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CHP#03

DYNAMICS -I

Q#01: Define Dynamics?

Ans: In physics, "dynamics" refers to the branch of mechanics that deals with the study of forces and motion, including the causes of motion and changes in motion. It involves understanding how objects move and interact under the influence of forces like gravity, friction, and electromagnetic force.

Q#02: Define Force? What are the effects of force on an object?

Ans: **<u>Force:</u>**

Force is the push or pull that one object exerts on another object. Force is an external agent capable of changing a body's state of rest or motion.

It has a magnitude and a direction. The direction towards which the force is applied is known as the direction of the force.

Formula:

F =ma

Unit:

Newton or Kgms^{-2}

Effects of Force: The effects of force on an object depend on various factors such as the magnitude and direction of the force, as well as the mass and shape of the object. Generally, force can cause an object to change its speed, direction, or shape. It can also cause an object to accelerate, decelerate, or remain at rest depending on the balance of forces acting on it.

Q#03: What do you know about contact and non-contact forces?

Ans: **<u>Contact Force</u>:**

Contact forces occur when two objects are physically touching each other.

Examples:

Friction: When two surfaces rub against each other, like the friction between a car's tires and the road.

Tension: Force transmitted through a string, rope, or cable, like the tension in a hanging object.

Normal Force: The force exerted by a surface to support the weight of an object resting on it, like the force exerted by a table supporting a book.

Air Resistance: Force opposing the motion of an object through air, like the resistance experienced by a moving car.

<u>Non-contact Force</u>:

Non-contact forces act at a distance without direct contact between the objects involved.

Examples:

Gravitational Force: The force of attraction between two masses, like the gravitational force between the Earth and objects on its surface.

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Electrostatic Force: The force between electrically charged objects, like the repulsion between two positively charged balloons.

Magnetic Force: The force between magnetic objects or a magnetic field and a magnetic object, like the force between two magnets or between a magnet and a piece of iron.

Q#04: What are the key differences between the four fundamental forces in nature?

Ans: Fundamental forces, also known as fundamental interactions, are the basic forces that govern interactions between particles in the universe. There are four recognized fundamental forces:

1. Gravitational Force:

Nature: Attractive force acting between all masses.

Range: Infinite.

Carrier Particle: Hypothetical graviton (not yet observed).

Relative Strength: Weakest of the four forces but dominant at macroscopic scales due to its infinite range and cumulative force.

2. Electromagnetic Force:

Nature: Acts between charged particles.

Range: Infinite.

Carrier Particle: Photon.

Relative Strength: Much stronger than gravity and governs interactions involving electricity, magnetism, and light.

3. Weak Nuclear Force:

Nature: Responsible for radioactive decay and neutrino interactions.

Range: Very short (less than the diameter of a proton, about 10^{-18}meters)

Carrier Particles: W and Z bosons.

Relative Strength: Stronger than gravity but weaker than electromagnetic and strong nuclear force.

4. Strong Nuclear Force:

Nature: Binds protons and neutrons in the nucleus and holds quarks together within protons and neutrons.

Range: Very short (about 10^{-15} meters).

Carrier Particle: Gluon.

Relative Strength: The strongest of all the fundamental forces but operates over the shortest distances.

These forces govern the interactions and structures of all matter in the universe.

Q#05: What role did Abdus Salam, Steven Weinberg and Sheldon Lee play in the development of electroweak theory?

Ans: Abdus Salam, alongside Steven Weinberg and Sheldon Glashow, formulated the electroweak theory in the 1960s. This theory unified the electromagnetic force with the weak nuclear force, explaining how particles interact at the subatomic level. Their work laid the foundation for the modern understanding of particle physics and earned them the Nobel Prize in Physics in 1979.

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Q#06 What is a system diagram?

Ans. A system diagram is a visual expression of all the objects required in order to analyze types of forces and net force.

Q#06: What is a force diagram and how is it used in physics?

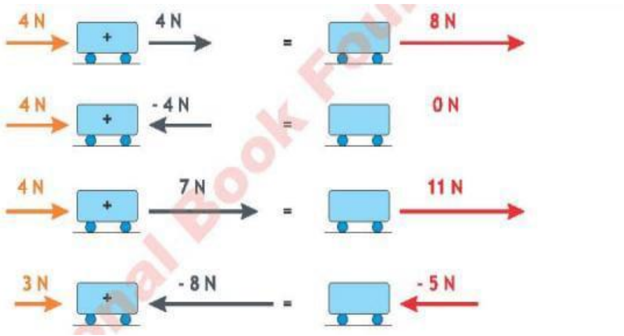
Ans: A force diagram, also known as a free-body diagram, is a visual representation used in physics to analyze the forces acting on an object. It depicts all the forces acting on the object as vectors, showing their direction and magnitude. By summing up these forces, physicists can determine the net force acting on the object, which can then be used to predict its motion according to Newton's laws. Essentially, it helps simplify complex systems by breaking them down into individual forces acting on an object.

Q#07: Define net force? How do you calculate the net force acting on an object?

Ans: **<u>Net Force</u>:**

The vector sum of all forces acting on an object is called net force.

To calculate the net force, if the forces are acting in the same direction, we add them together. If they are acting in opposite directions, we subtract the smaller force from the larger one.



Q#08: What is the purpose of free body diagram and how to make a free body diagram?

Ans: **<u>Purpose of free body diagram:</u>**

Free body diagrams are tools that are used to visualise the force and moments applied to a body and to calculate the resulting reactions in many types of mechanics problems.

Making a free body diagram involves representing all the forces acting on an object with labeled arrows pointing in the direction of each force. First, identify the object and draw it as a point or a simple shape. Then, identify all the forces acting on the object, such as gravity, normal force, friction, tension, etc. Finally, draw arrows representing each force, labeling them appropriately according to their type and direction.

Q#09: Define inertia. Why is it more difficult to push large man on swing compared to a small child?

Ans. **<u>Inertia:</u>**

The natural tendency of an object to remain in a state of rest or in state of uniform motion in a straight line termed as inertia.

Greater the mass, greater is inertia. That is the reason that it is more difficult to push a large man on swing that small child due to larger mass and larger inertia.

Q#q0: State Newton's first law of motion. Give some applications. Explain how does it relate to inertia?

Ans: **<u>Newton's first law</u>:**

An object at rest remains at rest, or if in motion, remains in motion at a constant velocity unless acted on by a net external force.

Mathematically:

$$F_{net} = 0$$

Examples:

- A ball rolling down a hill will continue to roll unless friction or another force stops it.
- If pulled quickly, a tablecloth can be removed from underneath of dishes.
- We feel pushback when standing in a bus

Since Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as law of inertia.

Q#10: Define newton's second law of motion? How does newton's second law of motion relate force, mass and acceleration?

Ans: **<u>Newton's second law</u>:**

Newton's second law of motion states that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

Mathematically:

$$a \propto F \ldots\ldots\ldots\ldots\ldots(1)$$

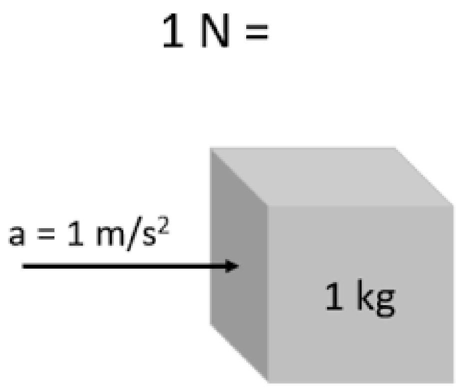
$$a \propto \frac{1}{m} \ldots\ldots\ldots\ldots\ldots(2)$$

$$a \propto \frac{F}{m}$$

$$a = k\frac{F}{m}$$

In SI unite k=1

$$a = \frac{F}{m}$$

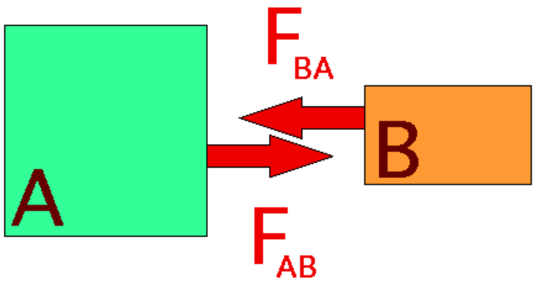


F= ma…………..(3)

- F is the force applied to the object (measured in newtons, N),
- m is the mass of the object (measured in kilograms, kg),
- a is the acceleration of the object (measured in meters per second squared, m/s^2).

<u>One Newton</u>:

One newton (N) is defined as the amount of force required to accelerate a one-kilogram mass by one meter per second squared. In other words, if a force of one newton is applied to a mass of one kilogram, it will cause that mass to accelerate at a rate of one meter per second squared.



Mathematically:

$$\mathbf{1N = 1kg \times 1ms^{-2}}$$

Q#11: Explain newton's third law of motion and provide a real-life example illustrating the law.

Ans: **<u>Newton's third law</u>:**

Newton's third law of motion states that for every action, there is an equal and opposite reaction. This means that if one object exerts a force on a second object, the second object simultaneously exerts a force of the same magnitude but in the opposite direction on the first object.

Mathematically:

$$\boldsymbol{F_{ab} = -F_{ba}}$$

The negative sign indicates that the direction of forces is opposite to each other.

Examples:

1. When you walk, your foot pushes backward against the ground. According to Newton's third law, the ground pushes forward against your foot with an equal and opposite force. This forward force propels you to move ahead. The interaction between your foot and the ground demonstrates the principle that for every action (your foot pushing backward), there is an equal and opposite reaction (the ground pushing forward).
2. Firing of a bullet: When a bullet is shot from a gun, the gun puts a force on the bullet that propels it forward.
3. During swimming, a swimmer moves ahead. The water pushes back on the swimmer as the swimmer pushes against it.

Q#12: What are some scenarios or conditions under which Newton's laws of motion fail to accurately describe the behavior of objects?

Ans: **1. Extreme speeds:** Newton's laws fail at velocities near the speed of light due to relativistic effects.

2. Tiny scales: At the quantum level, Newton's laws are inaccurate, replaced by quantum mechanics.

3. Near massive objects: Strong gravitational fields near black holes require Einstein's theory of general relativity.

4. Quantum realms: Quantum effects dominate at very small scales, rendering Newton's laws ineffective.

Q#13: Differentiate between mass and weight.

Ans:

Aspect	Mass	Weight
Definition	Measure of the amount of matter in an object.	Force exerted on an object due to gravity.
Units	Kilograms (kg)	Newtons (N)
Property	Intrinsic: does not change with location.	Extrinsic: changes with the gravitational field.
Measurement	Measured using a balance.	Measured using a scale.
Scalar vs Vector	Scalar quantity (has magnitude only).	Vector quantity (has both magnitude and direction).
Formula	$m = \frac{w}{g}$	w = mg
Example	An astronaut's mass is 80 kg on Earth and in space.	Astronaut's weight is 784 N on Earth and much less in space.

Q#14: Which instruments is commonly used to measure mass and Force.

Ans: <u>**Mass measuring instrument**</u>:

Balance Scale: A common instrument used to measure mass by comparing the object in question to known masses.

Digital Scale: Provides a direct readout of mass, often used in laboratories and for commercial purposes.

Triple Beam Balance: A mechanical scale with three beams that allow precise measurement of mass.

<u>**Force measuring instrument**</u>:

Spring Scale: Measures force based on the extension of a spring. It's often calibrated in Newtons or pounds.

Force Gauge: A device that measures force through mechanical or digital means, providing readings in units like Newtons.

Dynamometer: Measures force, torque, or power, commonly used in engineering and mechanical applications.

Q#15: What are gravitational field and gravitational field strength? Explain.

Ans: **Gravitational Force:**

Any two bodies in the universe attract each other with a force. This spectacle is called the gravitational attraction. This force of attraction is known as the gravitational force or force due to gravity.

Gravitational Field:

A gravitational field is a region around any massive object in which another mass experiences a force due to gravitational attraction.

All bodies near the surface of Earth experience gravitation attraction exerted by Earth.

Gravitational Field Strength:

The gravitational field strength (g) at any point in a gravitational field is the gravitational force per unit mass exerted on anybody placed at that point.

Mathematically:

$$g = \frac{F_g}{m}$$

Where

F_g = gravitational force (unit is N).

m = mass (unit is kg).

g = gravitational field strength (unit is N kg^{-1})

SI unit of gravitational field strength is newton per kilogram (N /Kg). Its direction is towards the massive body, such as Earth, that sets up the force field. The gravitational field strength on Earth is approximately 10 N/kg, while the gravitational field strength on the Moon is only 1/6 of that on Earth. Hence, you will only feel 1/6 of your weight on the Moon.

Q#16: Define momentum. What is its formula and unit? Is it scalar or vector quantity? Show that units of momentum, Ns and kg $\frac{m}{s}$ are equal.

Ans: **Momentum:**

It is defined as product of the mass of a particle and its velocity. Momentum is a vector quantity i.e. it has both magnitude and direction.

Mathematically:

$$\vec{p} = m\vec{v}$$

Unit:

Kgm/s or Ns.

To show that newton-second (NS) and kilogram-meter per second (kg m/s) are equal units of momentum:

1N = Kgms^{-2}

$$\mathbf{Ns = Kg\frac{m}{s^{-2}} \times s}$$

$$\mathbf{Ns = Kgm/s}$$

Q#17: State and prove newton's second law of motion in term of momentum.

Ans: A force **F** produces acceleration **a** in a body of mass m. By second Newton's law of motion it is written as

$$F_{net} = \text{ma} \ldots\ldots\ldots\ldots\text{(i)}$$

The acceleration produced changes the velocity of the body from initial velocity V_i to final velocity V_f during time interval "Δt'. Then by definition of acceleration

$$\text{a} = \frac{V_f - V_i}{\Delta t} \ldots\ldots\ldots\ldots (ii)$$

Putting equation (ii) in equation (i)

$$\text{F} = \frac{mv_f - mv_i}{\Delta t}$$

$$\text{F} = \frac{P_f - P_i}{\Delta t}$$

$$\text{F} = \frac{\Delta P}{\Delta t}$$

Hence, when a force acts on a body, it produces an acceleration in the body and will be equal to the rate of change of momentum of the body.

Q# 18: What is impulse, and how is it related to the change in momentum of an object?

Ans: **<u>Impulse</u>:**

Impulse is the product of a force applied to an object and the time over which it is applied or a large force applied for a very short duration. It measures the change in the object's momentum. Simply, impulse tells us how much the momentum of an object changes when a force acts on it for a certain period. It is denoted by J. Impulse is a vector quantity like force, and it also has direction.

Mathematically:

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

Where

J = Impulse.

F = Applied force.

Δt = Elapsed time.

SI unit of impulse is Newton- second (Ns)

Examples: Impulse is a physical phenomenon that occurs whenever two objects collide with each other or when objects come into contact. When a soccer player kicks the ball or when cars crash into each other, each object experiences an impulse.

It is directly related to the change in momentum of an object:

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

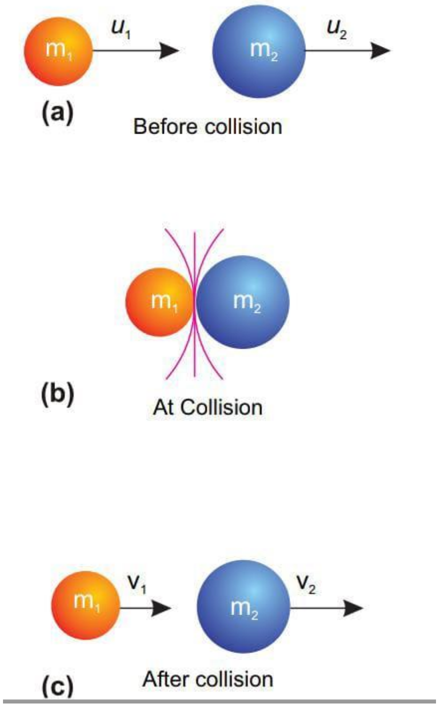
$$J = \Delta P$$

Where momentum (p) is mass (m) times velocity (v). The Impulse-Momentum Theorem states that the impulse applied to an object equals the change in its momentum.

Q#19: Define isolated system. State law of conservation of momentum. Explain with the help of two colliding spheres

Ans: **Isolated system:**

An isolated system is a system that has no net external force. This means that energy within an isolated is conserved and momentum is constant.



Law of conservation of momentum:

The law of conservation of momentum states that the total momentum of a closed system remains constant if no external forces act upon it. In simpler terms, the momentum before an event (such as a collision) is equal to the momentum after the event.

Consider an isolated system of two spheres of masses m_1 and m_2. They are moving in a straight line with initial velocities u_1 and u_2 respectively, such that u_1 is greater than u_2. Sphere of mass m_1 approaches the sphere of mass m_2 as they move.

Total initial momentum of the system before collision = $m_1u_1 + m_2u_2$

After sometime mass m_1 hits m_2 with some force. According to Newton's third law of motion, m_2 exerts an equal and opposite reaction force on m_1. Let their velocities become v_1 and v_2 respectively after collision. Then

Total final momentum of the system after collision = $m_1v_1 + m_2v_2$

According to the law of conservation of momentum

[Total initial momentum of the system before collision] = [Total final momentum of the system after collision]

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Above equation show that the momentum of an isolated system before and after collisions remain the same which is law of conservation of momentum.

Examples:

Balloon: Balloon and the air inside it form a system. Before releasing the balloon, the system was at rest and hence the initial momentum of the system was zero. As soon as the balloon is set free, air escapes out of it with some velocity. The air coming out of it possesses momentum. To conserve momentum, the balloon moves in a direction opposite to that of air rushing out.

Rocket Propulsion: Rockets have a gas chamber at one end of it. From this chamber, gas is ejected with an enormous velocity. Before the ejection of the gas, the total momentum is zero. Due to the ejection of gas from the rocket, the rocket gains a recoil velocity and acceleration in the opposite direction. This is because of the conservation of momentum.

Q#20: When a gun is fired, its recoils why?

Ans: **The recoil of a Gun:**

If a bullet is shot from a gun, both the bullet and the gun are at first very still i.e., the total momentum before firing is zero. The bullet gains a forward momentum when it gets discharged. As per the conservation of momentum, the gun gets a regressive momentum. The bullet of mass m is terminated with velocity v. The gun of mass M gains a retrogressive backward velocity V. Prior to terminating, the total momentum is zero. So, the total momentum after firing is also zero.

[Total momentum of the gun and the bullet after the gun is fired] = MV + mv

According to law of conservation of momentum

[Total momentum of the gun and the bullet after the gun is fired] = [Total momentum of the gun and the bullet before the gun is fired]

$MV + mv = 0$

$MV = - mv$

Hence

$V = -\frac{m}{M} v$

Basically, V is the recoil velocity. The mass of the bullet is very less than the mass of the gun i.e., $m << M$. The backward velocity of the gun is very less, $V << v$

Conceptual Questions

Q#01: When a motor cyclist hits a stationary car, he may fly off the motor cycle and driver in the car may get neck injury. Explain.

Ans: when a motor cyclist hits a stationary car, he may fly off the motor cycle because motorcycle suddenly stops and his body continues his motion due to inertia. In the car person is at rest when motor cycle hits the car, car may have a slight jerk back and man in the car may hit the steering with a jerk. So, he may get the neck injury.

Q#02: In autumn, when you shake a branch, the leaves get detached. Why does this happen?

Ans: When the tree is vigorously shaken, the tree is in motion while the leaves are at rest, due to inertia. The force acts on the leaves in changing directions and results in the leaves detaching from the trees.

Q#03: When a car takes a turn, the passengers experience a force acting on them away from the center of curve, why?

Ans: When a car in motion takes a sudden turn towards the left, passengers in a car experience an outward push. This is due to the centrifugal force acting on passengers.

Q#04: Why it is not safe to apply brakes only on the front wheel of a bicycle?

Ans: When brakes are applied only to the front wheel of a bicycle, the majority of the braking force is exerted on the front wheel. This causes a significant weight transfer to the front wheel, reducing the weight on the rear wheel. As a result, the rear wheel may lift off the ground, leading to a loss of traction and stability. This can result in the rider losing control of the bicycle and potentially causing an accident.

Q#05: Deduce newton's first law motion from newton's second law of motion.

Ans: According to second law of motion.

$F = ma$

If

$F = 0$

$0 = ma$

$ma = 0$

As

$m \neq 0$

Therefore

$a = 0$

Which means that the velocity of the body cannot change in absence of external force. If the body is initially at rest.

Q#06: Action and reaction are equal but opposite in direction. These forces always act in pair. Do they balance each other? Can bodies move under action -reaction pair?

Ans: Action and reaction exist in pair and are always equal in magnitude and opposite in direction. But they act on different bodies, hence they cannot balance each other.

Yes, bodies can move under action-reaction pair. For example, a swimmer pushing off a pool wall (the action) exerts a force on the wall, and the wall also exerts a force (the reaction) on her.

Q#07: Why are batsman gloves padded with foam?

Ans: The foam padding helps to distribute and dissipate the force of the ball, reducing the risk of hand and finger injuries. It acts as a shock absorber, minimizing the impact felt by the batsman's hands.

Q#08: How would you use newton's 3rd law of motion and law of conservation of momentum to explain motion of rocket?

Ans: **Newton's 3rd law and motion of rocket:** Newton's third law of motion states that to every action there is an equal and opposite reaction. Similarly, when a rocket moves, it exerts the action force on the gases to expel them backwards which in turn exerts an equal and opposite reaction force to move the rocket forward.

Law of conservation of momentum and motion of rocket: Rocket works on the principle of conservation of momentum. Rocket ejaculates gases in backward direction which creates momentum of the gases backwards and thus by conservation of momentum, the rocket gets a momentum in the forward direction making it to move forward.

Q#09: A man slips on the oily floor, he wants to move out of this bag to move out of this slippery area. How can this act help him?

Ans: A man throwing his bag to move out of this slippery area will help him by providing a surface which increases the frictional force and therefore prevents him from slipping.

Q#10: Where will your weight be greater near earth or near moon?

Ans: Your weight is greater on Earth in comparison to the Moon, given that weight is the force of gravity upon your mass, and this force is much stronger on Earth. The gravity on Earth is roughly 9.8 m/s^2 whereas it's only about 1.67 m/s^2 on the Moon.

Q#11: Why is it more difficult to push large man on swing compared to a small child?

Ans: There is a difference in the resistance to a change in motion between the man and the child. Also, when you try to stop their motions, you would again notice a difference in the resistance to a change in motion. Because large man has more inertia due to more mass.

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Q#12: Does all objects have equal tendency to resist its state of rest or uniform motion?

Ans: Absolutely not, the object with more mass has greater resistance to change (inertia), is the reason why it is difficult to move massive objects. Mass is a quantity depend upon inertia (the greater the mass of an object, the greater its inertia, and vice versa).

Numerical Problems for Assignment

1. Calculate the weight of a 10 kg object on Earth. (Take acceleration due to gravity, g, as 9.81 m/s). [98.1 N]

2. A 50 kg object experiences a force of 490 N due to gravity. What is the gravitational field strength at the location of the object? [9.8 m/s]

3. If a force meter reads 50 N when measuring the weight of an object, what is the mass of the object? (Take g=10 m/s for simplicity). [5 kg]

4. A spacecraft is orbiting the Earth at an altitude where the gravitational field strength is 6.0N/kg. Inside the spacecraft, there is a sealed container with a mass of 2.5kg. Calculate the weight of the container at this altitude. Then, if the container is brought back to the Earth's surface, where the gravitational field strength is 9.8 N/kg, what will be its new weight? Explain the difference in the weights at these two locations.

5. A student uses a force meter to measure the weight of a rock on the surface of the Earth and finds it to be 15N. The student then takes the same rock to a planet where the gravitational field strength is one-third of that on Earth. Using the force meter, what weight will the student measure for the rock on this planet? Explain your answer and discuss how the change in gravitational field strength affects the weight of the rock.

6. An electronic balance on Earth shows that a sealed container with a gas has a mass of 250 grams. The container is then taken to the Moon, where the gravitational field strength is about 1/6th that of the Earth. If the same container is weighed on an electronic balance on the Moon, what mass will it show? Explain your answer.

7. A force of 120 N is applied to a box of mass 15 kg. What is the resulting acceleration? (8m/s)

8. If a 2 kg object experiences a gravitational force of 19.6 N, what is the gravitational field strength at that location? (9.8N/kg)

9. A car of mass 1200 kg accelerates from rest to 18 m/s in 6 seconds. Find the net force acting on the car. (3600 N)

10. A force of 5 N acts on a 2 kg object for 3 seconds, causing it to accelerate. Calculate the change in velocity of the object. (7.5m/s)

11. A 70 kg astronaut experiences a weight of 686 N on planet Zog. Calculate the gravitational field strength on planet Zog. (9.8 m/s^2)

12. A car of mass 1500 kg moving at 20 m/s comes to a stop in 10 seconds. Calculate the average net force exerted on the car. (3000 N)

13. A spacecraft of mass 2500 kg is accelerating at 5 m/s in outer space. Calculate the force exerted by its engines. (12500 N)

14. An elevator of mass 500 kg moves upwards with an acceleration of 2 m/s. Calculate the tension in the supporting 2 cable. (Take g=9.81m/s) (5905 N)