Physics N – Mechanics

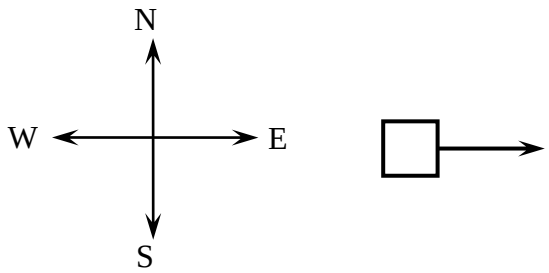
Chapter 1 One-Dimensional Motion

Section 1.2 Displacement versus Distance

(1) **1. [G]** A toy car, initially at a point *A* 5.0 m away from the origin, moves along a straight line and reaches point *B*, 12 m away from the origin. The toy car is then turned around and moves through 1.0 m.
a. What is the total distance travelled by the car?
b. What is the net displacement of the car?

Section 1.3 Average Velocity and Average Speed

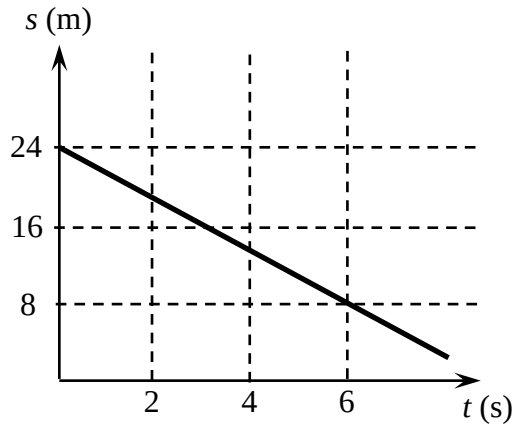
(2) **2. [G]** The box shown in the diagram below moves uniformly, covering a distance of 5.0 m every 2.0 seconds.



a. What is the speed of the box?
b. What is the velocity of the box?

Section 1.6 Velocity and Average Velocity from the Position-Time Graph

(3) **3. [G]** The graph below shows the variation of the displacement of a cyclist with time.



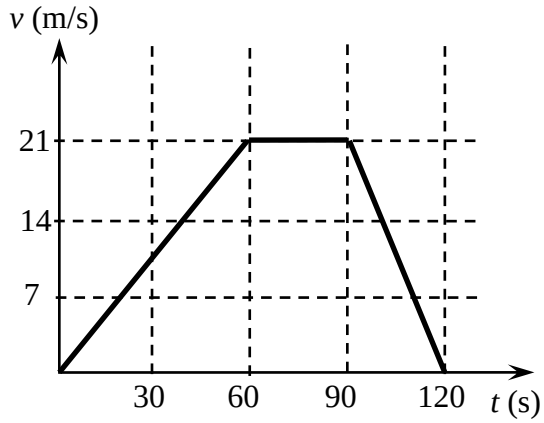
What is the velocity of the cyclist at $t = 4$ s?

Section 1.7 Acceleration

(4) 4. [G] When a car moves from an asphalt road into a rough dirt patch, its speed decreases from 20 m/s to 12 m/s in 2.0 seconds. What is the average acceleration of this car?

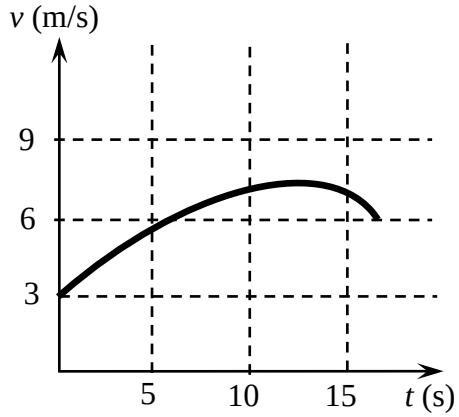
Section 1.8 Velocity-Time Graphs

(5) 5. [G] The diagram below shows the variation of a subway train's velocity with time.



a. What is the acceleration of the train at t = 30 s?
b. In what time interval is the magnitude of acceleration of the train the greatest?

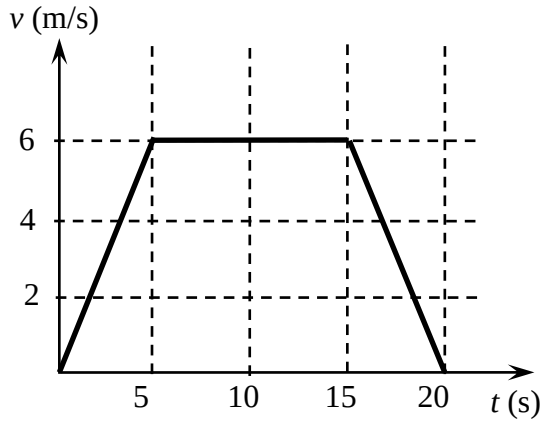
(6) 6. [G] The diagram below shows the variation of a cyclist's velocity with time.



Explain how to calculate the instantaneous acceleration of the cyclist at t = 10 s.

Section 1.10 Displacement as the Area under the *v*-*t* Graph

(7) **7. [G]** The diagram below shows the variation a cyclist's velocity with time.



What is the total displacement of the cyclist in 20 s?

Section 1.11 Motion with Constant Acceleration

(8) **8. [G]** The engine of a toy car, initially moving in the positive direction at 0.50 m/s, is turned on, accelerating the car at a rate of +0.20 m/s^2. What is the displacement of the car after 6.0 seconds?

Section 1.12 Free Fall

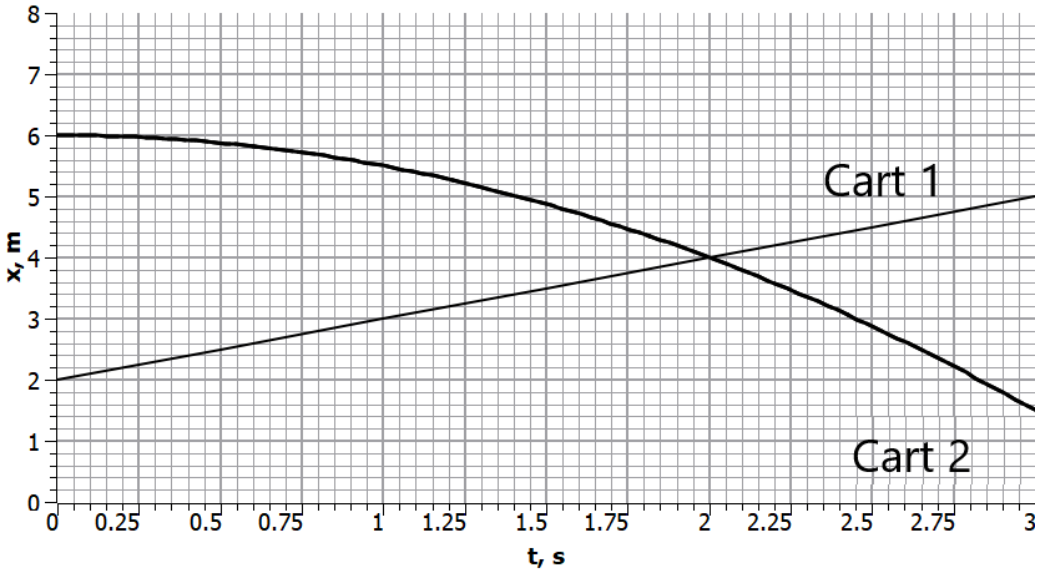
(9) **9. [G]** An object, released from rest several meters above the ground, moves at a constant acceleration in the absence of air resistance. What is the numerical value of this acceleration?

Section 1.13 One-Dimensional Relative Motion

(10) **10. [G]** A motorboat is moving in a river at 6.0 m/s due North. The river is flowing at 2.0 m/s due East. What is the speed of the motorboat relative to a stationary observer on the shore?

Section 1.14 Integration and Differentiation: Beyond URM and UARM

(11) **11. [T]** The variation of the position of two carts with time is shown in the graph below. Initially, the first cart moves with speed *u* and the second cart is at rest.



a. Determine the initial distance between the carts.

b. Determine the value of *u*.

c. Indicate the instant the carts pass each other.

d. The second cart moves with a constant acceleration. Calculate its value.

e. Calculate the speed of the second cart as it passes the origin.

Chapter 2 Motion in Two and Three Dimensions

Section 2.3 Ideal Projectile Motion

(12) **1. [G]** A cannon ball is launched at 37° above the ground with an initial speed of 125 m/s. Assume drag is negligible and take $g = 9.8\ m/s^2$.

a. Calculate the greatest height the ball attains.
b. Calculate the smallest speed of the ball as it moves through the air.
c. Calculate the range of the ball.

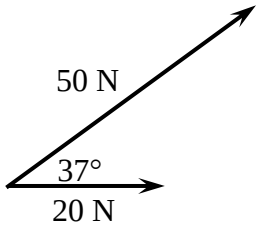
Chapter 3 Newton's Laws of Motion

Section 3.1 Describing Forces

(13) **1. [G]** The weight of an apple on Earth is 1 N. Do you expect its weight to be the same on the Moon's surface? Explain your answer.

Section 3.3 Superposition of Forces

(14) **2. [G]** Two forces, of magnitudes 20 N and 50 N, act at an angle of 37° with each other as shown in the diagram below.



a. Show the sum of these forces on the diagram.
b. Calculate the magnitude of the sum of these forces.

Section 3.5 Newton's Second Law of Motion

(15) **3. [G]** A car of mass 800 kg can decelerate from 20 m/s to 0 m/s in 4.0 seconds. Calculate the force applied by the car's brakes.

(16) **4. [G]** Define inertia and relate it to the mass of an object.

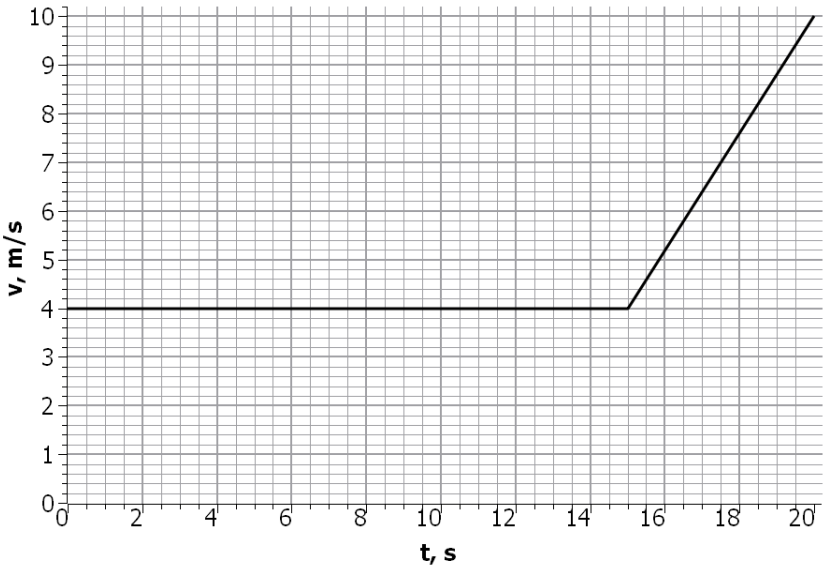
Section 3.6 Newton's Third Law of Motion

(17) **5. [G]** A person, walking at a speed of 0.9 m/s, applies a force of 500 N on the ground. What is the magnitude of the force exerted by the ground on this person?

Section 3.8 Applications of Newton's Second Law

(18) **6. [T]** a. Explain, with reference to forces, when an object moves rectilinearly at constant speed.

b. A cyclist is pedaling along a level road and then freewheels (moves without touching the pedals) down a hill inclined at 15° with the horizontal. The graph below shows how the speed of the cyclist varies with time. Given: $g = 9.80\ m/s^2$.



i. Determine the acceleration of the cyclist at t = 18 s.

ii. Determine the total displacement of the cyclist from t = 0 s to t = 20 s.

iii. Explain whether the net work done **on** the cyclist from t = 0 s to t = 20 s is positive or negative.

iv. The weight of the cyclist and his bike is 800 N. Calculate;
1. the normal reaction on the cyclist;
2. the resistance forces on the cyclist as he descends down the slope.

Chapter 4 Work, energy, and Power

Section 4.1 Work Done by a Force

(19) 1. [G] A box, of weight 40 N, slides through 10 m along a frictionless inclined plane making an angle of 30° with the horizontal.

a. Calculate the work done by the normal reaction on the box.
b. Calculate the work done by the weight on the box.

Section 4.2 Work-Energy Theorem

(20) 2. [G] What is the speed of a car of mass 500 kg whose kinetic energy is 20 kJ?

Section 4.3 Potential energy

(21) 3. [G] A bird, of mass 800 g, has a gravitational potential energy relative to the ground of 25 J. How high above the ground is the bird found? Given: $g = 9.8\ m/s^2$.

(22) 4. [G] A spring, of force constant 250 N/m, stores 0.10 J of energy. What is the extension of this spring?

Section 4.4 Mechanical Energy

(23) 5. [G] A pendulum consists of a small sphere (a bob) tied to a 1.0 m string and suspended from a ceiling. The pendulum is displaced to the side, so that the bob is 0.050 m above its initial position and the string is taut. The pendulum is then released from rest. What is the greatest speed that the bob attains? Given $g = 9.8\ m/s^2$.

(24) 6. [T]

a. Define the term “inertia.”

A helicopter, moving at 260 km/h at a height of 200 m above the ground, releases a humanitarian aid parcel ($t = 0$ s). Assume the drag is negligible. Given: $g = 9.80\ m/s^2$.

b. Determine, in m/s, the initial speed of the parcel once it is released.

c. Describe, in words, the shape of the parcel’s subsequent trajectory.

d. Calculate the time the parcel is airborne.

e. Calculate the speed with which the parcel reaches the ground.

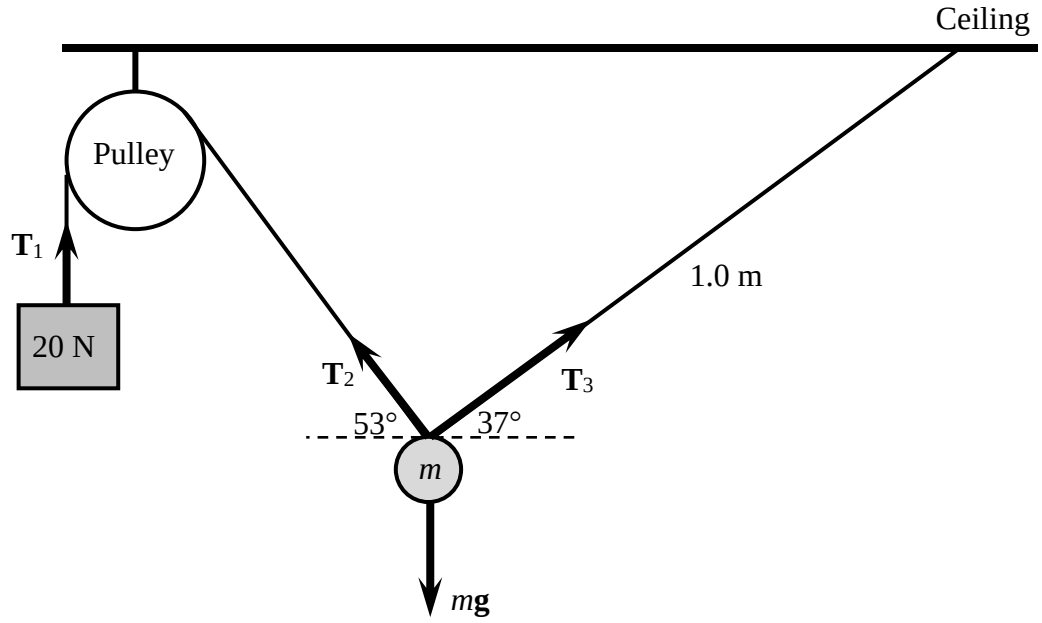
The air drag is, in fact, not negligible and can be expressed as $F = -12v$, where v is the instantaneous speed of the parcel expressed in m/s and F is in newtons. On a new mission, the helicopter releases the parcel of mass 15 kg while hovering stationary 200 m above the ground.

f. Calculate the terminal speed of the parcel.

g. Calculate the percentage of energy lost as heat while the parcel falls.

(25) **7. [T]** a. State the condition for translational equilibrium.

A block of weight 20 N and a ball of mass m are suspended by a rope threaded through a frictionless pulley as shown in the diagram below. The length of the rope connecting the ball to the ceiling is 1.0 m. The system is in translational equilibrium. Given: $g = 9.80$ m/s^2.



b. Calculate

i. the tension T_1;
ii. the tension T_2;
iii. the tension T_3;
iv. the mass of the ball m.

c. The string, in which the tension is T_2, is now cut.

i. Determine the initial potential energy of the ball relative to the ceiling.
ii. Determine the potential energy of the ball as it passes by its new equilibrium position.
iii. Determine the speed of the ball as it passes by its new equilibrium position.

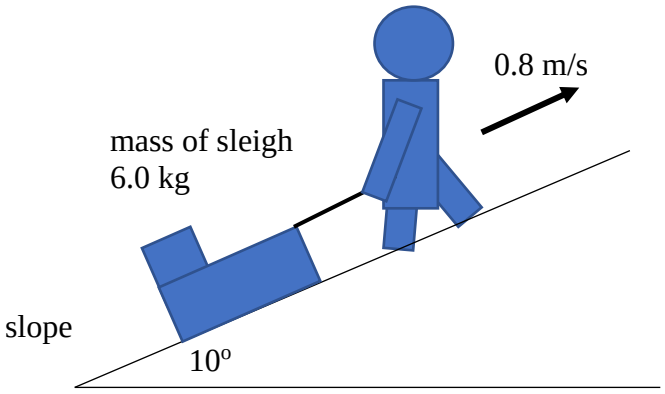
Section 4.6 Power

(26) **8. [G]** An electric generator consumes 100 kJ of energy, out of which 75 kJ is wasted as heat and sound energy.
What is the efficiency of the generator?

(27) **9. [G]** A motor lifts a 40 kg load by 2.0 m in 5.0 s. Given g = 9.8 m/s^2.
What is the power output of the motor?

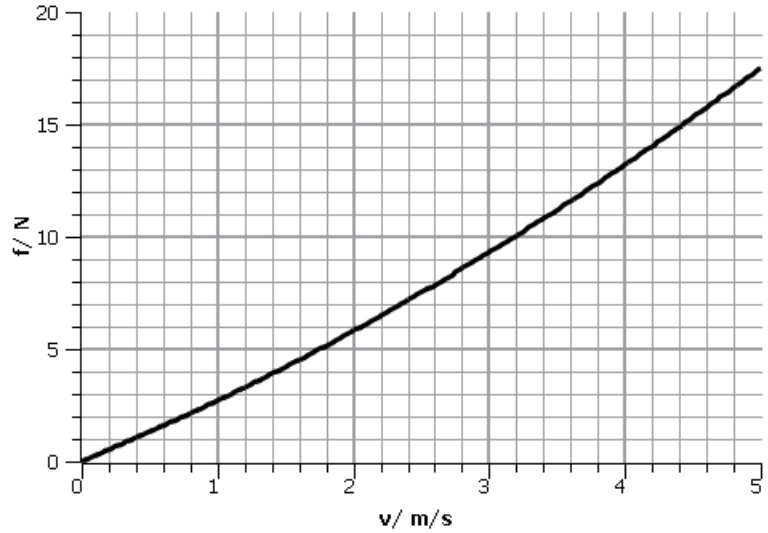
(28) **10. [T]**
a. Explain the difference between speed and velocity.

b. A boy is pulling a sleigh up a hill, as shown below.



The mass of the sleigh is 6.0 kg and it moves at 0.80 m/s. The boy exerts a force of 20 N on the sleigh, parallel to the slope.
Calculate the component of the weight of the sleigh along the slope.

c. A resistive force f opposes the motion of the sleigh.
The graph below shows the variation of f with the speed of the sleigh.



i. Explain whether the acceleration of the sleigh is constant.

ii. Calculate the acceleration of the sleigh when its speed is 0.80 m/s.

iii. Calculate, for the same instant, the power developed by the net force up the slope.

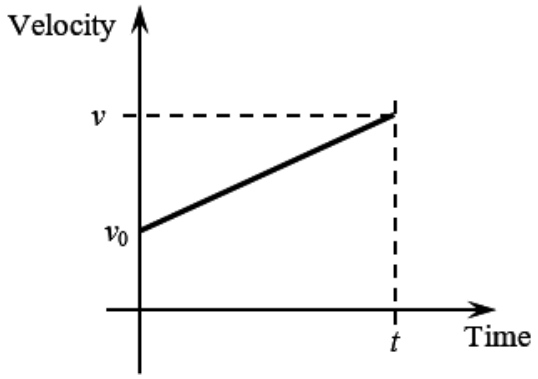
Chapter 5 Momentum and Collisions

Section 5.1 Linear Momentum and Impulse

(29) **1. [G]** What is the speed of a vehicle of mass 500 kg, whose momentum is 4×10^3 kg.m/s?

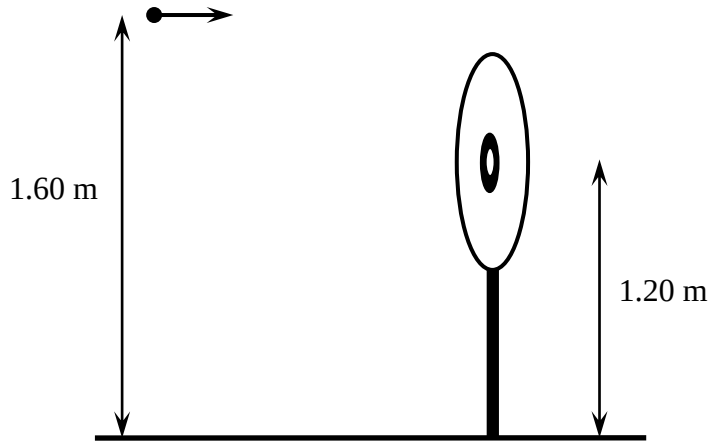
(30) **2. [G]** A ball, of mass 0.15 kg and moving at 5.0 m/s, undergoes a perfectly elastic collision with a wall. If the collision lasts for 0.20 s, what is the average force exerted by the wall on the ball?

(31) **3. [T]** a. The figure below shows how the velocity of an object moving in a straight line varies with time.



By referring to the area below the graph, show that, for a uniformly accelerated motion, the average velocity can be found as the average of the initial and final velocities, $v_{av} = \frac{v_0 + v}{2}$.

A dart, of mass 50.0 g, is projected horizontally at 1.60 m above the ground towards a board whose center is 1.20 m above the ground. The initial speed of the dart is 2.00 m/s. The dart hits the center of the board. Neglect the effect of frictional forces. Given: g = 9.80 m/s^2.



b. Determine the time of flight of the dart towards the board.

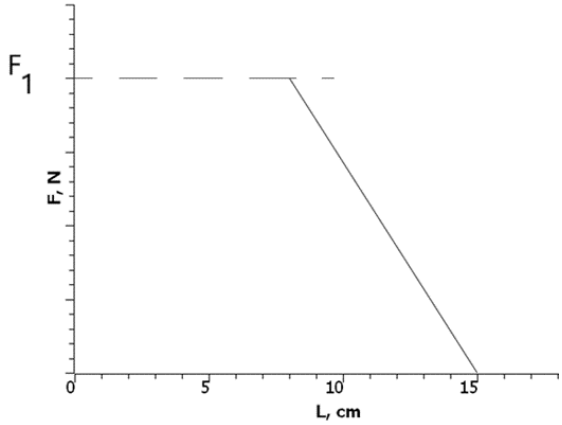
c. Determine the horizontal distance from the dart's initial position to the board.
d. Determine the speed with which the dart hits the board.

e. The dart's head cuts 11.0 mm into the board before coming to rest.

i. Calculate the average retarding force the board exerts on the dart.

ii. By calculating the change in the dart's momentum, calculate the time it takes to bring the dart to rest.

(32) **4. [T]** a. The graph below shows how the length of a spring varies with the force compressing it. The spring constant of the spring is 450 N/m. When the spring is compressed to 8 cm the force acting on the spring is denoted F_1.



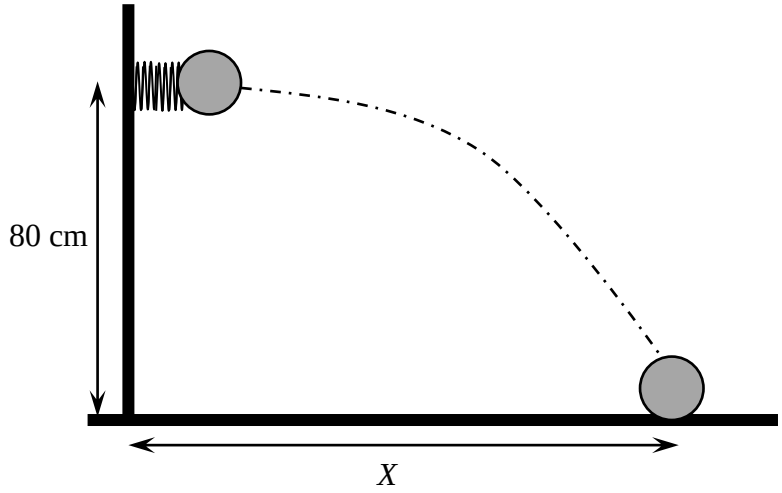
i. State the length of the spring when it is not deformed.

ii. Determine the value of F_1.

iii. On the graph, represent the work that should be done to compress the spring from its original length to 10 cm.

iv. Calculate the elastic potential energy stored in the spring when it is 8 cm long.

b. The spring is compressed in a way to store 1.0 J. It is used to shoot a ball, of mass 100 g, initially at 0.80 m above the ground. The ball lands on the ground and comes to rest *X* meters from the launch site. Given: $g = 9.80\ m/s^2$.



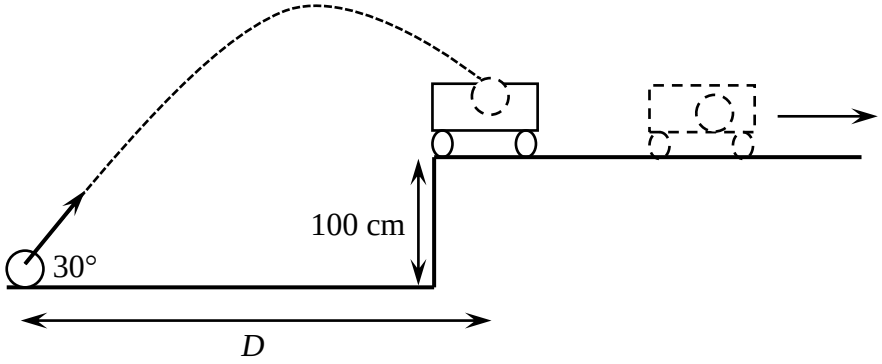
i. During the launch, 95% of the initial potential energy of the spring is converted into the kinetic energy of the ball. Calculate the speed with which the ball is launched.

ii. Calculate the amount of energy dissipated from the time the ball is launched to when it comes to rest.

iii. The value of *X* is measured to be 1.50 m. Explain, why drag on the airborne ball is not negligible.

iv. If the time the ball is airborne is 0.42 s and the change in the ball's momentum is 0.53 kg.m/s, what is the value of the average drag on the ball while in air?

(33) **5. [T]** A spring gun projects a 50 g ball at a speed of 12.0 m/s making an angle of 30° with the horizontal. The ball falls into a cart of mass 300 g, initially stationary on a platform 100 cm above the ground. The ball sticks to and moves with the cart. Given: g = 9.80 m/s^2.



a. Calculate the time the ball is airborne.

b. Calculate the horizontal distance D from the launch site to the cart.

c. For the instant when the ball is just about to hit the cart, calculate
i. the horizontal component of its velocity;
ii. the vertical component of its velocity.

d. Determine the horizontal speed of the cart after the ball collides with it.

e. Without making calculations, explain whether one can expect the initial momentum of the ball (at the time it was launched) to be equal to the final momentum of the ball and cart.

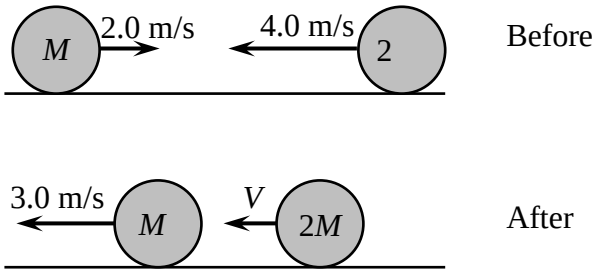
Section 5.2 Conservation of Momentum

(34) **6. [G]** Two carts, of masses $m_1 = m$ and $m_2 = 2m$, move toward each other at v_1 = 5.0 m/s and v_2 = 6.0 m/s, respectively. The carts collide, and the lighter cart rebounds at 3.0 m/s.
What is the velocity of the heavier cart? State its magnitude and direction.

Section 5.5 Problems Involving Linear Momentum and Energy

(35) **7. [T]** a. Explain how the principle of conservation of momentum can be derived from Newton's laws of motion.

b. Two billiard balls travel directly towards each other. The balls collide and bounce back. The speeds and the masses of the balls are shown in the diagram below.



Calculate the value of *V*.

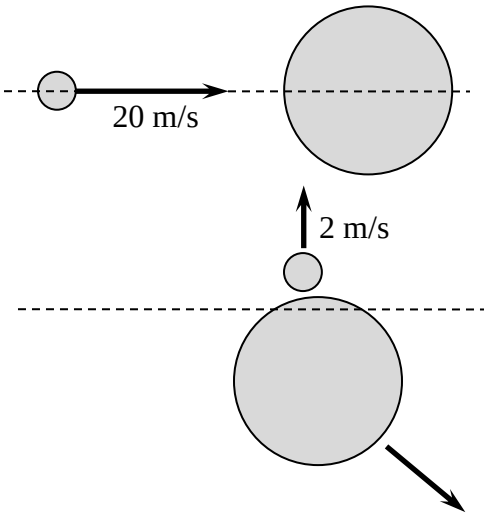
c. Express, in terms of *M*, the kinetic energy of the system of balls
i. before the collision;
ii. after the collision.

d. Based on your answers to c., classify this collision as elastic or inelastic. Explain your answer.

e. Suggest one more test to check whether the collision is elastic or inelastic.

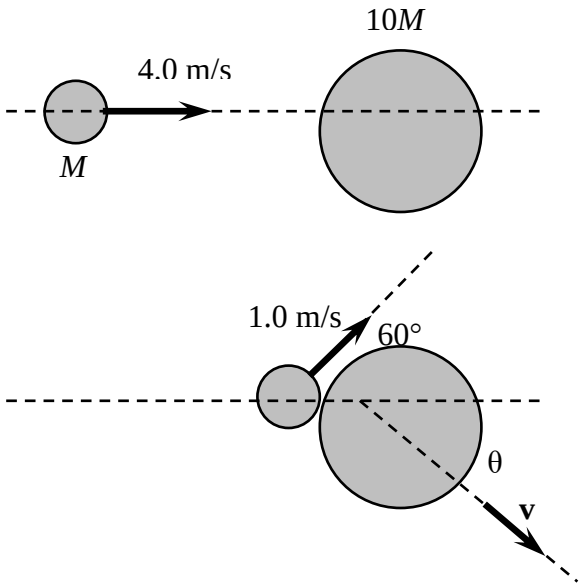
Section 5.6 Collisions in Two Dimensions

(36) **8. [G]** A ball, of mass *m* and moving at 20 m/s, collides with a stationary heavy ball of mass 5*m*. The lighter ball bounces off at 90° with its original direction at 2 m/s.



What is the speed of the heavier ball after the collision?

(37) **9. [T]** A ball, of mass *M* and moving at 4.0 m/s, collides with another ball of mass 10*M*, initially at rest. As a result, the lighter ball bounces back at an angle of 60° with its initial direction at 1.0 m/s.



a. Determine

i. the direction of motion of the 10*M* ball;

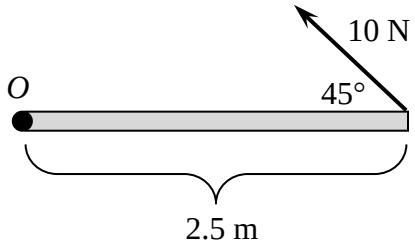
ii. the speed of the 10*M* ball after collision.

b. Explain, with reference to quantitative data, whether this collision is perfectly elastic or not.

Chapter 6 Torque and Equilibrium

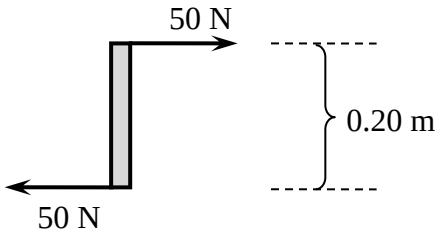
Section 6.1 Torque

(38) **1. [G]** A force, of magnitude 10 N, is applied on a rod hinged at *O* as shown below. The length of the rod is 2.5 m.



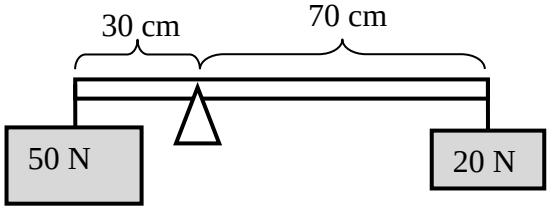
What is the moment of this force about *O*?

(39) **2. [G]** What is the moment of a couple of forces, of magnitude 50 N, applied normally to the opposite ends of a rod of length 0.20 m?



Section 6.3 Equilibrium of Extended Bodies

(40) **3. [G]** Two weights, 20 N and 50 N, tied to the opposite sides of a uniform ruler can keep it in balance. The lighter weight is 70 cm away from the pivot and the heavier is 30 cm away from the pivot.



a. State the conditions for equilibrium.
b. Determine the weight of the ruler.

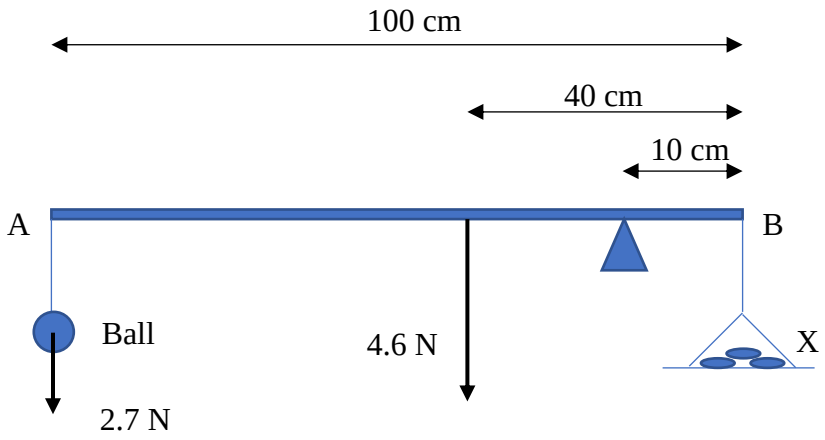
(41) **4. [T]** A solid ball of diameter 4.2 cm is made from a material of density 7.2 g.cm^{-3}.

a. Show that the weight of the ball is 2.7 N

The ball in **(a)** is hung from the end *A* of a non-uniform bar *AB*, as shown below.

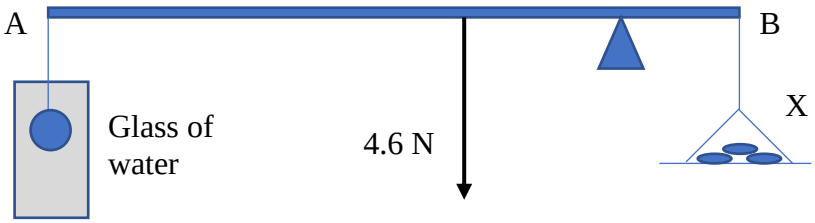
The bar has length 100 cm and weight 4.60 N. Its centre of gravity is 40 cm from *B*. The bar is pivoted at *P*. The pivot is 10 cm from *B*.

An object *X* is hung from end *B*. The weight of *X* is adjusted until the bar is horizontal and in equilibrium.



i. Explain why the center of mass and the center of gravity of the object are located at the same point.
ii. Calculate the weight of *X*.

c. The ball is now immersed in water, as illustrated below.



A student conducting this experiment reasons: “The water column above the ball exerts pressure on it. Therefore, the net downward force on the left end of bar *AB* will increase and it will tilt counter clockwise”

i. Explain why the student’s reasoning is incorrect, and why the bar *AB* will tilt clockwise.
ii. Explain how the weight of *X* must be changed to obtain equilibrium for bar *AB*.

Physics N – Electricity and Waves

Chapter 1 Current, Resistance, and Electromotive Force

Section 1.2 Electric Potential and Potential Difference

(42) **1. [G]** Define the potential difference across an electric component

Section 1.3 Electric Current

(43) **2. [G]** A 5.0 C of charge flows in a circuit every minute. What is the current in this circuit?

(44) **3. [G]** The mean drift velocity of the electrons in a silver wire, of cross-sectional area 2.0×10^{-6} m^2, is 0.11 mm/s. The electron number density for silver is 5.86×10^{28} m^{-3}. What is, in A, the current in this wire? Given: $q = 1.6 \times 10^{-19}$ C

Section 1.4 Ohm's Law

(45) **4. [G]** The p.d. across a circuit element is 12 V when a current of 0.30 A flows through it. What is the resistance of this element?

(46) **5. [G]** Sketch the *I*-*V* characteristics for a
a. metallic conductor;
b. filament lamp;
c. diode.

(47) **6. [G]** State Ohm's law.

Section 1.5 Resistance and Resistors

(48) **7. [G]** Calculate the resistance of a 3.0 m long copper wire of cross-sectional area 1.0 mm^2. The resistivity of copper is 1.69×10^{-8} Ω.m.

Section 1.6 Voltage and Electromotive Force

(49) **8. [G]** A battery, of emf 12.0 V, has an internal resistance of 1.0 Ω. What is the terminal potential difference across this battery when a 20 Ω resistor is connected to it?

Chapter 2 DC Circuits

Section 2.2 Electrical Energy and Power

(50) **1. [G]** The p.d. across a 20 Ω heating element is 120 V. What is the power output of the heating element?

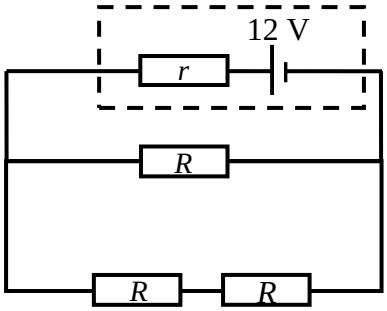
Section 2.4 Resistors in Series and in Parallel

(51) **2. [G]** Three resistors, of resistances 15 Ω, 5 Ω, and *X* Ω, are connected in series. The equivalent resistance of this combination is 50 Ω. What is the value of *X*?

(52) **3. [G]** Three resistors, of resistances 80 Ω, 20 Ω, and 10 Ω, are connected in parallel. What is the equivalent resistance of this combination of resistors?

(53) **4. [T]** a. Explain what an ohmic conductor is.

The circuit shown below consists of a power supply, having an emf of 12 V and an internal resistance *r*, and three identical resistors each of resistance 60 Ω.



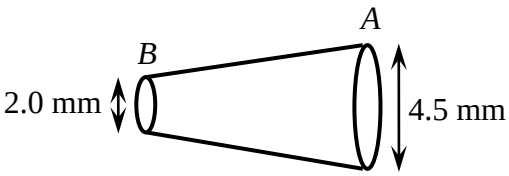
The current through the supply is 0.25 A.

b. Determine the equivalent resistance of the resistors.

c. Determine the terminal p.d. across the power supply.

d. Determine the internal resistance of the power supply.

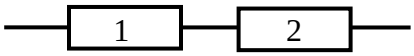
A copper wire has a conical shape as shown in the diagram below. The diameter of its wide end *A* is 4.5 mm and the diameter of its narrow end *B* is 2.0 mm. The current flows from *A* to *B*.



e. Determine the ratio of the drift speed of electrons at ends *A* and *B*, $\frac{v_A}{v_B}$.

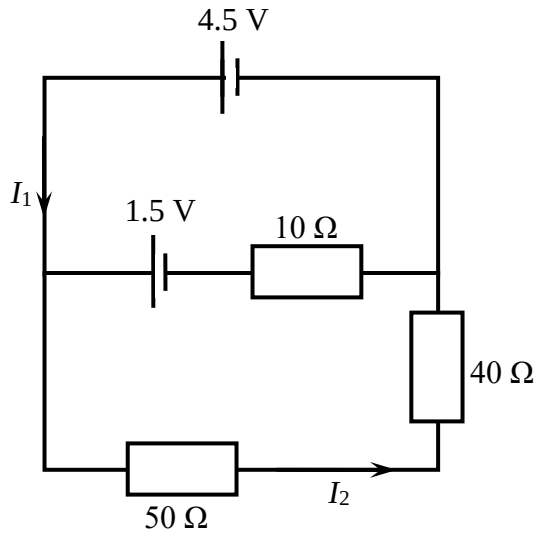
Section 2.6 Multiloop Circuits

(54) **5. [G]** In the diagram below, the current through resistor 1 is 0.50 A and the p.d. across it is 8 V. The p.d. across the combination of resistors 1 and 2 is 12 V.



a. What is the current through resistor 2?
b. What is the p.d. across resistor 2?

(55) **6. [G]** Consider a circuit diagram below.

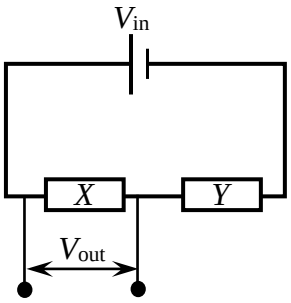


a. What is the value of current I_2 in this diagram?
b. What is the value of current I_1 in this diagram?

Section 2.7 Practical Electric Circuits

(56) **7. [G]** Describe how the increase in temperature affects the resistance of
a. a positive temperature coefficient thermistors;
b. a negative temperature coefficient thermistors.

(57) **8. [G]** The potential divider below consists of a battery, of negligible internal resistance and supplying a voltage V_{in} = 24 V, and two resistors of resistances R_x = 50 Ω and R_Y =100 Ω. The output voltage of the divider is V_{out}.

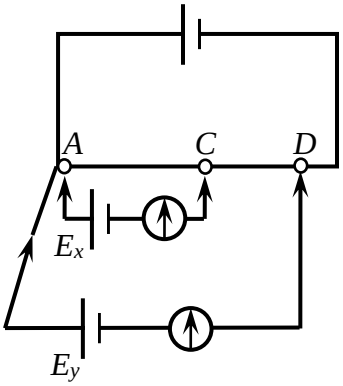


What is the value of *V*out?

(58) **9. [G]** Explain how a potential divider will behave in different ambient conditions, if one of its resistors is substituted by

a. a light dependent resistor (LDR);
b. a negative temperature coefficient (NTC) thermistor.

(59) **10. [G]** In the circuit below, the batteries of unknown emfs, E_x and E_y, are connected in series with galvanometers and are attached to points *A*, *C*, and *D* to another circuit as shown.



When *AC* = 15 cm and *CD* = 5 cm, both galvanometers read zero.
What is the ratio of E_x to E_y?

(60) **11. [T]** A circuit consists of different components connected by a wire of total length of 29.0 m, cross-sectional area of 3.2×10^{-7} m^2, and resistivity 1.7×10^{-8} Ω.m. The current in the wire is 0.20 A. Given: $e = 1.60 \times 10^{-19}$ C.

a. Calculate the resistance of the wire.

b. Calculate the p.d. across the length of the wire.

c. Calculate the power dissipated in this wire.

d. The drift speed of the free electrons in the wire is 4.6×10^{-5} m/s. Calculate the number density of free electrons in this wire.

The wire develops a fault as shown in the diagram below.

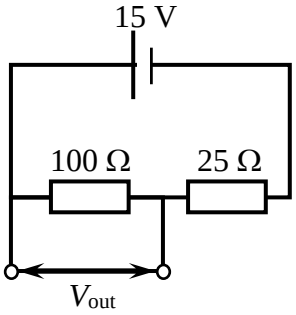
e. Explain why the faulty contact can be hot to the touch.

f. Consider four identical resistors, each of resistance 60 Ω.

i. In the space below, sketch the diagram showing how the resistors should be connected to obtain an equivalent resistance of 100 Ω.

ii. Derive an expression for the equivalent resistance of the arrangement drawn in f.i.

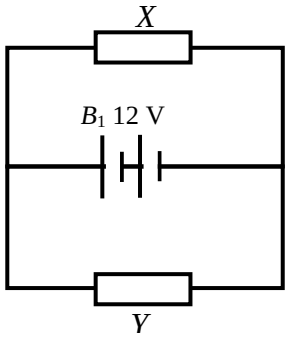
iii. The combination of resistors is used in a potential divider as shown in the diagram below. Determine the output potential difference, V_{out}, of the arrangement.



(61) **12. [T]** a. Define the term resistance.

b. A wire, of length 25 cm and resistance 3.0 Ω, is made of a metal with resistivity 1.68×10^{-8} Ω.m. Calculate the cross-sectional area of this wire.

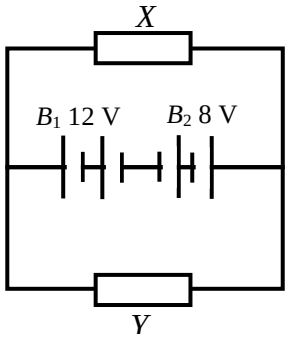
c. Resistor *X*, of resistance 20 Ω, is connected in parallel to a resistor *Y*, of resistance 60 Ω, as shown in the diagram below. The 12 V emf source has a negligible internal resistance.



i. Explain why the current through resistor *X* is less than the current through the battery.

ii. Calculate the current through resistor *X*.

d. A second battery, of emf 8.0 V, is added to the circuit as shown in the diagram below.

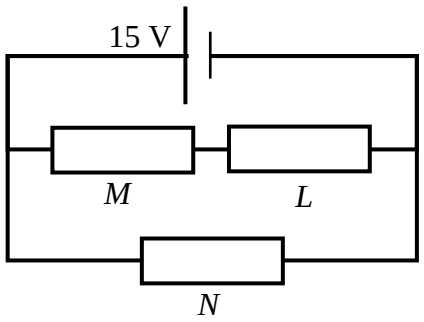


State whether this addition will increase, decrease, or leave unchanged the p.d. across

i. resistor *X*;

ii. battery B_1.

e. Another electric circuit consists of a battery, of emf 15 V and a negligible internal resistance, and three resistors of resistances $R_L = 20\ \Omega$, $R_M = 10\ \Omega$, and $R_N = 50\ \Omega$, as shown in the diagram below.

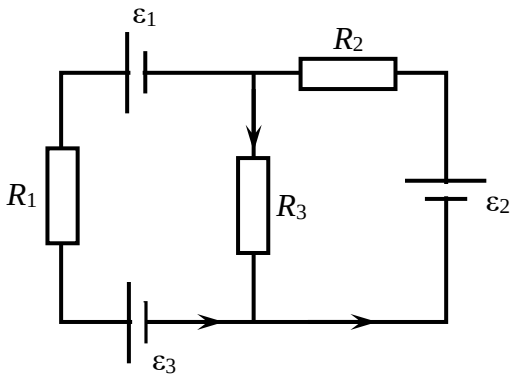


Calculate:

i. the equivalent resistance of the circuit.

ii. the p.d. across resistor *M*.

(62) **13. [T]** Consider the circuit shown below. All emf sources in the circuit have a negligible resistance.



The current through resistor R_1 is I_1, the current through resistor R_2 is I_2, and the current through resistor R_3 is I_3. The direction of the current in some of the branches is indicated by arrows.

Write the appropriate Kirchhoff's law to describe the relation between

a. I_1, I_2, and I_3;

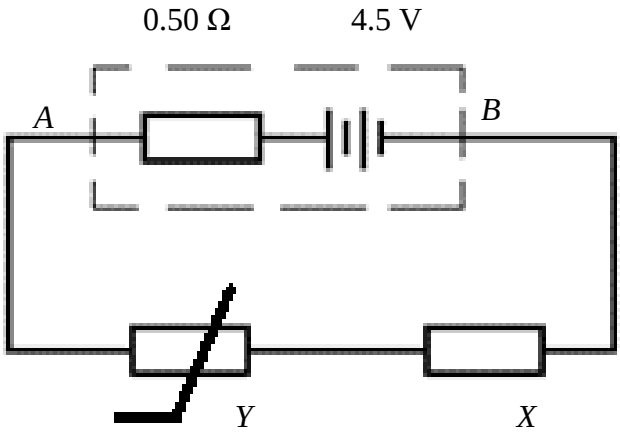
b. ε_1, ε_3, I_1, I_3, R_1, and R_3;

c. ε_1, ε_2, ε_3, I_1, I_2, R_1, and R_2;

(63) 14. [T]

a. Define a *volt*.

A battery C of e.m.f. 4.50 V and internal resistance 0.500Ω is connected in series with a resistor *X* and a thermistor *Y*, as shown in the diagram below.



a. Qualitatively explain what happens to the potential difference across *AB* as an ice cube is placed on the thermistor.

b. The ice cube is removed and after some time the resistance of *Y* becomes 8.0 Ω. The current in the circuit is then 0.220 A.

Calculate

i. the resistance of *X*;

ii. the p.d. across the cell;

iii. the amount of energy wasted in the cell every second.

Chapter 3 Mechanical Waves and Sound

Section 3.1 Types of Mechanical Waves

[64]**1. [G]** Define:
a. longitudinal wave;
b. transverse wave

Section 3.2 Mathematical Description of Periodic Waves

[65]**2. [G]** Calculate the period of a wave whose frequency is 120 Hz.

[66]**3. [G]** What is the phase difference between two consecutive troughs of a transverse wave?

[67]**4. [G]** The period of a wave, propagating along a taut rope, is 2.00 ms and its wavelength is 30.0 cm. What is the speed of this wave?

Section 3.4 Sound Waves

[68]**5. [G]** A light bulb, of power 20 W, emits light in all directions. Modeling the light bulb as a point source, what is the intensity of the radiation 0.50 m away from the bulb?

[69]**6. [G]** The intensity of a sound wave, emitted by a loudspeaker, is 40 mW/m^2. How will the detected intensity change, if the amplitude of the sound produced by the loudspeaker decreases twofold?

Section 3.5 Doppler Effect

[70]**7. [G]** An ambulance, emitting a sound wave of frequency 900 Hz, is receding from a stationary observer at 25 m/s. What is the frequency of the sound detected by the observer? Given: speed of sound in air = 340 m/s.

[71]**8. [T]** a. A high jumper, on his way to the hurdle, runs past a loudspeaker at the stadium. As the jumper approaches the loudspeaker at 6.0 m/s, she hears a sound of frequency 600 Hz. Given: speed of sound in air = 340 m/s.

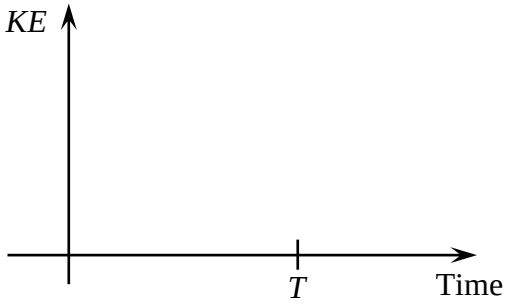
Determine the frequency of sound that is emitted by the loudspeaker.

The mass of the high jumper is 50 kg. During the jump, she can be modelled as a point object. The jumper leaves the ground at a speed of 6.4 m/s vertically upward. Given: $g = 9.80$ m/s^2.

b. Calculate the maximum height reached by the jumper.

c. Determine the greatest potential energy the jumper acquires with respect to the ground.

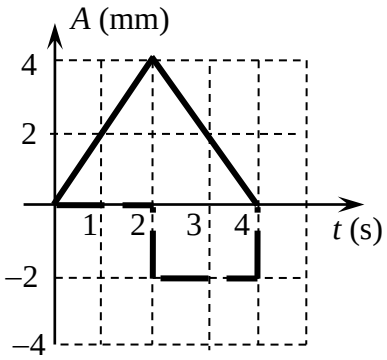
d. On the graph below sketch how the kinetic energy of the high jumper varies with time from the moment she leaves the ground to the moment $t = T$ when she falls back on the mat. No numerical values are necessary.



e. In reality, air drag acting on the jumper in not negligible. Describe qualitatively when the magnitude of the drag force on her is the greatest throughout her trajectory.

Section 3.6 Wave interference

[72]**9. [G]** The diagram below shows the displacement of two simplified wave forms (solid and dashed lines).



Use the principle of superposition of waves to determine the resultant displacement and draw the resultant wave.

Section 3.7 Standing Waves

[73]**10. [G]** Define the following points on a stationary wave:
a. node;
b. antinode.

[74]**11. [G]** Explain how a stationary wave is formed along a string fixed at both ends.

[75]**12. [G]** The fundamental frequency of a stationary wave along a string of fixed length, in an air column closed at one end, and in an air column open at both ends is the same and equal to 200 Hz.
In which pair of systems will the frequencies of all harmonics produced be identical? Explain your answer.

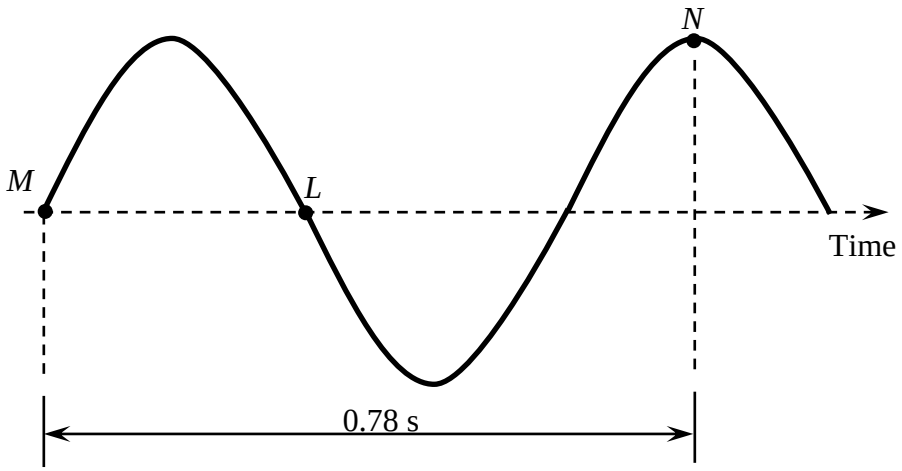
[76]**13. [T]** a. Show that the base unit of power is $kg.m^2/s^3$.

b. The frequency of a standing wave along a taut string is given by $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$, where T is the tension in the string, L is its length, and μ is a constant.
Use this information to determine the SI base units of μ.

c. A group of the students are measuring the current through a wire. Describe a situation when their measurements are
i. precise, but not accurate;
ii. accurate, but not precise.

(77)**14. [T]** a. Define the term "stationary wave."

b. The diagram below shows the oscillation with time of a medium's particle along a progressive wave. *M*, *L*, and *N* are three instants of time. The time interval between *M* and *N* is 0.78 s.



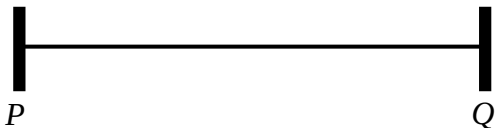
i. Determine the period of this wave.

ii. Determine the frequency of this wave.

iii. State the phase difference between instants *M* and *L*.

iv. The speed of the wave is 12 m/s. Calculate the wavelength of this wave.

c. Another progressive wave is used to form a stationary wave of fundamental frequency in a resonator *PQ*.

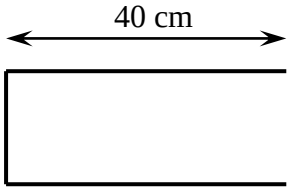


i. Sketch the displacement of the string at the instant the points of the wave have the maximum displacement.

ii. On your sketch locate the nodes and antinodes; label them by (N) and (A) respectively.
iii. The speed of the progressive wave forming this stationary wave is 250 m/s. The length of the string is 120 cm. Calculate

1. the fundamental frequency of wave;
2. the frequency of the fourth harmonic of this wave.

(78)**15. [T]** A pipe, of length L = 40 cm, is open at one end. A tuning fork is played next to the pipe to produce a stationary wave in the pipe.



a. Explain how a stationary wave forms.

b. On the diagram above sketch the positions of nodes and antinodes of the lowest possible harmonic that can be excited in this pipe.

c. State the phase difference between the node and antinode. Show your work.

d. Given: speed of sound in air = 340 m/s.

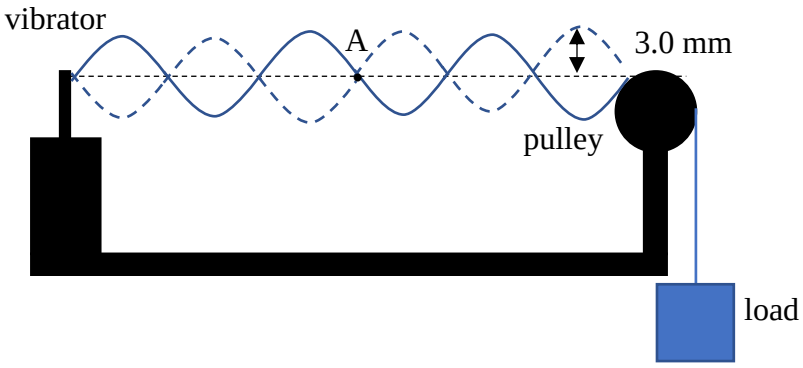
i. Determine the frequency of the lowest possible harmonic in the pipe.

ii. Determine the frequency of the next possible harmonic in the pipe.

e. The closed end of the pipe is now open. Will a stationary wave form if the tuning fork used to strike the pipe has the frequency determined in d.i? Explain your answer

(79)**16. [T]** a. Define stationary waves.

One end of a string is attached to a vibrator. The string is kept taut by attaching its other end to a load. The diagram below is not to scale.



The vibrator vibrates at frequency *f*, sending a transverse wave that travels along the string at 40 m/s to form a stationary wave. The maximum displacement of the rope from the equilibrium position is 3.0 mm. The distance between the vibrator and the pulley is 120 cm.

The snapshot (thick line) of the resulting pattern is made at t = 0 s.

b. Calculate the frequency *f*.

c. State the distance of point A on the string from the equilibrium position at times:
i. t = 5 ms.
ii. t = 2.5 ms.

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Chapter 4 Light Interference and Diffraction

Section 4.1 Electromagnetic Waves

[80]**1. [G]** The wavelength of a light wave propagating through vacuum is 650 nm. What is its frequency? Given: $c = 3.00 \times 10^8$ m/s.

Section 4.2 Light Polarization

[81]**2. [G]** Define light polarization.

[82]**3. [G]** A plane polarized light, of intensity 1.6 $mW.m^{-2}$, is incident at a Polaroid film whose transmission axis is at an angle of 30° with the incident wave's plane of polarization. What is, in $mW.m^{-2}$, the intensity of the transmitted light through the film?

[83]**4. [T]** a. Explain why the term "polarization" does not apply to longitudinal waves.

b. A plane polarized light has an intensity of 60.0 mW/m^2. It is incident on a polaroid film whose transmission axis is at an angle of 25° with the plane of the light's polarization.

i. Determine the intensity of the transmitted light.

ii. Determine the ratio of the amplitude of the incident light to that of the transmitted light.

Section 4.3 Diffraction of Waves

[84]**5. [G]** Water waves in a ripple tank are incident on a barrier with a gap. How will the diffraction pattern change when the gap gradually decreases?

Section 4.4 Interference of Waves

[85]**6. [G]** Two sound waves, of the same wavelength 40 cm and the same amplitude 1.2 mm, are incident at a certain point in space.

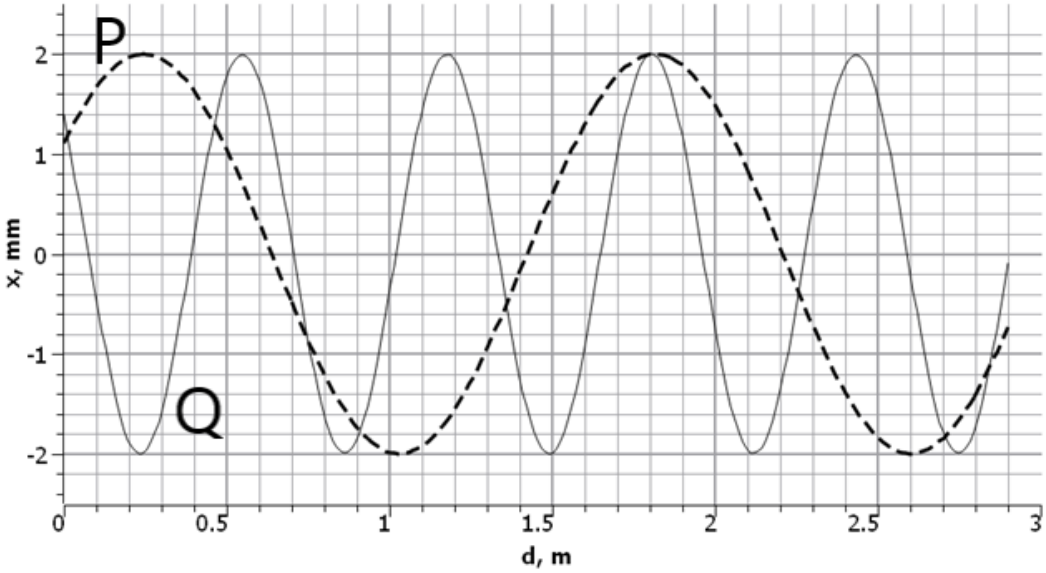
a. What smallest path difference between these waves will result in a constructive interference?

b. What smallest path difference between these waves will result in a destructive interference?

[86]**7. [G]** When are two light sources said to be coherent?

[87]**8. [G]** In a double-slit experiment the wavelength of the laser light is 632 nm, the separation of slits is 1.50 mm, and the slit-to-screen distance is 2.20 m. What is the distance between two consecutive bright fringes on the screen?

(88)**9. [T]** The diagram below shows the snapshot of two mechanical waves propagating in the same direction.



a. State one physical quantity of the waves that is the same.

b. State one physical quantity of the waves that is different.

c. Explain why these two waves are not coherent.

d. The waves now propagate through the same space simultaneously.

i. Indicate the position where the waves interfere constructively.

ii. Determine the amplitude of the resultant wave at the point identified in d.i.

e. The speed of the progressive wave is 200 m/s. Calculate the frequency of wave Q.

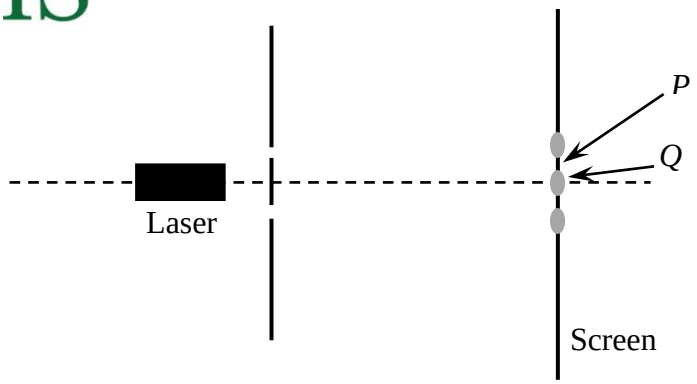
f. Compare the intensities of the waves P and Q. Explain your answer

Section 4.5 Diffraction Grating

(89)**10 .[G]** A laser light is incident on a diffraction grating with 150 lines/mm. The second order maxima is observed at an angle of 12° with the optical axis.

What is the wavelength of the laser light?

(90)**11. [T]** A laser beam passes through a plate with two slits, separated by 0.20 mm. On a screen, 1.50 m away from the slits, the bright spots are located 3.4 mm apart.



a. Calculate the wavelength of the laser used.

b. State the path difference between rays arriving at point *P*.

c. State the phase difference between rays arriving at point *Q*.

d. Assuming all other parts of the setup remain unchanged, describe the difference, if any, on the interference pattern if

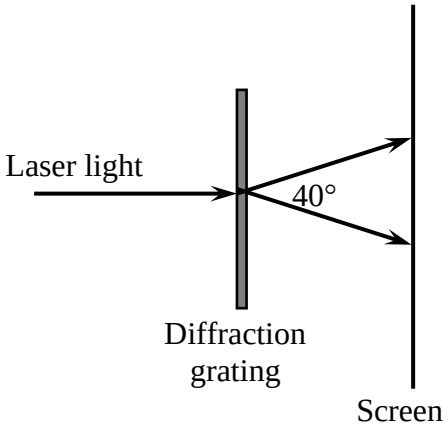
i. a laser of lower intensity is used;
ii. slits of smaller diameter are used;
iii. a diffraction grating is used.

(91)12. [T] a. Explain what a transverse wave is.

b. Explain in brief the nature of electromagnetic waves.

c. Explain what diffraction grating is.

d. When a laser light passes through a 400-lines/mm diffraction grating, the angle between the second order maxima is 40° as shown in the diagram below.



Determine the wavelength of the laser.

e. Describe the change, if any, in the order number of maxima seen on the screen in the following two cases:

i. a longer wavelength light is used in the experiment;

ii. the screen is moved further away from the diffraction grating.

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Chapter 5 Atomic Physics

Section 5.1 The Atomic Model

(92)**1. [G]** Describe the composition of an atom based on Rutherford's model.

Section 5.2 The Atom

(93)**2. [G]** Consider the following electrically neutral nuclide: $^{56}_{26}\text{Fe}$.

a. How many protons does it contain?
b. How many neutrons does it contain?
c. How many electrons does it contain?

(94)**3. [G]** Two nuclides are isotopes of the same element. What is true about
a. their proton numbers?
b. their nucleon numbers?

Section 5.3 Radioactivity

(95)**4. [G]** State the mass, the charge, and the typical speed of each of the following particles emitted in a radioactive decay?
a. alpha particles
b. beta particles
c. gamma ray

(96)**5. [G]** a. Alpha decay of gadolinium into samarium: $^{149}_{64}\text{Gd} \rightarrow {}^{-}\text{Sm} + {}^{-}\alpha$

b. Beta-minus decay of technetium into ruthenium: $^{99}_{43}\text{Tc} \rightarrow {}^{-}\text{Ru} + {}^{-}\beta^{-}$

c. Beta-plus decay of nitrogen into carbon: $^{12}_{7}\text{N} \rightarrow {}^{-}\text{C} + {}^{-}\beta^{+}$

(97)**6. [T]** A nucleus of mercury $^{175}_{80}Hg$ decays by the emission of an alpha particle and a photon of frequency 2.2×10^{20} Hz.
a. State the proton and the nucleon numbers of the Hg—175 nucleus.
b. Calculate the wavelength of the radiation produced in the decay.
c. List two ways by which the beam of alpha-particles and photons can be separated.

d. The α-particle emitted by the bismuth nucleus has an initial kinetic energy of 7.8×10^{-13} J. How many atoms can the alpha particle ionize, if the energy necessary to remove an electron from an atom of air molecules is, on average, 33 eV?

Section 5.4 Families of Particles

(98)**7. [G]** Name particles that are
a. hadrons;
b. leptons.

(99)**8. [G]** State the quark composition of the following particles:
a. protons
b. neutrons

(100)**9. [G]** List all flavors of quarks.

(101)**10. [G]** Describe what happens to quarks during a beta-minus decay.

(102)**11. [T]** a. Explain what a fundamental particle is.

b. Give an example of one sub-atomic particle that, in the presence of a charged object, will
i. change its motion;
ii. maintain its motion.

c. A hadron is made of three quarks.
i. What type of hadron is it?
ii. The hadron contains an up quark and a down quark. This hadron is also neutral. What is the flavor of its third quark? Explain your answer.

(103)**12. [T]**

a. Use the quark model to show that the charge of an antiproton is -1.

b. State the force responsible for keeping quarks of the antiproton together.

c. A nucleus of $^{112}_{53}I$ decays by the emission of a beta plus particle. A nucleus of $^{140}_{54}Xe$ decays by the emission of a beta minus particle.

i. Complete the table below to state the proton and neutron numbers of the nuclei produced in each of these decays.

	nucleus formed after $^{112}_{53}I$ decay	nucleus formed after $^{140}_{54}Xe$ decay
proton number		
neutron number		

ii. Name the antimatter particle produced in the beta plus decay. What family of particles does it belong to?

iii. Name the antimatter particle produced in the beta minus decay. What family of particles does it belong to?

Chapter 6 Fluids and Properties of Materials

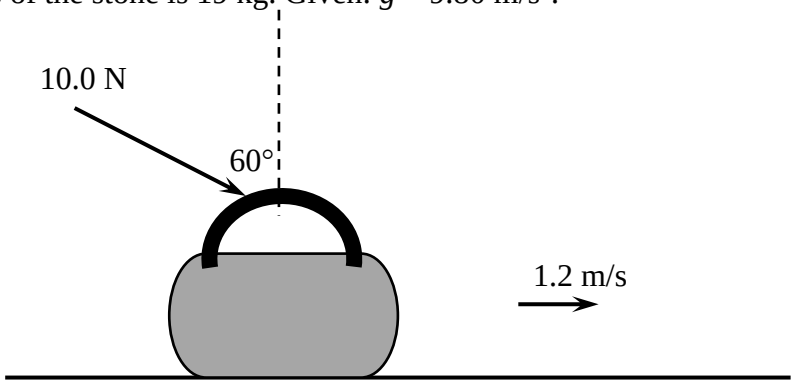
Section 6.1 Density

[104]**1. [G]** A metal solid ball has a radius of 2.0 cm and a mass of 90 g. What is, in kg/m^3, the density of the ball? Give your answer to the nearest integer.

Section 6.2 Pressure

[105]**2. [G]** A steel box is fully submerged in water at a depth of 30 cm below the surface of water. What pressure does water exert on the box? Given: ρ_{steel} = 7,000 kg/m^3, ρ_{water} = 1,000 kg/m^3, and g = 9.8 m/s^2.

[106]**3. [T]** An athlete is pushing a curling stone with a force of magnitude F = 10.0 N inclined at 60° with the vertical, so that the stone is moving along a horizontal road uniformly at 1.2 m/s. The mass of the stone is 19 kg. Given: g = 9.80 m/s^2.



a. Calculate the force of friction on the curling stone.

b. Calculate the power developed by the athlete.

c. Determine the pressure the curling stone exerts on the ground if its cross-sectional area is 615 cm^2.

d. Describe the forces that are reactions to the
   i. friction on the stone;
   ii. weight of the stone.

Section 6.3 Buoyancy

[107]**4. [G]** A solid sphere, of radius 4.0 cm, is fully submerged into a liquid of density 1,020 kg/m^3. What is the magnitude of upthrust acting on the sphere? Given: g = 9.8 m/s^2

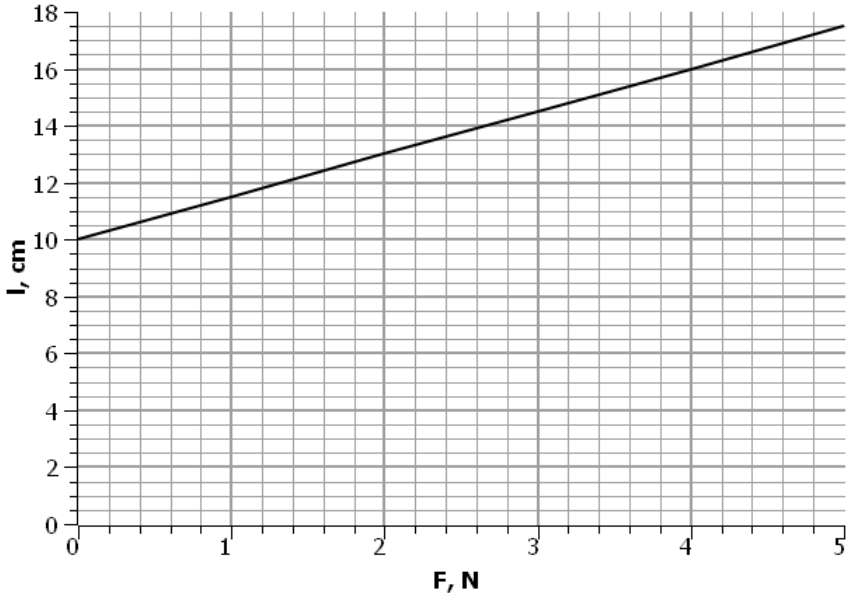
Section 6.4 Mechanical Properties of Materials

[108]**5. [G]** The gradient of a force versus extension graph for a given spring is 250 N/m. What is the magnitude of the force that stretches this spring by 5.0 cm?

[109]**6. [G]** A metal alloy rod, of length 2.0 m and cross-sectional area of 2.4 ×10^{-5} m^2, is subjected to a tensile force of magnitude 1,200 N. As a result, the length of the rod increases by 0.50 mm.

a. What is the stress in the rod?
b. What is the strain in the rod?
c. What is the Young modulus of the alloy the rod is made of?

[110]**7. [T]** The graph below shows the variation of the length of a spring with the force applied to it.



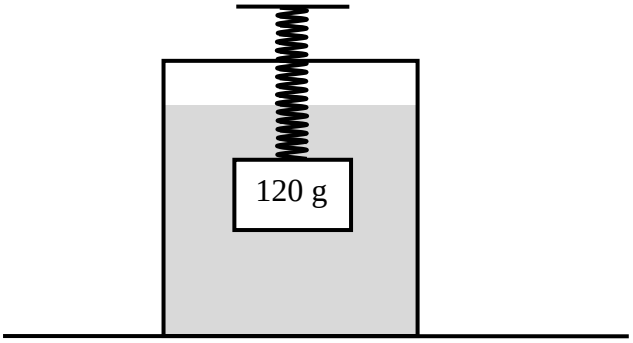
a. Which aspect of this graph shows that the spring obeys Hooke's law?

b. Determine, in N/m, the spring constant of the spring.

c. What work should be done on the spring to stretch it from a length of 10 cm to a length of 12 cm?

A block, of mass 120 g and density 2,700 kg/m^3, is attached to the spring and hung vertically. Given: g = 9.80 m/s^2.
d. Calculate the extension of the spring.

e. The block is now immersed into a glass filled with a liquid as shown below.

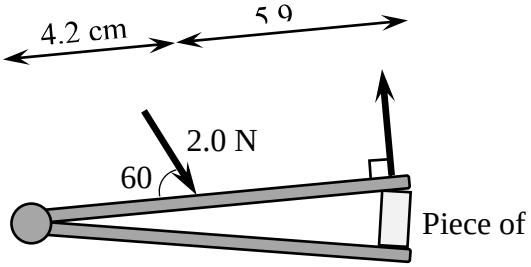


i. With reference to pressure, explain why the extension of the spring becomes smaller than the value calculated in d.

ii. The extension of the spring becomes 1.1 cm. Use this information to determine the density of the liquid.

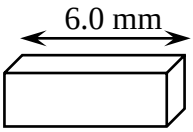
(111)**8. [T]** a. State the principle of moments.

Tweezers are used to hold small objects. A 2.0 N pushing force exerted by the fingers holding the tweezers is applied 4.2 cm from the pivot and directed at 60° with the plane of the handle. The load is located 5.9 cm further away and exerts a force normal to the plane of the handle.



b. Calculate the net force exerted by the piece of metal on one of the handles.

c. The tweezers are used to compress a rectangular piece of wire. The density of the wire is 8,730 kg/m^3 and its weight is 0.011 N.



Cross-sectional

i. Calculate the cross-sectional area of the wire.

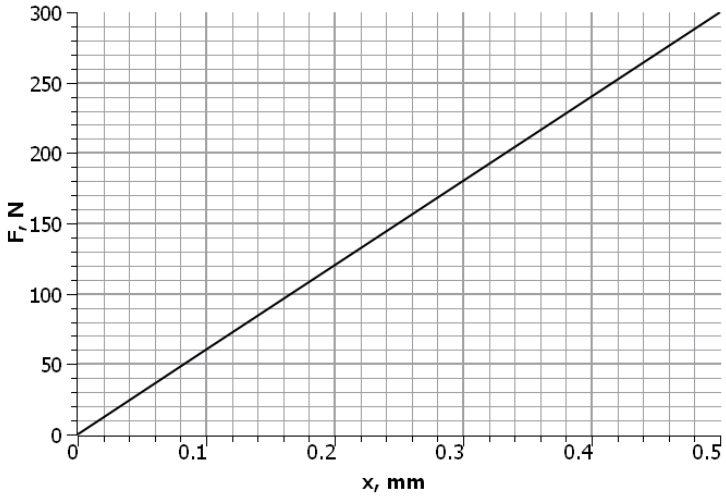
ii. The wire is held by the tweezers such that the force is applied to the faces whose cross-sectional area was calculated in c.i. Determine the stress on the wire as it is squeezed between the handles of the tweezer.

(112)**9. [T]** a. Formulate Hooke's law in terms of

i. absolute extension of an elastic material;

ii. relative extension of an elastic material.

b. A tin rod, of initial length L = 1.0 m, has a cross-sectional area of A = 12 mm^2. The students want to determine the Young modulus, E, of the rod. The following graph shows how the rod's length varies with a force exerted on one of its ends.



i. Derive an expression for finding Young modulus in terms of the given and the slope of the graph.

ii. Determine the Young modulus of tin.

iii. Calculate the work that should be done on the rod to change its length from 1.0000 m to 1.0004 m.

iv. Tin is a very malleable material: its shape and dimensions are easily changed by hammering and pressure. What does this say about the elastic limit of tin relative to less malleable materials? Explain your answer.

c. Another group of students measured the Young modulus of a steel wire and obtained the following result: $E = 180.0 \pm 0.9$ GPa. The reference book of the mechanical properties of materials states that the Young modulus for this type of steel is $E = 205 \pm 5$ GPa. State and explain whether the students' result is

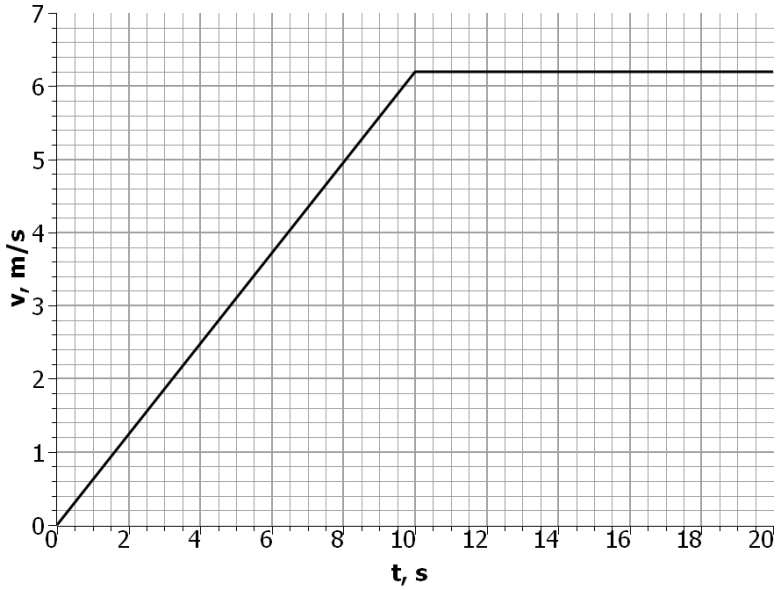
i. accurate;
ii. precise.

(113)10. [T]

a. State Newton's third law of motion.

b. A tractor is towing a car stuck on a muddy road as shown below.

The graph below shows the variation of the velocity of the tractor with time.



i. Calculate the initial acceleration of the tractor.

ii. Calculate the distance travelled by the tractor in the following time intervals:
1. $t = 0$ s and $t = 10$ s;
2. $t = 10$ s and $t = 20$ s.

iii. Once on level road (t > 10 s), the resistive force on the car is 400 N and that on the tractor is 550 N.

1. Determine the tension in the tow-bar cable.
2. Determine the force exerted by the engine of the tractor.
3. Determine the work done by the tractor engine from t = 10 s to t = 20 s.

c. While the tractor pulls the car out of the mud, a stress of 1.8 GPa in the cable stretches it by 3.0% of its initial length. Determine the Young modulus of the cable.

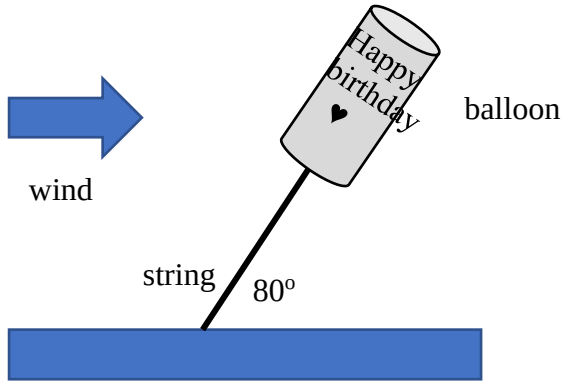
d. At t = 15 s, the tractor driver notices another car, resting on a curb ahead, and blows the horn of frequency 700 Hz. What is the frequency of sound detected by the driver in the resting car? Given: speed of sound in air = 340 m/s.

(114)11. [T]

a. Complete Fig. 1.1 by putting a tick (√) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

Quantity	Scalar	Vector
displacement		
potential energy		
strain		
velocity		

A helium balloon is tied to the ground as shown below.



b. The balloon, which can be modelled as a cylinder, is in equilibrium, with the string at an angle of 80° to the horizontal. Assume that the force on the balloon due to the wind is in a horizontal direction.

The radius of the balloon is 4.0 cm and its height is 25 cm. Its density is 0.50 $kg.m^{-3}$.

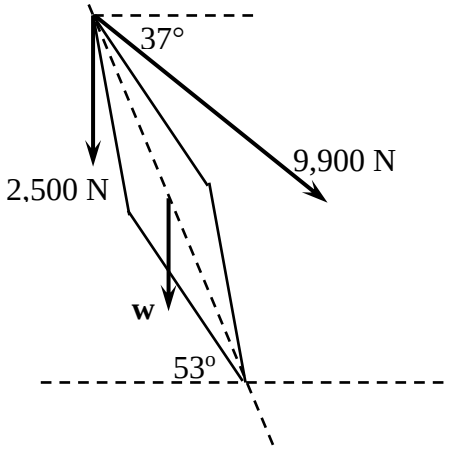
(i) Show that the weight of the balloon is 6.1 mN.

(ii) The tension in the string is 8.8 mN. Determine the upthrust acting on the sphere.

(iii) Would you expect the density of air to be greater or smaller than the density of the balloon? Explain your answer.

(115)12. [T] a. Explain what is meant by rotational equilibrium.

b. The arm of a crane is uniform and held in equilibrium by a cable. The arm makes an angle of 53° with the horizontal and the cable supporting the arm makes an angle of 37° with the horizontal. The weight of the load of the crane is 2,500 N and the tension in the cable is 9,900 N.



i. Name one more force that acts on the crane's arm. On the diagram label its point of application *P*.

ii. Using the given information and the diagram above, deduce the weight of the crane's arm.

c. The graph below shows how the strain in the cable of the crane varies with the stress on it.

i. State Hooke's law.

ii. Calculate the Young modulus of the material the cable is made of.

iii. List additional quantities you need to know to determine the elastic potential energy stored in the cable for a given strain.