m/s. The ball lands on the ground 30 m below the height at which it was released.

For parts a) and b) of this problem, show all work including all formulas used, substitution with units, and answer with units.
- a) Calculate the time elapsed between when the ball is released and when it hits the ground.[3 points]
- b) Calculate the horizontal displacement of the ball when it hits the ground? [3 points]
- c) What is horizontal component of the velocity of the ball immediately before it hits the ground? [1 point]
- d) If the ball were thrown straight down from the same height at the same speed, would the speed at which the ball hits the ground be less than, greater than, or the same as when it was thrown horizontally? [1 point]
Part III.
Circle the ONE question you are choosing to do. 43 44 45

SCRAP WORK – will NOT be graded.
If you need more space, ask the proctor for extra paper, and put your name on all pages.

The declaration below must be signed.
I do hereby affirm that I had no unlawful knowledge of the questions or answers prior to the examination and that I have neither given nor received assistance in answering any of the questions during the examination.

__________________________
Signature