Answer all questions, beginning each new question in the space provided. Show all work. Show all formulas used for each problem prior to substitution of numbers. Label diagrams and include appropriate units for your answers. Write your name and section number at the top of each page in the space provided and write the name of your section instructor in the place provided in the cover sheet. You may use an alphanumeric calculator (one which exhibits physical formulas) during the exam as long as you do not program any formulas into memory. By using an alphanumeric calculator you agree to allow us to check its memory during the exam. Simple scientific calculators are always OK!

Score on each problem:

1. (15) ____
2. (5) ____
3. (10) ____
4. (10) ____
5. (10) ____

Total Score (out of 50 pts) ____
Total Score (scaled up to 100 pts) ____

Be Prepared to Show your Student ID Card

A Formula Sheet Is Attached To The Back Of This Examination
For your convenience you may carefully remove it from the Exam. Please take it with you at the end of the exam or throw it in a waste basket. Thank you!
Name (last name only) ______________________ Section Number _______

Problem 1: (15 points - 3 pts each – no partial credit – no need to show logic – in each question, put a circle around the letter that you think is the best answer.)

1-1. The diagram represents the straight-line motion of a car (note the axes carefully!). Which one of the following statements is true?

(a) the car accelerates, stops, and reverses
(b) the car returns to its starting point when \( t = 9 \) s
(c) the car accelerates at 6 m/s\(^2\) for the first 2 s
(d) the car decelerates at 12 m/s\(^2\) for the last 4 s
(e) the car is moving for a total time of 12 s

1-2. If a vector of magnitude 20 is subtracted from a vector of magnitude 15, the magnitude of the resultant vector CANNOT be:

(a) 33  (b) 15  (c) 20  (d) 25  (e) 4

1-3. If you weigh yourself in a stationary elevator, you find your weight to be \( W \). If you weigh yourself in an elevator that is moving downward and speeding up, you will measure your apparent weight \( W' \) to be

(a) \( W' > W \)
(b) \( W' < W \) (but not 0)
(c) \( W' = W \)
(d) \( W' = 0 \)
(e) none of the above

1-4. Three books (X, Y and Z) rest on a table. The weight of each book is indicated. The force exerted by book Z on book Y is:

(a) 0  (b) 5 N  (c) 9 N  (d) 14 N  (e) 19 N

1-5. A block of mass \( m \) is pushed along a horizontal floor by an applied force \( F \) that acts downwards at an angle \( \theta \) from the horizontal as shown. The normal force exerted on the block by the floor is:

(a) \( mg \)
(b) \( mg - F\cos\theta \)
(c) \( mg + F\cos\theta \)
(d) \( mg - F\sin\theta \)
(e) \( mg + F\sin\theta \)
Problem 2: (5 points) A particle travels in a straight line along the x-axis. Its position, as a function of time, is given by \( x(t) = 3t^2 - 2t - 2 \), where \( x \) is given in meters and \( t \) in seconds.

(i) [1 pt] Write down an expression for the instantaneous velocity \( v \) as a function of time.

\[ v(t) = 6t - 2 \]

(ii) [2 pts] What is the average velocity of the particle between \( t = 0 \) and \( t = 1 \) s?

\[ x(0) = -2 \ m; \ x(1) = -1 \ m \ ; \ \Delta x = -1 - (-2) = +1 \ m \ ; \ v_{\text{avg}} = +1 \ m/s \]

or

from (i) \( v(0) = -2 \) and \( v(1) = 4 \), and \( v \) is linear in \( t \), so \( v_{\text{avg}} = (1/2)[v(0)+v(1)] = +1 \ m/s \)

(iii) [2 pts] What is the magnitude of displacement of the particle between \( t = 0 \) and \( t = 1 \) s?

\[ x(0) = -2 \ m; \ x(1) = -1 \ m \ ; \ \Delta x = -1 - (-2) = +1 \ m \]
Problem 3: (10 points) A car traveling at a high speed of 40 m/s in the left lane of a highway is passing a truck traveling in the right lane with a constant velocity of 25 m/s. At this point in time and space (say \( x = 0 \) and \( t = 0 \)), the driver of the car notices a radar speed trap up ahead and slams on the brakes and continually slows down at a rate of \(-5 \text{ m/s}^2\). The truck catches up with the car at time \( t = t_1 \) when both are at position \( x = x_1 \).

(i)[2 pts] Sketch a velocity vs time graph for the car and truck between \( t = 0 \) and \( t = t_1 \)

(ii)[2 pts] Sketch a position vs time graph for the car and truck between \( t = 0 \) and \( t = t_1 \)

(iii)[2 pts] At what time \( t_2 \) do the car and the truck have the same velocity [graph (i) can help]

\[
\text{From graph (i) } v \text{ decreases linearly with time for car. Slowing down from 40 m/s to 25 m/s at a rate of } 5 \text{ m/s per sec would take 3 s, so } t_2 = 3 \text{ s.}
\]

\[
\text{With equations: } v = v_0 + at
\]

\[
v = 25 \text{ m/s } \quad v_0 = 40 \text{ m/s } \quad a = -5 \text{ m/s}^2 \quad \text{so } t = 3 \text{ s}
\]

(iv)[4 pts] Find the time \( t_1 \) and position \( x_1 \) when the truck catches up with the car

\[
\text{Both must be at the same position when truck catches up with car.}
\]

\[
x_f = v_{0, \text{car}} t + \frac{1}{2} at^2 \text{ for car and } x_f = v_{0, \text{truck}} t \text{ for truck}
\]

\[
or 40t + \frac{-5}{2}t^2 = 25t \quad \text{or} \quad t^2 - 6t = 0 \quad \text{or} \quad t(t - 6) = 0 \quad \text{so } t_2 = 6 \text{ s}
\]

\[
\text{Using } x_f = v_{0, \text{truck}} t \text{ for truck, } x_f = 25 \times 6 \quad \text{or} \quad x_2 = 150 \text{ m}
\]
Problem 4: (10 points) A stone is launched at $t = 0$ with a speed of 15 m/s from ground level at an angle of 45° above the horizontal (positive x-direction), aimed at the top of a building. At exactly the same time, a water balloon is dropped from the top of the building. The stone hits the water balloon when the stone is at the maximum height in its parabolic trajectory.

(i)[2 pts] Draw a suitable diagram, defining your variables and coordinate system

![Diagram]

(ii)[1 pt] Express the velocity vector of the stone at $t = 0$ in $\hat{i}, \hat{j}$ format

$$v = v_0 \cos 45° \hat{i} + v_0 \sin 45° \hat{j} \quad \text{or} \quad v_0 = (10.6 \hat{i} + 10.6 \hat{j}) \text{ m/s}$$

(iii)[1 pt] Express the velocity vector of the stone when it hits the balloon in $\hat{i}, \hat{j}$ format

$$v = v_0 \cos 45° \hat{i} \quad \text{or} \quad v = 10.6 \hat{i} \text{ m/s}$$

(iv)[3 pts] How far horizontally from the launch point is the building located?

$$D = \frac{\text{Range}}{2} = \frac{v_0^2 \sin 2\theta_0}{2g} = \frac{15 \times 15}{2 \times 9.8} = 11.5 \text{ m or 11 m (to sig fig) (either is acceptable)}$$

(v)[3 pts] How tall is the building?

(Simple solution)

$$H = D \tan 45° = 11.5 \text{ m or 11 m (to 2 sig fig) (either is acceptable)}$$

(Complicated solution)

Find the maximum height to which the stone rises
Find the time it takes to get there
Use that time to find how far the balloon drops in that time
Add the two to get the building height
Problem 5: (10 points) In the system shown, two objects A and B are connected by a string that passes over a massless pulley. There is no friction anywhere and the objects are observed to be moving with constant speed. Object A has a mass \( m_A = 20 \) kg.

(i) [3 pts] Draw free-body diagrams denoting all the forces acting on the two objects.

(ii) [3 pts] Focusing first on object A, find the tension in the string.

\[
T - m_A g \sin 60^\circ = 0 \quad \text{so} \quad T = 20 \times 9.8 \times \sin 60^\circ = 170 \text{ N}
\]

(iii) [3 pts] Focusing next on object B, and using the result from part (ii), find the mass \( m_B \).

\[
T - m_B g \sin 30^\circ = 0
\]

\[
m_B = \frac{170}{9.8 \times \sin 30^\circ} = 34.7 \text{ kg or } 35 \text{ kg (to 2 sig fig) (both acceptable)}
\]

(iv) [1 pt] From all the available information, can you tell which way the blocks are moving? [A one-line reason for your answer is needed to get this extra point.]

No way to tell. Since forces are balanced, zero or constant speed in any direction possible.