Answer key for General physics mid exam

Part I **1) C 2) B 3) A 4) C 5) A**

Part II

1. Bonus
2. Positive
3. Impulse
4. Bernoulli's principle

Part III

1. **The correct statement is (b) Net force causes a change in motion.** To understand this, we need to know that net force is the overall force acting on an object. When there is net force acting on an object, it can cause the object to start moving, stop moving, or change its **direction** or **speed**. For example, pushing a car with a force greater than the force of **friction** will cause the car to **accelerate**, leading to a **change** in its motion.
2. Firstly, we have to define momentum. Momentum is defined as the product of mass and velocity. Also considering the third law of motion which states that: for every action, there is equal and opposite reaction. Considering the 2nd law of motion which states that the rate of change in the momentum of a body is equal to the applied force and takes place in the direction of the applied force. They both have same mass and velocity definitely; they will both experience same momentum. Also from the question, the both share same velocity hence; they will both hit the wall with same velocity meaning they will both feel the same impact from the wall as well. Hence the third law of motion proves this right.
3. **A conservative force:** is one for which the work done is independent of path. Equivalently, a force is conservative if the work done over any closed path is zero.

   A non-conservative force: is one for which the work done depends on the path. For a conservative force, the infinitesimal work is an exact differential.

4. In the initial condition, the garden hose has an initial cross-sectional area and thus the initial velocity of flow. **When we reduce the cross-sectional area of the hose by placing the thumb on it, the velocity of water increases**. This can be explained by the use of **the continuity equation.**

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Part IV

1) a. Position vector of the rabbit can be written as:

$$\vec{r} = x\hat{\imath} + y\hat{\jmath}$$

The rabbit's position vector in a unit vector notation and direction at $t = 15s$ are:

$$x(t = 15s) = -0.5(15)^2 + 7(15) + 28 = -112.5 + 105 + 28 = 20.5m$$

$$y(t = 15s) = 0.3(15)^2 - 9(15) + 30 = 67.5 - 135 + 30 = -37.5m$$

$$\therefore \vec{r}(t = 15s) = (\mathbf{20.5\hat{\imath} - 37.5\hat{\jmath}})\boldsymbol{m}$$

$$\tan\theta = -\frac{37.5}{20.5} \Rightarrow \theta = \tan^{-1}\left(-\frac{37.5}{20.5}\right) = \mathbf{-61.3^\circ}$$

b. The rabbit's velocity in a unit vector notation and direction at $t = 15s$ are given as:

$$\vec{v}(t) = \frac{dx}{dt}\hat{\imath} + \frac{dy}{dt}\hat{\jmath} = \big((-t + 7)\hat{\imath} + (0.6t - 9)\hat{\jmath}\big)m/s$$

$$\vec{v}(t = 15s) = \big((-15 + 7)\hat{\imath} + (0.6(15) - 9)\hat{\jmath}\big)m/s = \mathbf{-8\hat{\imath}m/s}$$

$$\tan\theta = \frac{0}{8} \Rightarrow \theta = \tan^{-1}\left(\frac{0}{8}\right) = \mathbf{0^\circ}$$

c. The rabbit's acceleration in a unit vector notation and direction at $t = 15s$ are given as:

$$\vec{a}(t) = \frac{dv_x}{dt}\hat{\imath} + \frac{dv_y}{dt}\hat{\jmath} = \big((-1)\hat{\imath} + (0.6)\hat{\jmath}\big)\,m/s^2 = \boldsymbol{(-\hat{\imath} + 0.6\hat{\jmath})\,m/s^2}$$

$$\tan\theta = -\frac{0.6}{1} = -0.6 \Rightarrow \theta = \tan^{-1}(-0.6) = \mathbf{-31.0^\circ}$$

2) a. The horizontal distance where the package strike the ground is calculated as:

$$x = v_x t = v_0 \cos\theta\, t = v_0 t \;\; because\; \theta = 0^\circ$$

$$\boldsymbol{x = v_0 t} \qquad (*)$$

The time at which the package strikes the ground is calculated from the vertical displacement as follow:

$$-y = v_{0,y}t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2 \;\; because\; v_{0,y} = 0$$

$$y = \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{220m}{9.8m/s^2}} = \sqrt{22.45} = 4.74s$$

Then by substituting the value of t in (*)

$$x = 50\,{}^{m}/_{s}\,(4.74s) = \mathbf{237.0m}$$

b. The horizontal and vertical components of the velocity of the package just before it hits the ground are given as follows:

$$\boldsymbol{v_x = v_{0,x} + a_x t = v_{0,x} = 50m/s}$$

$$\boldsymbol{v_y = v_{0,y} + a_y t = v_{0,y} - gt} = 0 - 9.8\,{}^{m}/_{s^2}\,(4.74s) = \mathbf{-46.5m/s}$$

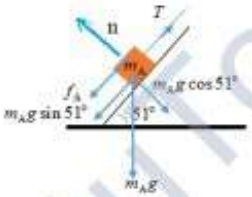
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3) **Applying Newton's second law to both objects and assuming the motion of the block is to the right, we obtain**

Motion of m_A

$$\sum F_x = T - m_A g \sin 51° - f_A = m_A a \quad (1)$$

$$\sum F_y = m_A a_y = n - m_A g \cos 51° = 0 \Rightarrow n = m_A g \cos 51° \quad (2)$$



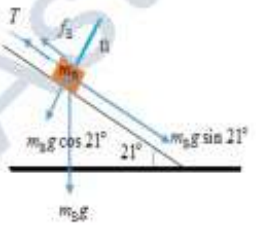
From equations (1) and (2)

$$T - m_A g \sin 51° - \mu_k m_A g \cos 51° = m_A a \quad (3)$$

Motion of m_B

$$\sum F_x = m_B g \sin 21° - T - f_B = m_B a \quad (4)$$

$$\sum F_y = m_B a_y = n - m_B g \cos 21° = 0 \Rightarrow n = m_B g \cos 21° \quad (5)$$



From equations (4) and (5)

$$m_B g \sin 21° - T - f_B = m_B a = m_B g \sin 21° - T - \mu_k n = m_B a$$

$$m_B g \sin 21° - T - \mu_k m_B g \cos 21° = m_B a \quad (6)$$

By adding equation (3) and (6) we get:

$$m_B g \sin 21° - \mu_k m_B g \cos 21° - m_A g \sin 51° - \mu_k m_A g \cos 51° = a(m_A + m_B)$$

$$a = \frac{m_B g \sin 21° - \mu_k m_B g \cos 21° - m_A g \sin 51° - \mu_k m_A g \cos 51°}{m_A + m_B}$$

$$\boldsymbol{a = g\left[\frac{m_B(\sin 21° - \mu_k \cos 21°) - m_A(\sin 51° + \mu_k \cos 51°)}{m_A + m_B}\right] = g\left[\frac{0.06m_B - 0.97m_A}{m_A + m_B}\right] = \frac{0.6m_B - 9.7m_A}{m_A + m_B}}$$

4) **a. The applied load is $F = mg = 4kg * 9.8\,{}^{m}/_{s^2} = 39.2N$**

Cross sectional area of the wire is:

$$A = \pi r^2 = \pi(2 * 10^{-3}m)^2 = 4\pi * 10^{-6}m^2 = 12.56 * 10^{-6}m^2$$

We know that: $stress = \frac{F}{A} = \frac{39.2N}{12.56*10^{-6}m^2} = \mathbf{3.12 * 10^6\,{}^{N}/_{m^2}}$

b. Strain produced in the wire is calculated as:

$$Strain = \frac{change\ in\ length}{original\ length} = \frac{\Delta l}{l_0} = \frac{0.00048m}{8m} = \mathbf{6.0 * 10^{-5}}$$

c. We know that young's modulus is given by the ratio of stress and strain; Hence

$$Y = \frac{Stress}{Strain} = \frac{3.12 * 10^6\,{}^{N}/_{m^2}}{6.0 * 10^{-5}} = \mathbf{5.2 * 10^{10}\,{}^{N}/_{m^2}}$$

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