Physics Solution-2016

14. For first particle, $X : \frac{d}{2}$ is traveled at 30 km/hr in time t_1

    Remaining $\frac{d}{2}$ at 45 km/hr in time t_2

    $\frac{Dist}{Speed} = \frac{d}{2 \times 30 \ \ km/hr} = t_1$

    $\frac{d}{2 \times 45 \ \ km/hr} = \frac{d}{90} = t_2$

    Total time given is $2hrs = t_1 + t_2$

    $\frac{d}{60} + \frac{d}{90} = 2$

    $\rightarrow d = 72 \ \ km \cdots (1)$

    For second particle, Y: using $s = ut + \frac{1}{2}at^2$(Kinematic Equation)

    where $u = 0 \ \ s = 72$ (By (1)) and $t = 2hrs \rightarrow 72 = \frac{1}{2} \times a \times 42$

    $a = 36 \ \ km/hr^2$

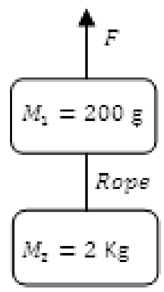
    for Y, time required to attain 45 km/hr at $a = 36$ is (using $v = u + at; u = 0$)

    $45 = 36 \times t$

    $\therefore t = \frac{5}{4}hrs = 75 \ \ minutes$

    Ans: 75

15. Draw FBD (Free Body Diagram) for both blocks separately

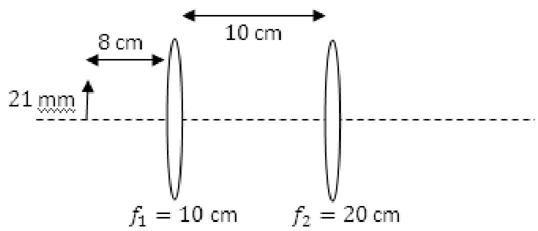


For 2 kg block: for maximum tension condition,
Weight, W (downwards) = mg = 20 N and
T (upwards) = Tension in the rope (Uniform since the rope is light) = 80 N (Given)
$\therefore F_{net} = T - W = 60$ N
$\therefore a = \frac{F_{net}}{m} = 30$ m/s^2
The rope is inextensible $\rightarrow$ both blocks experience same acceleration
Now for 0.2 kg block: for maximum tension condition,
Weight, W (downwards) = mg = 2 N and
Tension, T (downwards) = 80 N
external force, F (upwards), and
$a = 30$ m/s^2
$\therefore F_{net} = ma = 6$ N and is acting upwards
But $F_{net} = F - (T + W)$

$\therefore F = F_{net} + (T + W) = 88$ N
Ans: 88

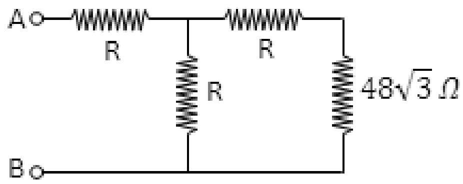
16. Initial distance between plates is 20 m.
    As both are moving towards each other with 5 m/s, the relative velocity between two plates is 10 m/s
    Time required to cover distance of 20 m $= \dfrac{20}{10} = 2$ s.
    Hence the ball is travelling for 2 s only with constant sspeed of 25 m/s.
    So it will travel $2 \times 25 = 50$ m.
    Ans: 50

17. Using cartesian sign convention:



For 1st convex lens, $u = -8$ cm, $f = +10$ cm. Object size = 21 mm
Using Len's Formula: $\dfrac{1}{v} = \dfrac{1}{f} + \dfrac{1}{u}$
$\therefore \dfrac{1}{v} = \dfrac{1}{10} - \dfrac{1}{8} = \dfrac{-1}{40}$
$\therefore v = -40$ cm which means image will form to left of 1st lens
Magnification by 1st lens $= \dfrac{-v}{u} = -\dfrac{(-40)}{8} = 5$
$\therefore$ size of image $= 5 \times 21$ mm (original size) $= 105$ mm.
This image by 1st lens will act as object for second lens.
For 2nd convex lens, $u = -(40 + 10) = -50$ cm , $f = +20$ cm and object size = 105 mm
Using Len's Formula: $\dfrac{1}{v} = \dfrac{1}{f} + \dfrac{1}{u}$
$\dfrac{1}{V} = \dfrac{1}{20} - \dfrac{1}{50} = \dfrac{3}{100}$
$\therefore v = +\dfrac{100}{3}$ cm
Magnification by 2nd lens $= \dfrac{-v}{u} = \dfrac{-(100/3)}{50} = \dfrac{-2}{3}$
$\therefore$ Final size $= \dfrac{2}{3} \times 105$ mm $= 70$ mm.
Ans: 70

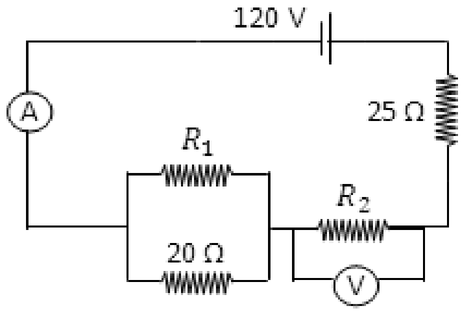
18. Consider the circuit



Let $48\sqrt{3} = x$
In the circuit, x is in series with R giving resistance $(x + R)$,
$(x + R)$ is in parallel with R, giving
Resistance $= \dfrac{R(x+R)}{R+(x+R)}$
This resistance is in series with R giving total resistance of circuit as $= R + \dfrac{R(x+R)}{2R+x}$
But resistance of circuit is given as x,
$\therefore x = \dfrac{R(2R+x)+R(x+R)}{2R+x}$
$x(2R+x) = R[(2R+x)+(x+R)]$
$2Rx + x^2 = R[3R+2x]$
$2Rx + x^2 = 3R^2 + 2xR$
$x^2 = 3R^2$
$48 \times 48 \times 3 = 3 \times R^2 \therefore R = 48\Omega$
Ans: 48

19. Let the speed of the bus be V km/h, Speed of cyclist is 20 km/h
T is time in minutes between start of two buses at A or B
Relative speed of the bus stating from A, as seen by the cyclist $= (V - 20)$ km/h,
Relative speed of the bus starting from B as seen by the cyclist $= (v + 20)$ km/h
Distance between 2 buses starting from $A = \dfrac{18}{60}(V - 20)$ km
Distance between 2 buses starting from $B = \dfrac{6}{60}(V + 20)$ km
However in both cases, distance between two buses is the same $= V(\dfrac{T}{60})$ km
$\therefore \dfrac{6}{60}(V+20) = \dfrac{18}{60}(V-20) = V\dfrac{T}{60}$
$V + 20 = 3V - 60$ which gives $V = 40$.
Substituting for V and solving for T,
$6(40 + 20) = 40T$
$\therefore T = 9$ min
Ans: 9

20. Consider the circuit



The current in the circuit is 2 A, and Voltage of source is 120 V
$therefore$ Total resitsnace of circuit $= \frac{V}{I} = \frac{120}{2} = 60\ \Omega$
Now, current flowing through R_2 is 2 A,
Voltage acrooss R_2 is 40 V,
$\therefore R_2 = \frac{V}{I} = 20\ \Omega$
Equivalent Resistance of R_1 in parallel with 20 Ω resistor is $= \frac{20R_1}{20 + R_1}$
Total Resistance in the circuit is
$25\ \Omega + 20\ \Omega + \frac{20R_1}{20 + R_1}\ \Omega = 60\ \Omega$
$60 = 45 + \frac{20R_1}{20 + R_1}$
$15(20 + R_1) = 2R_1$
$300 + 15R_1 = 20R_1$
$300 = 5R_1$
$R_1 = 60\ \Omega$
Ans: 60

21. Heat generated during 1st half of the fall for raindrop = loss in mechanical energy during the motion
Heat generated = Loss in ME = Loss in PE + loss in KE,
Note that loss in KE will be negative as velocity of raindrop increases during this motion
Heat generated $= mg(h_2 - h_1) - \frac{1}{2}mV^2$
$= 0.01 \times 10 \times (500 - 250) - \frac{1}{2} \times 0.01 \times 10^2$
$= 25 - 0.5$ J $= 24.5$ J. Nearest integer is 25
Ans: 25

22. Given: $F = 100\ N \quad u = 0 \quad m = 400\ kg$
F = ma
$\therefore 100 = 400 \times a$
$\therefore a = \frac{100}{400} = 0.25\ m/s^2$
As v = u + at (kinematic equation),
v after 3 s $= 0 + 0.25 \times 3 = 0.75$ m/s

Power = F.v
$\therefore p = 100 \times 0.75 = 75$ watt
Ans: 75

23. Given: Refractive indices $\eta_{air} = 1$ and $\eta_{liquid} = \sqrt{5}$
diameter of disc=66 m and point source is 33mm above its center
Considering the light ray touching the disc's circumference,
It makes angle of 45°
Using Snell's law for refraction at air-water interface
$\eta_{air} \sin 45° = \eta_{liquid} \sin r$
$\therefore \frac{1}{\sqrt{2}} = \sqrt{5}. \sin r$
$\therefore \sin r = \frac{1}{\sqrt{10}}$
$\therefore \cos r = \sqrt{1 - \frac{1}{10}} = \frac{3}{\sqrt{10}}$
$\therefore \tan r = \frac{\sin r}{\cos r} = \frac{1}{3}$
It can be seen that,
$\tan r = \frac{The\ extra\ radius\ of\ shadow\ (other\ than\ disc\ itself)}{The\ depth\ of\ the\ water}$
The depth is 33 mm, hence we get extra radius of shadow as 11 mm
$\therefore$ The total diameter of shadow is $11 + 66 + 11 = 88$ mm

Ans: 88

24. For upward motion
While going upwards as both forces (friction and weight) act downwards,
acceleration $= g + \frac{g}{5} = \frac{6\ g}{5}$ and is acting downwards
Let initial speed be u and T_1 be total time for upward travel, final speed v = 0.
$\therefore 0 =$ u + a T_1
$\therefore u = \frac{6\ g}{5} \times T_1$
$\therefore T_1 = \frac{5\ u}{6\ g}$
Height reached during upward motion H can be derived using v^2 = u^2 + 2as
$\therefore 0 = u^2 + 2 \times -(\frac{6\ g}{5}) \times H$
$\therefore H = \frac{5u^2}{12g}$
For downward motion; acceleration $= g - \frac{g}{5} = \frac{4\ g}{5}$ and is acting downwards
using $s = ut + \frac{1}{2}at^2$, where $s = -H, u = 0, t = T_2$
$-H = 0 + \frac{1}{2} \times -(\frac{4\ g}{5}) \times (T_2)^2$
$\therefore \frac{5\ u^2}{12\ g} = \frac{2\ g}{5} T_2^2$

$\therefore T_2^2 = \dfrac{25\ u^2}{24\ g^2}$

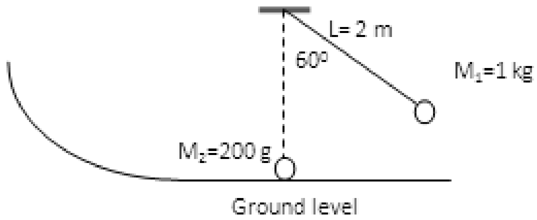
Now, N $= 30 \times (\dfrac{T_1}{T_2})^2$

$\therefore N = 30 \times \dfrac{25\ u^2}{36\ g^2} \times \dfrac{24\ g^2}{25\ u^2}$

$\therefore N = 20$

Ans: 20

25. Consider the figure



When pendulum is taken up through 60°,

increases in potential energy $= mgL(1 - \cos 60°) = 1 \times 10 \times 2 \times [1 - \dfrac{1}{2}]$

$= \dfrac{2}{10} \times 2[1 - 1/2] = 10$ J

When pendulum reaches lowest point, loss in PE = gain in KE

$\frac{1}{2} \times m \times V^2 = \dfrac{1}{2} \times 1 \times V^2 = 10$

$\therefore V = \sqrt{20}$ i.e. $V = 2\sqrt{5}$

M_1 collides with stationary M_2, after collision M_1 is stationary and M_2 moves with V_2

Conserving linear momentum during collision,

$1 \times 2\sqrt{5} = \frac{2}{10} \times V_2$

$\therefore V_2 = 10\sqrt{5}$

for motion of M_2 up the curve, applying conservation of mechanical energy

$\frac{1}{2}mv^2$(loss in KE) $= mgh$ (gain in PE)

$\therefore \frac{1}{2} \times \frac{2}{20} \times (10\sqrt{5})^2 = \frac{2}{10} \times 10 \times h$

$\therefore h = 25$ m

Ans: 25

26. Acceleration due to gravity of planet, $a_p = \dfrac{m_p \times G}{(r_p)^2} = 6.7\ m/s^2$ (given)

$\therefore 6.7\ m/s^2 = \dfrac{m_p \times 6.7 \times 10^{-11}}{(4700 \times 10^3)^2}$

$\therefore m_p = 2209 \times 10^{21}\ kg = 2209 \times 10^{24}\ gm$

Density$=\dfrac{Mass}{Volume}$

$\therefore$ Density $= \dfrac{2209 \times 10^{24}\ g}{\dfrac{4}{3} \times \dfrac{22}{7} \times (42 \times 10^7)^3\ cc}$

$\therefore$ Density = 6 gm/cc

Ans: 6

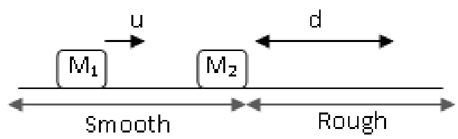
Physics Solution-2015

14. Displacement $S = A - Bt + Ct^2 \therefore S = 6 - 3t + t^2$
Differentiating w.r.t. to t, we get Velocity V = -3 + 2 t
$Furtherdifferentiatingw.r.t.tot, wegetAccelerationA = 2$
At t = 4, V = -3 + 2 (4) = 5 m/s
Att= 4, A = 2 m/s^2
Force on the body = $ma = 4 \times 2 = 8$ N
Power delivered = $F.V$
$\therefore P = 8 \times 5 = 40$ W
Ans: 40

15. A constant force acts, hence constant acceleration.
By Newton's second law, $a = \dfrac{F}{m} = \dfrac{F}{2}$
Using, $v^2 = u^2 + 2\ as$, where $v = 6$ m/s, $u = 0$ m/s and $s = 2$ m
$36 = 2 \times \dfrac{F}{2} \times 2$
$\therefore F = 18$ N
Ans: 18

16. Given, frequency of throw is 2 balls/sec.
$\therefore$ 1 ball is thrown after 1/2 sec.
$\therefore$ any ball reaches the top in 1/2 sec.
For upward motion of 1/2 sec,
u = initial velocity, v = final velocity = 0 and a = -10 m/s^2.
$v = u + at$
$\therefore u = \frac{1}{2} \times 10 = 5$ m/s
To get height attained, $v^2 = u^2 + 2\ as$
$\therefore s = \frac{u^2}{2\ g} = \frac{25}{2 \times 10} = 1.25$m
$\therefore$ Height H = $s = 125$ cm, so $\dfrac{H}{5} = 25$
Ans: 25

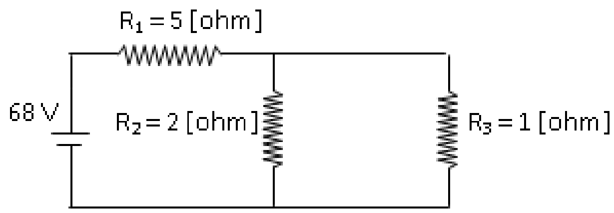
17. Consider the figure



Given, $M_1 = 1\ kg, M_2 = 2\ kg, u = 4\ m/s, d = 20\ cm$
M_1 moves with 4 m/s towards right and collides with M_2 at rest
By conservation of linear momentum,

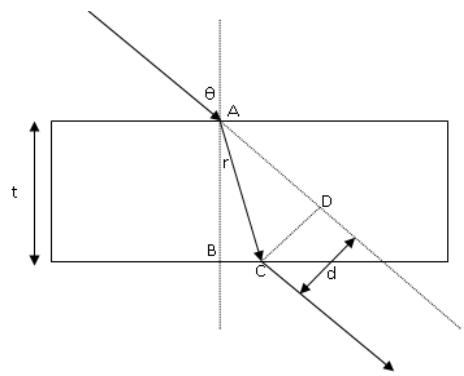
$M_1u_1 + M_2u_2 = M_1V_1 + M_2V_2$
$\therefore 1 \times 4 + 2 \times 0 = 1 \times 0 + 2 \times V_2$
$\therefore 4 = 2 \times V_2$
$\therefore V_2 = 2$ m/s.
After collision, M_2 begins to move with 2 m/s and stops after traveling a distance 20 cm.
Using $v^2 = u^2 + 2\ as$, we get
$0 = (2)^2 + 2 \times a \times 0.2$
$\therefore O = 4 + 0.4\ a$
$\therefore a = \dfrac{-4}{0.4} = -10$ m/s^2.
Frictional force $= ma = 2 \times 10 = 20$ N
Ans: 20

18. Consider given circuit,



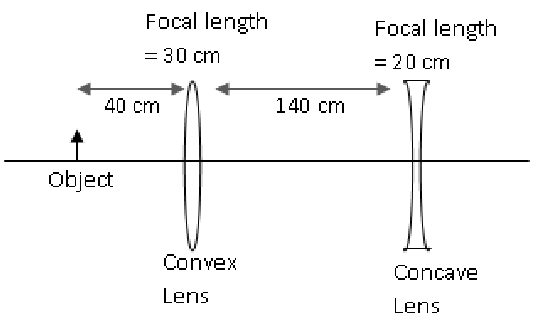
R_2 and R_3 are in parallel and this combination is in turn in series with R_1.
$\therefore$ Resistance of the circuit $R_T = R_1 + \dfrac{R_2 \times R_3}{R_2 + R_3}$
$\therefore R_T = 5 + \dfrac{2}{3} = \dfrac{17}{3}$
In the circuit, current through battery, $I = \dfrac{V}{R_T} = \dfrac{68}{17/3} = 12$ A.
$\therefore$ 12 A current is passing through R_1.
$\therefore$ Voltage drop across $R_1 = IR_1 = 12 \times 5 = 60$ V.
$\therefore$ Potential difference across R_2 or R_3 is $68 - 60 = 8$ V.
$\therefore$ Power dissipated in $R_2 = \dfrac{V^2}{R_2} = \dfrac{(8)^2}{2} = 32$ W
Ans: 32

19. Please refer to figure



Slab's refractive index is $\sqrt{3}$. Applying Snell's law at point A:
$1 \times sin\theta = \sqrt{3} \times sin\ r$
$\therefore \frac{\sqrt{3}}{2} = \sqrt{3} \times sin\ r$
$\therefore \frac{1}{2} = sin\ r$ i.e. $\angle r$ or $\angle$ BAC $= 30°$
$\therefore \angle$ CAD $= \theta - r = 60° - 30° = 30°$
Consider $\triangle$ ABC:
$cos\ r = cos\ 30° = \frac{\sqrt{3}}{2} = \frac{AB}{AC} = \frac{t}{AC}$
$\therefore \frac{\sqrt{3}}{2} = \frac{17\sqrt{3}}{AC}$
$\therefore AC = 34$
Consider $\triangle$ ACD:
$sin(\theta - r) = sin\ 30° = \frac{1}{2} = \frac{CD}{AC} = \frac{d}{AC}$
$\therefore \frac{1}{2} = \frac{d}{34}$ $\quad\quad \therefore d = 17$
Ans: 17

20. Using cartesian sign convention:

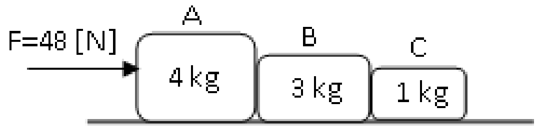


For 1st convex lens, $u = -40$ cm, $f = +30$ cm.
Using Len's Formula: $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$
$\therefore \frac{1}{v} = \frac{1}{30} - \frac{1}{40} = \frac{-1}{120}$
$\therefore v = +120$ cm which means image will form to right of 1st lens
This image by 1st lens will act as object for second lens.
For 2nd concave lens, $u = -(140 - 120) = -20$ cm , $f = -20$ cm
Using Len's Formula: $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$
$\frac{1}{v} = -\frac{1}{20} - \frac{1}{20} = -\frac{2}{20}$
$\therefore v = -10$ cm i.e. image will be at 10 cm from concave lens on left side
Ans: 10

21. Capacity of bowl, $V = 300$ cc and mass of bowl $= 236$ gm
Using Archimedes Principle: for floating system, $F_{buoyant}$ i.e weight of water dis-

placed = weight of system
$\therefore F_{buoyant}$ = Volume of water displaced $\times$ density $\times$ g = Total mass of system $\times$ g
Maximum volume of water displaced = capacity of bowl = 300 cc
Total mass of system = mass of bowl + mass of oil
$\therefore$ 300 $\times$ 1 (density of water) = 236 + mass of oil
$\therefore$ mass of oil = 64 g = Volume of oil $\times$ density
$\therefore$ volume of oil $= \dfrac{64}{0.8} = 80$ cc
Ans: 80

22. Draw 2 separate FBDs, 1 for entire system of 3 blocks and FBD for block A



For system of 3 blocks:
Total mass $= 4 + 3 + 1 = 8$ kg
$a = \dfrac{F}{m} = \dfrac{48}{8} = 6$ m/s^2
This acceleration is same for all 3 blocks.
Now for block A:
its acceleration is 6 m/s^2
F_{net} on block A = ma = 4 $\times$ 6 = 24 N
2 horizontal forces are acting on block A, External force, F and force applied by B on A
$\therefore$ force applied by B on $A = F - F_{net} = 48 - 24 = 24$N
Ans: 24

23. Draw FBD of the elevator
2 forces are acting on elevator, its weight acting downwards (= mg) and tension in the cable, T acting upwards
It is accelerating upwards with a = -2 m/s^2 $\therefore F_{net} = ma = 700 \times 2$
But $F_{net} = mg - T$
$\therefore (700)(10) - T = (700)(2)$
$\therefore T = (700)(8) = 56 \times 10^2$ N
Ans: 56

24. $g = \dfrac{GM}{R^2}$
Let mass of the astronaut = m
Weight on earth $= m \times g_{earth} = m\dfrac{G \times M_{earth}}{R^2_{earth}} = 120$
$\therefore m = \dfrac{120 \times R^2_{earth}}{G \times M_{earth}}$
Weight on mars $= m \times g_{mars} = m\dfrac{G \times M_{mars}}{R^2_{mars}} = k(say)$

$\therefore m = \dfrac{k \times R_{mars}^2}{G \times M_{mars}}$

$\therefore \dfrac{120 \times R_{earth}^2}{G \times M_{earth}} = \dfrac{k \times R_{mars}^2}{G \times M_{mars}}$

$\therefore k = 120 \times (\dfrac{M_{mars}}{M_{earth}}) \times (\dfrac{R_{earth}^2}{R_{mars}^2})$

$\therefore k = 120 \times (\dfrac{1}{10}) \times (\dfrac{2}{1})^2$

$\therefore k = \dfrac{120 \times 4}{10} = 48$

Ans: 48

25. Given $A = \dfrac{100}{\pi} cm^2 = \dfrac{1}{100\pi} m^2$

$N = 100\ turns, f = 50\ Hz, B = 0.1\ Tesla, t = \dfrac{1}{40} sec$

Formula: $V = 2\pi f\ NAB \sin(2\pi\ f\ t)$

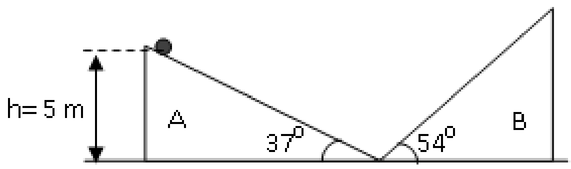
Substitute given values generated

$V = 2\pi \times 50 \times 100 \times \dfrac{1}{100\pi} \times 0.1 \times \sin(2\pi \times 50 \times \dfrac{1}{40})$ volts

$\therefore V = 10 \times \sin(\dfrac{5\pi}{2}) = 10 \times 1 = 10$ volts

Ans: 10

26. consider the figure



Particle travels down the slope of A and then travels up the slope of B

Using conservation of mechanical energy,

PE at top of A = PE at top of B

$\therefore mgh_A = mgh_B$, hence $h_B = 5$ m

Oscillation motion of the particle can be considered to be composed of:

down the length of slope of A (S_A), then up the length of slope of B (S_B), then down the slope S_B and then up the slope S_A

Since no friction present, time required for moving along S_A is same while going upwards or downwards

Also, time required for moving along S_B is same while going upwards or downwards

So we will calculate time required for downward motion for both the slopes

For slope $S_A, u = 0$ m/s,

s $= \dfrac{h_A}{sin37°} = \dfrac{5}{0.6} = \dfrac{25}{3}$ m and

a $= g \sin 37° = 10 \times 0.6 = 6$ m/s^2

$s = ut + 1/2\ at^2 \therefore \dfrac{25}{3} = \dfrac{1}{2} \times 6 \times t^2$

$\therefore t_A = 5/3$ sec

For slope $S_B, u = 0$ m/s,

s $= \dfrac{h_B}{sin54^\circ} = \dfrac{5}{0.8} = \dfrac{25}{4}$ m and
a $= g\sin 54^\circ = 10 \times 0.8 = 8$ m/s^2
$s = ut + 1/2\ at^2 \therefore \dfrac{25}{4} = \dfrac{1}{2} \times 8 \times t^2$
$\therefore t_B = 5/4$ sec
T = time period for 1 complete oscillation $= t_A + t_B + t_B + t_A$
$\therefore 5T = 5 \times 2(\frac{5}{3} + \frac{5}{4}) = 10(\frac{35}{12}) = 29.166$
Ans: 29

Physics Solution-2014

1. $v^2 = \dfrac{3RT}{M}$
   Checking for units, v^2 is in m/s^2 $= \dfrac{Joule}{Mole \times kelvin} \times \dfrac{kelvin}{gram/mole}$
   $= \dfrac{Joule}{Gram} = \dfrac{kg}{Gram} \times \frac{m^2}{s^2} = \dfrac{10^3 \times Gram}{Gram} \times \dfrac{m^2}{s^2} = 10^3 \times \dfrac{m^2}{s^2}$.
   $\therefore$ we get $v^2 = 10^3 \times \dfrac{3\ RT}{M}$, where M is expressed in gram /mole
   Substituting given values in the formula, we get
   $v^2 = 10^3 \times \dfrac{3 \times 8.4 \times 300}{25}$
   $v^2 = 10^5 \times \frac{3\times 8.4\times 3}{25} = 3.024 \times 10^5$
   $\therefore$ n = 5
   Ans: 5

2. For 2^{nd} stone:
   $u_2 = 0$, $t_2 = 1.5$ sec and $a = g = -10$ m/s^2
   $s_2 = u_2t_2 + \dfrac{1}{2}at_2^2$
   $\therefore s_2 = -5\ (1.5)^2 = -5\ (2.25)$m
   For 1^{st} stone dropped 2 sec earlier to 2^{nd} stone:
   $u_1 = 0$, $t_1 = 2 + 1.5 = 3.5$ sec and $a = g = -10$ m/s^2
   $s_1 = u_1t_1 + \dfrac{1}{2}at_1^2$
   $\therefore s_1 = -5\ (3.5)^2 = -5\ (12.25)$m
   D = distance between the stones $= s_1 - s_2$, taking numerical values
   $\therefore$ D = 5 (12.25) − 5 (2.25) = 5 (10) = 50 m
   Ans: 50

3. The buoy after being dropped in water moves downstream with speed of water
   For boat going upstream,
   speed of boat = 7 m/s and speed of water= 3 m/s
   $\therefore$ speed of boat w.r.t. banks = 7 − 3 = 4 m/s (as it is going against the water)
   distance= 4.2 km = 4200 m
   $\therefore$ Time $t_{up} = \dfrac{Distance}{Speed} = \dfrac{4200}{4} = 1050$ sec

During this time buoy has travelled $1050 \times 3 = 3150$ m
Hence it is at $4200 + 3150 = 7350$ m away from the boat ater time, t_{up}
For boat going downstream,
speed of boat $= 7\ m/s$ and speed of water= 3 m/s
$\therefore$ speed of boat w.r.t. banks $= 7+3 = 10$ m/s (as it is going with the flow of water)
Let the buoy travel distance x with speed 3 m/s before the boat catches up
$x =$ Speed $\times$ time $= 3 \times t_{buoy}$
for boat, $t_{down} = \dfrac{Distance}{Speed} = \dfrac{7350 + x}{10}$
but $t_{buoy} = t_{down}$
$\therefore t_{down} = \dfrac{7350 + 3 \times t_{buoy}}{10}$
$\therefore 7 \times t_{down} = 7350 \therefore t_{down} = 1050$ sec
Total time $T = t_{up} + t_{down} = 1050 + 1050 = 2100 = 21 \times 10^2$ sec
Ans: 21

4. Weighing scale measures the Normal reaction (N) between the object and the scale
When the lift is at rest, Normal reaction, N balances weight of the object
$\therefore N_{rest} = mg = 50 \times 10 = 500$
However the scale shows value $N/g = 50$ when lift is at rest
While lift is going downwards:
$F_{net} = W - N = 500 - (N/g) \times g = 500 - 48 \times 10 = 20$ N
but $a_{lift} = \dfrac{F_{net}}{m} = \dfrac{20}{50} = 0.4$ m/s$^2 = 40$ cm/sec^2
Ans: 40

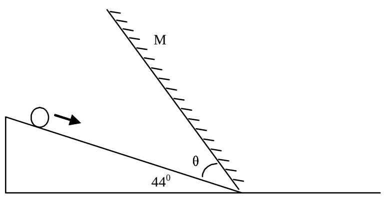
5. Mass of ball = 1 kg, Height from which it is thrown = 280 m
Total mechanical energy at highest point = Potential energy of ball
PE at height $h = mgh = 1 \times 10 \times 280 = 2800$ J.
Since ball comes to rest (no KE) on ground, all of PE is lost
Mechanical energy lost = 2800 J.
Heat absorbed = Mass $\times$ Specific Heat Capacity $\times$ Change in Temperature.
$\therefore 2800 = 1 * 400 * \triangle T$
$\therefore \triangle T = \dfrac{2800}{400} = 07°C$
Ans: 07

6. Lets consider direction of velocity as positive if moving to right and negative if it is to the left.
$\therefore u_1 = +2\ m/s, u_2 = -7\ m/s, m_1 = 2\ kg, m_2 = 1\ kg$
After collision, the combined ball of mass $m = 3\ kg$ moves with velocity say v.
By law of conservation of linear momentum,
$m_1u_1 + m_2u_2 = mv$
$\therefore (2 \times 2) + (1 \times (-7)) = 3\ v$
$\therefore v = \dfrac{4-7}{3} = -1$ m/s
Initial Kinetic energy $= \dfrac{1}{2}m_1u_1^2 + \dfrac{1}{2}m_2u_2^2$

$= (\frac{1}{2} \times 2 \times 4) + (\frac{1}{2} \times 1 \times 49) = (4) + (\frac{49}{2})$
$= \frac{57}{2}$J
Final kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2} \times 3 \times 1 = \frac{3}{2}$J
Kinetic energy lost = Initial KE - final KE
$= \frac{57}{2} - \frac{3}{2} = \frac{54}{2} = 27$ J
Ans: 27

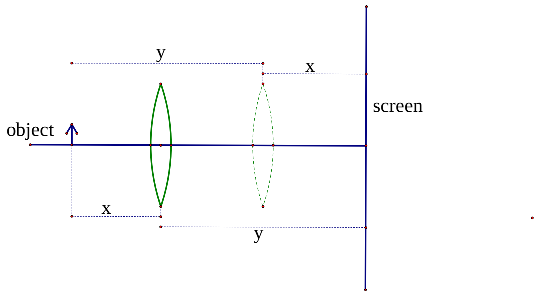
7. The metal ball is made up of metal (having density 8.8 g/cc and mass 264 g) and single cavity (having volume V_cavity and no mass).
   Volume of metal in the metal ball $= \frac{Mass}{Density} = \frac{264}{8.8} = 30$ cc
   Using Archimedes Principle,
   F_{boyant} = weight of ball in air - weight of ball in water $= (264 - 221) \times g$
   But $F_{boyant} = V_{water\ displaced} \times d_{water} \times g$
   $\therefore 43 \times g = V_{water\ displaced} \times 1 \times g$
   $V_{water\ displaced}$ = Volume of metal ball
   $\therefore$ Volume of metal ball = 43 cc
   $\therefore$ volume of cavity = (volume of metal ball)-(volume of metal)
   $= 43 - 30 = 13$ cc
   Ans: 13

8. Consider the figure



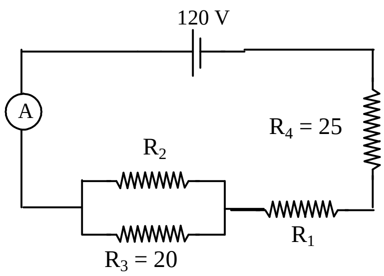
   For image of the ball to be seen moving vertically downwards, at every instant the image needs to be formed on verticle line passing through common point of mirror and the incline.
   By laws of reflection, angle of image with mirror = angle of ball or incline with mirror
   $\therefore$ angle of image with mirror=θ.
   Since image is on vertcle line, $44° + \theta + \theta = 90°$
   $\therefore \theta = 23°$
   Ans: 23

9. As shown in the figure, consider 2 positions of the lens between fixed object and screen. The full-line lens showing position 1 and the dotted lens showing position 2.



For position 1:
Let x = object distance (u) and y = image distance (v)
We know magnification $m = \dfrac{v}{u} = 2$ (given)
$\therefore \dfrac{y}{x} = 2$ i.e. $y = 2x$
For position 2:
Distance between object and screen is fixed $= (x + y) = 3x$
magnification $m = \dfrac{v}{u} = \dfrac{1}{2}$ (given)
i.e. $2u = v$
but $u + v = 3x$
$\therefore v = x$
and hence $u = y$
$\therefore$ object distance $(u) = y$ and image distance $(v) = x$
Now consider shift of lens from position 1 to position 2
distance shifted $= 36\text{(given)} = y - x$
but $y = 2x \quad \therefore x = 36$ and $y = 72$
Consider position 1 and using Cartesian sign convention
$u = -36, v = +72$
$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$
$$\therefore \frac{1}{f} = \frac{1}{72} - \frac{1}{-36} = \frac{1}{72} + \frac{1}{36}$$
$$\therefore \frac{1}{f} = \frac{1}{24}$$
$\therefore f = 24$
Ans: 24

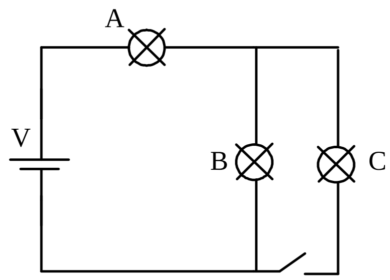
10. Consider the circuit



Current through the battery in the circuit is given as 2 A.
Current through $R_4 = I_{R_4} = 2$ A

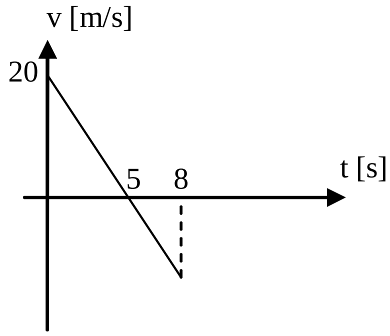
$\therefore$ voltage across $R_4 = V_{R_4} = I_{R_4} \times R_4 = 2 \times 25 = 50$V
Voltage across resister R_1 is given as 40V
$\therefore$ The voltage across the $(R_2 + R_3)$ combination is: $120 - (50C + 40V) = 30$V.
$\therefore$ voltage across $R_3 = V_{R_3} = 30$ V, also voltage across $R_2 = V_{R_2}$ is same i.e. 30 V
$\therefore I_{R_3} = \dfrac{V_{R_3}}{R_3} = \dfrac{30}{20} = 1.5$A.
$\therefore I_{R_2} =$ Current through the battery $-I_{R_3} = 2 - 1.5 = 0.5$A.
$\therefore R_2 = \dfrac{V_{R_2}}{I_{R_2}} = \dfrac{30}{0.5} = 60\Omega$
Ans: 60

11. Consider the circuit



The bulbs are identical. Let their resistance be R.
When key is open, A is in series with B
$\therefore R_{open} = R + R = 2R\ \Omega$
When key is closed, A is in series with parallel combination of B and C
$\therefore R_{closed} = R + (\dfrac{R \times R}{R + R}) = R + \dfrac{R}{2} = \dfrac{3R}{2}\ \Omega$
During operation of key, V rmains unchanged and also current through battery is same as current through A
When key is open, $I_{open} = \dfrac{V}{R_{open}} = \dfrac{V}{2R}$ A
When key is closed, $I_{closed} = \dfrac{V}{R_{closed}} = \dfrac{V}{3R/2} = \dfrac{2V}{3R}$ A
$\therefore I_{closed} = \dfrac{4}{3} \times \dfrac{V}{2R} = \dfrac{4}{3} \times I_{open}$
Consider power emiited by A:
when key is open, $P_{open} = I_{open}^2 \times R = 27$ watt (given)
when key is closed, $P_{closed} = I_{closed}^2 \times R$
$\therefore P_{closed} = (\dfrac{4}{3} I_{open})^2 \times R = \dfrac{16}{9} \times I_{open}^2 \times R$
$\therefore P_{closed} = \dfrac{16}{9} \times P_{open} = \dfrac{16}{9} \times 27 = 48$ watt.
Ans: 48

12. Consider the graph of velocity v/s time for the motion



At $t = 0$, its velocity is 20 m/s, at $t = 5$, it is zero
Using the slope of the line, we get At $t = 8$, its velocity as -12 m/s
Displacement = Area under the curve
From the graph,
Displacement for motion from $t = 0$ till $t = 5$ is $\frac{1}{2} \times 20 \times 5 = 50$ m
Displacement for motion from $t = 5$ till $t = 8$ is $\frac{1}{2} \times -12 \times 3 = -18$ m
Distance covered = numerical sum of two displacements $= 50 + 18 = 68$ m
Ans: 68

13. Acceleration due to gravity on earth $= g = 10$ m/s^2
But $g_{earth} = \dfrac{G \times M_{earth}}{R^2_{earth}}$, similarly $g_{planet} = \dfrac{G \times M_{planet}}{R^2_{planet}}$

$$\therefore \frac{g_{earth}}{g_{planet}} = \frac{M_{earth}}{M_{planet}} \times \frac{R^2_{planet}}{R^2_{earth}}$$

Now mass = Volume $\times$ density $= \dfrac{4\pi R^3}{3} \times d$
Substituting and cancelling $4\pi/3$, we get

$$\therefore \frac{g_{earth}}{g_{planet}} = \frac{d_{earth} \times R^3_{earth}}{d_{planet} \times R^3_{planet}} \times \frac{R^2_{planet}}{R^2_{earth}}$$

$$\therefore \frac{g_{earth}}{g_{planet}} = \frac{d_{earth} \times R_{earth}}{d_{planet} \times R_{planet}}$$

$$\therefore \frac{10}{g_{planet}} = (\frac{d_{earth}}{d_{planet}}) \times (\frac{R_{earth}}{R_{planet}}) = (\frac{1}{1.1}) \times (\frac{1}{3}) = \frac{1}{3.3}$$

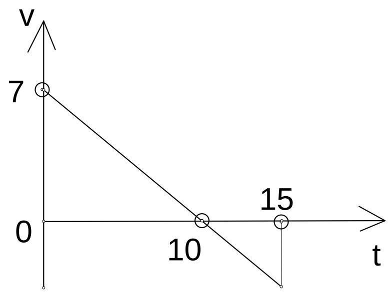
$\therefore g_{planet} = 10 \times 3.3 = 33$ m/s^2 on the surface.
Ans: 33

Physics Solution-2013

1. Let the initial velocity of the particle at $t = 0$ be u m/s
Let the acceleration of the particle $= a$ m/s^2
In the first 4 seconds interval; the distance traveled $(d_1) = 240$m and In the next 4 seconds interval; the distance traveled $(d_2) = 640$m
$\therefore$ In the first 8 seconds interval; the distance traveled $= 240 + 640 = 880$m
Using $s = ut + \frac{1}{2}at^2$
$s_4 = 240 = 4\ u + \frac{1}{2}(a)(4)^2 = 4\ u + 8\ a$

$\therefore 60 = u + 2\ a \cdots (1)$
Also $s_8 = 880 = 8\ u + \frac{1}{2}(a)(8)^2 = 8\ u + 32\ a$
$\therefore 110 = u + 4\ a \cdots (2)$
Subtracting (1) from (2), we get
$50 = 2\ a$
$\therefore a =$ acceleration of the particle $= 25$ m/s^2
Ans: 25

2. Consider the graph of velocity v/s time for the motion



At $t = 0$, its velocity is 7 m/s, at $t = 10$, it is zero
Using the slope of the line, we get At $t = 15$, its velocity as -3.5 m/s
Displacement = Area under the curve
From the graph,
Displacement for motion from $t = 0$ till $t = 10$ is
$s_1 = \dfrac{1}{2} \times 7 \times 10 = 35$ m
Displacement for motion from $t = 10$ till $t = 15$ is
$s_2 = \dfrac{1}{2} \times -3.5 \times 5 = -8.75$ m
Net displacement $= s_1 + s_2 = 35 + (-8.75) = 26.25$ m
Ans: 26

3. Let motorcyclist 1 start from A and 2 start from B with same acceleration, (a)
$u_1 = 72$ km/h $= 20$ m/s and $u_2 = -36$ km/h $= -10$ m/s
Let the motor cyclists cross at time t
$s_1 = u_1 t + \frac{1}{2} a\ t^2 = 20\ t + \frac{1}{2} \times 2\ t^2 = 20\ t + t^2$
$s_2 = u_2 t + \frac{1}{2}(-a)\ t^2 = -10\ t - \frac{1}{2} \times 2\ t^2 = -10\ t - t^2$
When they cross, $s_1 - s_2 = 500$
$\therefore 20t + t^2 + 10t + t^2 = 500$
$\therefore 2t^2 + 30t - 500 = 0$
$\therefore t^2 + 15t - 250 = 0$
$\therefore (t + 25)(t - 10) = 0$
$\therefore t = -25$ or 10 sec.
Discarding negative value, we get $t = 10$ i.e. they cross in 10 *sec*
Ans: 10

4. Draw FBD of the ball during upward motion:
   2 forces are acting on the ball - the weight of the ball (W) acting downwards. $W = mg$
   and Tension (T) in the rope pulling the ball which is acting upwards
   At maximum acceleration condition, $T_{max} = 5\ mg$ (given)
   $\therefore F_{net} = T_{max} - W = 4\ mg$ and is acting upwards
   $\therefore$ maximum acceleration of the ball $= \dfrac{F_{net}}{m} = \dfrac{4\ mg}{m} = 4\ g = 40\ \ \text{m/s}^2$
   Ans: 40

5. Draw FBD of the block. Since the motion is only horizontal, we can ignore the vertical forces (weight and Normal reaction balance each other).
   Applied Force of 40N is opposed by frictional force of 13N
   $\therefore F_{net} = 40 - 13 = 27\text{N}$
   $\therefore a$ of the block $= \dfrac{F_{net}}{m} = \dfrac{27}{10} = 2.7\ \ \text{m/s}^2$
   Initial momentum $(P_0) = m \times u = 10 \times 0 = 0\ \ \text{kg m/s}$
   Final momentum $(P_3) = m \times v = 10 \times 8.1 = 810\ \ \text{kg m/s}$
   $\therefore$ Change in momentum $= P_3 - P_0 = 81$ kg m/s
   Ans: 81

6. The bullet's velocity decreases from initial ($u = 1000$ m/s) to final ($v = 600$ m/s) due to air friction
   The change in KE will be due to the work done by friction.
   $\triangle E = \frac{1}{2}mu^2 - \frac{1}{2}mv^2 = \frac{1}{2} \times m\ (1000)^2 - \frac{1}{2} \times m\ (600)^2$
   $= \frac{1}{2} \times 10^{-2} \times (100 \times 10^4 - 36 \times 10^4) == \frac{1}{2} \times 10^{-2} \times (64 \times 10^4)$
   $\therefore \triangle E =$ work done by friction $= 32 \times 10^2$ J
   Since W is given as $= n \times 10^2$ J, we get $n = 32$
   Ans: 32

7. Since $V = IR$, we get I_{max} when we have R_{min}
   And we get I_{min} when we have R_{max}
   $V = I_{max} \times R_{min} = I_{min} \times R_{max}$
   $\dfrac{R_{max}}{R_{min}} = \dfrac{I_{max}}{I_{min}}$
   We get R_{max} when all 3 resistances are in series
   $\therefore R_{max} = R_1 + R_2 + R_3 = 20 + 10 + 5 = 35\omega$
   We get R_{min} when all 3 resistances are in parallel
   $\therefore \dfrac{1}{R_{min}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} = \dfrac{1}{20} + \dfrac{1}{10} + \dfrac{1}{5} = \dfrac{1+2+4}{20}$
   $\therefore R_{min} = \dfrac{20}{7}\Omega$
   Now, $\dfrac{I_{max}}{I_{min}} = \dfrac{R_{max}}{R_{min}} = \dfrac{35}{20/7} = \dfrac{35 \times 7}{20} == \dfrac{49}{4} = 12.25$
   Ans: 12

8. Please correct the typo error in the paper and read total volume as 2.5×10^{-3} m^3

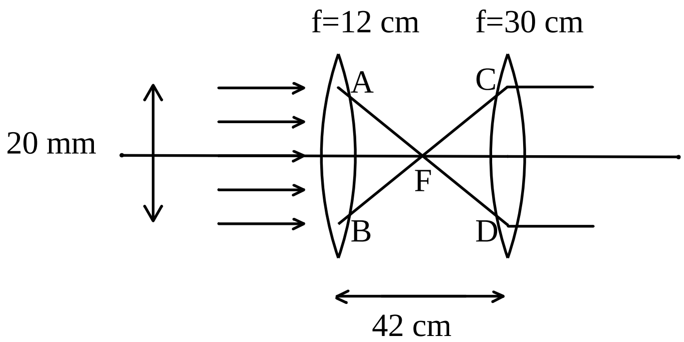
   Area of wire $= \dfrac{volume}{length} = \dfrac{2.5 \times 10^{-3}}{1} = 2.5 \times 10^{-3}$ m^3

   Resistance $= \dfrac{Resistivity \times length}{Area} = \dfrac{0.1 \times 1}{2.5 \times 10^{-3}}$

   $\therefore R = \dfrac{1000}{25} = 40\Omega$

   Ans: 40

9. Please refer to schematic figure shown



   The incident beam parallel to optical axis will get refracted by lens 1 (f = 12) such that it gets converged at the point of focus (pt F) at 12 cm from the lens.
   Each of the converged ray passing through F will then reach lens 2(f = 30). Since point F is also point of focus for lens 2, after passing through lens 2, each ray will emerge parallel to optical axis.
   Consider $\triangle AFB$ and $\triangle CFD$
   These are similar triangles (as side AB || side CD)
   $\therefore$ ratio of lengths of sides as well as altitudes is equal.

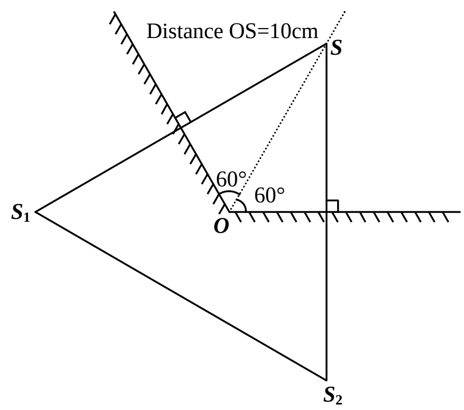
   $\therefore \dfrac{AB}{CD} = \dfrac{FP_1}{FP_2}$, where P_1 and P_2 are poles of lens 1 and lens 2 respectively.

   $\therefore \dfrac{20}{CD} = \dfrac{12}{30}$

   $\therefore CD = 50$ cm

   Ans: 50

10. As shown in the figure, point S will create two images, image S_1 in mirror 1 and image S_2 in mirror 2.



For mirror 1:
Distance $OS = 10$ (given)
$\therefore$ object distance for mirror 1 $= OS\ sin\ 60° = 10 \times \dfrac{\sqrt{3}}{2} = 5\sqrt{3}$
$\therefore$ image distance for mirror 1 will also be $5\sqrt{3}$.
$\therefore$ Distance $SS_1 = 10\sqrt{3}$.
For mirror 2:
similarly distance $SS_2 = 10\sqrt{3}$.
Consider $\triangle SS_1S_2$:
Now $\angle\ OSS_1 = 30°$ (as SS_1 is perpendicular to mirror 1)
And $\angle\ OSS_2 = 30°$ (as SS_2 is perpendicular to mirror 2)
In $\triangle SS_1S_2$, side SS_1 = side SS_2 and included $\angle\ S_1SS_2 = 60°$
$\therefore \triangle SS_1S_2$ is an equilateral $\triangle$
$\therefore S_1S_2 = 10\sqrt{3} = 10 \times 1.73 = 17.3$
Ans: 17

11. Weight of body in air $= mg = 100$ N $\therefore m = 10$ kg
Using Archimedes Principle,
F_{boyant} = weight of body in air - weight of body in water
$= 100 - 85 = 15$ N
But $F_{boyant} = V_{water\ displaced} \times d_{water} \times g$
$V_{water\ displaced} = V_{body}$
$\therefore 15 = V_{body} \times 10^4$
$\therefore 15 = \dfrac{m_{body}}{d_{body}} \times 10^4 = \dfrac{10}{d_{body}} \times 10^4$
$\therefore d_{body} = \dfrac{10^5}{15} = 6.6667 \times 10^3$ kg/m^3 = 6.6667 g/cc
$\therefore 10\ d = 66.67$
Ans: 67

12. Acceleration due to gravity on earth $= g = 10$ m/s^2
But $g_{earth} = \dfrac{G \times M_{earth}}{R^2_{earth}}$,
The density and radius are changed, then
$g_{new} = \dfrac{G \times M_{new}}{R^2_{new}}$

$\therefore \dfrac{g_{earth}}{g_{new}} = \dfrac{M_{earth}}{M_{new}} \times \dfrac{R_{new}^2}{R_{earth}^2}$

Now mass = Volume × density = $\dfrac{4\pi R^3}{3} \times d$

Substituting and cancelling $4\pi/3$, we get

$\therefore \dfrac{g_{earth}}{g_{new}} = \dfrac{d_{earth} \times R_{earth}^3}{d_{new} \times R_{new}^3} \times \dfrac{R_{new}^2}{R_{earth}^2}$

$\therefore \dfrac{g_{earth}}{g_{new}} = \dfrac{d_{earth} \times R_{earth}}{d_{new} \times R_{new}}$

$\therefore \dfrac{10}{g_{new}} = (\dfrac{d_{earth}}{d_{new}}) \times (\dfrac{R_{earth}}{R_{new}}) = (\dfrac{1}{0.5}) \times (\dfrac{1}{3}) = \dfrac{1}{1.5}$

$\therefore g_{new} = 10 \times 1.5 = 15$ m/s^2

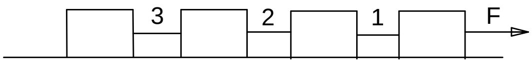
Ans: 15

Physics Solution-2012

1. The two trains each traveling with speed of 40 km/hr, are coming towards each other from a distance of 80 km apart.
   $\therefore$ Time after which trains will collide = 1 hr
   $\therefore$ The bird is traveling for 1 hr only before the trains collide. It is moving with constant speed 60 km/h
   so distance traveled by bird = $speed \times time = 60 \times 1 = 60km$
   Ans: 60

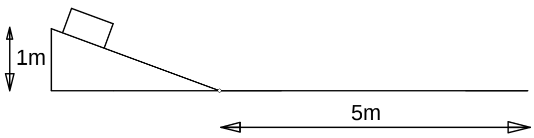
2. For first ball's downward motion:
   $u = 0, s = -8$ m
   Velocity of ball just before striking: $v^2 = u^2 + 2as$
   $\therefore v^2 = 0 + 2 \times 10 \times 8 = 160 \therefore v = \sqrt{160}$
   This is same speed with which it starts its upward motion
   At same instance second ball is released from 8 m above the ground
   Let the two balls collide at a dist d from top i.e. They collide at a dist of $(8-d)$ from bottom.
   For ball 1 upward motion: $s_1 = ut + \frac{1}{2}at^2$
   $\therefore (8-d) = \sqrt{160} \times t - 5t^2$
   For ball 2 downward motion: $s_2 = ut + \frac{1}{2}at^2$
   $\therefore d = \frac{1}{2} \times 10t^2 = 5\ t^2$
   $\therefore t = \sqrt{d/5}$
   Time t is same for both balls,
   $\therefore 8 - d = \sqrt{160} \times \sqrt{\frac{d}{5}} - d$
   $\therefore 8 = \sqrt{32 \times d}$
   $\therefore 64 = 32d \therefore d = 2$ m
   $\therefore$ The ball collide at a dist of $(8 - 2 = 6\ m)$ above the ground.
   Ans: 6

3. Draw 3 separate FBDs, 1 FBD for entire system of 4 blocks, 1FBD for first block and 1 FBD for last block
Since block undergo horizontal motion only, we can ignore vertical forces



For system of 4 blocks:
Total mass $= 5 + 5 + 5 + 5 = 20$ kg and only external force F is acting
$a = \dfrac{F}{m} = \dfrac{100}{20} = 5\ \text{m/s}^2$
This acceleration is same for all 4 blocks.
Now for first block:
its acceleration is 5 m/s^2
F_{net} on the block = ma $= 5 \times 5 = 25$ N
2 horizontal forces are acting on block A, External force, F and tension T_1 opposing it
$\therefore T_1 = F - F_{net} = 100 - 25 = 75\text{N}$
Now for last block:
its acceleration is 5 m/s^2
F_{net} on the block = ma $= 5 \times 5 = 25$ N
Only 1 horizontal force, Tension T_3 is acting on it.
$\therefore T_3 = F_{net} = 25\text{N}$
$\therefore T_1 : T_3 = \dfrac{T_1}{T_3} = \dfrac{75}{25} = 3$
Ans: 3

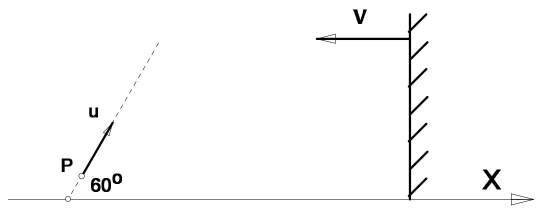
4. Consider the figure



Block has PE $= m\ g\ h$ at the top of slope which is converted to KE when it reaches the bottom.
$\therefore = \frac{1}{2}mv^2 = m\ g\ h.$
$\therefore v^2 = 2\ g\ h = 2 \times 10 \times 1 = 20$
$\therefore$ Velocity at the bottom of incline is $v = 2\sqrt{5}$ m/s
For horizontal motion, we know that the block stops after moving 5 meters.
We have $u = 2\sqrt{5}, s = 5, v = 0$
Using $v^2 = u^2 + 2as$, we get $0 = 20 + 2.a.5$
$\therefore a = -2\ \text{m/s}^2$
F_{net} on the block = ma $= 10 \times -2 = -20$ N
Draw FBD of the block on horizontal surface.
Since block undergo horizontal motion only, we can ignore vertical forces
Only 1 horizontal force, frictional force, f is acting on it.
$\therefore f = F_{net} = 20\text{N}$ and acting opposite to the motion
but $f = \mu mg \quad \therefore \mu = \dfrac{20}{10 \times 10} = 0.2$

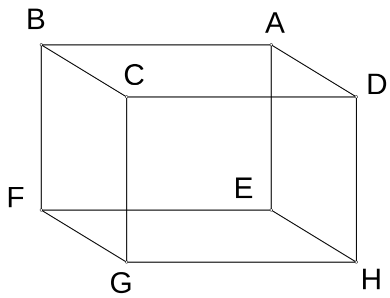
$\therefore 100\mu = 20$
Ans: 20

5. Consider the figure



Particle P is moving with $u = 10$ cm/s and its motion makes an angle of $60°$ with the x axis.
The mirror is perpendicular to x axis. Any any instant image of P will be formed behind mirror at same perpendicular distance from the mirror as that of P in front of the mirror.
Hence we need to consider only the horizontal component of motion of P i.e. $u_{horizontal} = 10cos(60°) = 5$ m/s.
The mirror is moving parallel to x axis with $v = 20$ m/s towards P.
$\therefore$ Relative horizontal speed of P w.r.t the plane mirror $= 20 + 5 = 25$ m/s
$\therefore$ Relative speed of the image and $P = 25 + 25 = 50$ m/s
Ans: 50

6. Consider the circuit



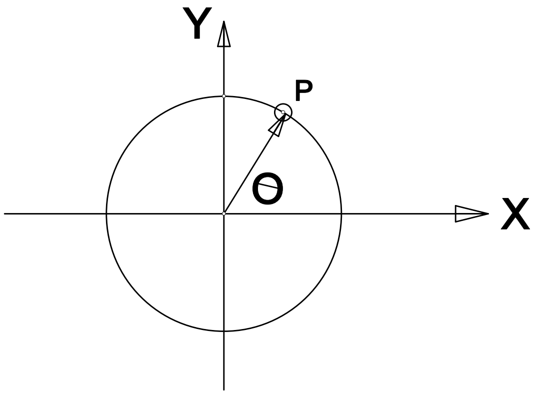
When battery connected across A (say +ve terminal) and G (-ve terminal),
current through the battery $I = \dfrac{V}{R_{AG}} = \dfrac{100}{5/3} = 60\text{A}$
Consider node A:
Current $I(60A)$ which approaches node A has 3 paths to branch out, namely AB, AD and AE
As per symmetry and as all branches have same resistance,
I gets equally split in these 3 branches
$\therefore I_{AB} = I_{AD} = I_{AE} = 20$ A
Consider node D:
Current $I_{AD} = 20$ A, which approaches node D has 2 paths to branch out, namely DC and DH
As per symmetry and as all branches have same resistance,

I gets equally split in these 2 branches

$\therefore I_{CD} = I_{DH} = 10$ A

Ans: 10

7. Consider the figure



Both the particles start from same point C.

Particle 1 is moving faster than particle 2. When they meet again, if particle 2 would have moved through angle (θ) then particle 1 would have moved through angle $(360 + \theta)$

Relative angular velocity of particle $1 = \omega_1 - \omega_2 = 5\ \omega_2 - \omega_2 = 4\ \omega_2$

The two particles meet again after 3 s

$\therefore 4\ \omega_2 \times t = 360$ gives us $4\ \omega_2 \times 3 = 360$

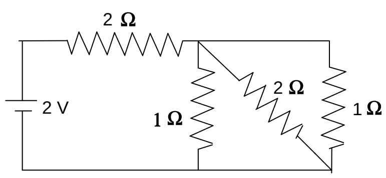
$\therefore \omega_2 = 360/12 = 30$ deg/sec

Now, 1.5 sec after start of motion

Angle covered $= \omega_2 \times 1.5 = 30 \times 1.5 = 45$ deg

Ans: 45

8. Consider the circuit



Resistor R of 2 Ω next to the battery is in series with (parallel combination of remaining 3 resistors of $1\ \Omega, 2\ \Omega$ and $1\ \Omega$)

$$\frac{1}{R_{parallel}} = \frac{1}{1} + \frac{1}{2} + \frac{1}{1} = \frac{2+1+2}{2} = \frac{5}{2}$$

$\therefore R_{parallel} = \dfrac{2}{5}\ \Omega$

Total resistance of circuit $R_0 = R + R_{parallel} = 2 + \dfrac{2}{5} = \dfrac{12}{5}\ \Omega$

Now current through the battery $I_0 = \dfrac{V_0}{R_0} = \dfrac{2}{12/5} = \dfrac{10}{12}$ A

Current = Charge flow per unit time $\therefore I_0 = \dfrac{Q_0}{t}$

$\therefore Q_0 = I_0 \times t = \dfrac{10 \times t}{12}$ C

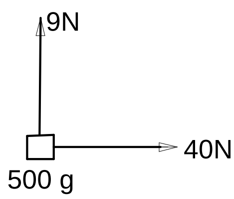
It is given that $W_B = Q_0 V_0$

$\therefore 60 = \dfrac{10 \times t}{12} \times 2$

$\therefore \dfrac{60 \times 12}{10 \times 2} = t = 36\text{s}$

Ans: 36

9. Consider the figure



Net force F_{net} acting one the object is resultant of the two forces shown
Since they have $90°$ angle between them, the parallelogram completed with them as sides will be a rectangle
The resultant would be diagonal of the rectangle, which can be found by using Pythagoras theorem.

$\therefore F_{net} = \sqrt{40^2 + 9^2} = 41$ N

Acceleration of the block $= \dfrac{F_{net}}{m} = \dfrac{41}{0.5} = 82 \;\; \text{m/s}^2$

Ans: 82

10. Using cartesian sign convention:
For convex lens, $f = +5\ cm, u = -10\ cm$

Using lens formula, $\dfrac{1}{v} = \dfrac{1}{f} + \dfrac{1}{u} = \dfrac{1}{5} + \dfrac{1}{-10} = \dfrac{1}{5} - \dfrac{1}{10} = \dfrac{1}{10}$

$\therefore v = +10 \;\; \text{cm}$

Now, for concave lens,

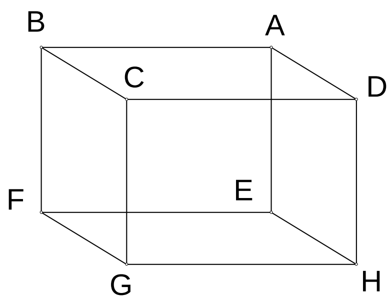
$f = -10\ cm, u = -(25 - 10) = -15\ cm$

Using lens formula, $\dfrac{1}{v} = \dfrac{1}{f} + \dfrac{1}{u} = \dfrac{1}{-10} + \dfrac{1}{-15} = -(\dfrac{1}{10} + \dfrac{1}{15}) = -\dfrac{1}{6}$

$\therefore v = -6 \;\; \text{cm}$

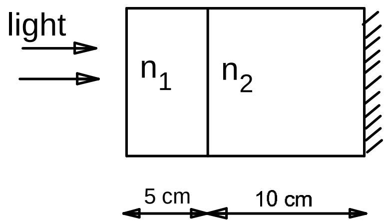
Ans: 6

11. Consider the figure



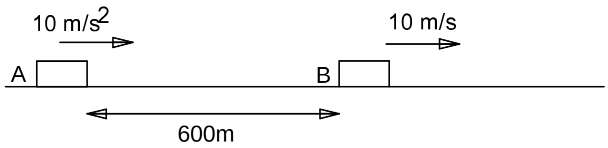
Let the ant start at corner C and travels to opposite corner E along shortest path along the faces of the cube
One such shortest path would be
1. $C-$ midpoint of opposite side $AD - E$
Similarly other paths would be
2. $C-$ midpoint of opposite side $AB - E$
3. $C-$ midpoint of opposite side $FG - E$
4. $C-$ midpoint of opposite side $BF - E$
5. $C-$ midpoint of opposite side $DH - E$
6. $C-$ midpoint of opposite side $GH - E$
Ans: 6

12. Consider the figure



Speed of light is constant in any medium.
Light incident perpendicular to the face of slab 1 will travel,
first 5 cm in slab 1 for time t_1,
then 10 cm in slab 2 for time t_2, get reflected and
then 10 cm in slab 2 for time t_2 and
finally 5 cm in slab 1 for time t_1 and come out of slab 1.
Refractive index $\eta = \dfrac{speed\ of\ light\ in\ the\ vacuum}{speed\ of\ light\ in\ the\ slab} = \dfrac{c}{v}$
For slab 1: $\eta_1 = \dfrac{c}{v_1} = 1.5$ and
$\therefore v_1 = \dfrac{c}{1.5} = \dfrac{3 \times 10^8}{1.5} = 2 \times 10^8$ m/s
For slab 2: $\eta_2 = \dfrac{c}{v_2} = 2$ and
$\therefore v_2 = \dfrac{c}{2} = \dfrac{3 \times 10^8}{2} = 1.5 \times 10^8$ m/s
Now $t = \dfrac{distance\ traveled\ by\ light}{speed\ of\ light\ in\ the\ slab}$
$\therefore t_1 = \dfrac{5 \times 10^{-2}}{2 \times 10^8} = 2.5 \times 10^{-10}$ sec
$\therefore t_2 = \dfrac{10 \times 10^{-2}}{1.5 \times 10^8} = (20/3) \times 10^{-10}$ sec
Total time T required for light to come out of face of slab 1
$T = t_1 + t_2 + t_2 + t_1 = 2(t_1 + t_2)$
$\therefore T = 2(\dfrac{5}{2} + \dfrac{20}{3}) \times 10^{-10}$ sec
$\therefore T = 2(\dfrac{15+40}{6}) = (\dfrac{55}{3}) \times 10^{-10} = 18.33 \times 10^{-10}$ sec
Ans: 18

13. Consider the figure



Let, t be the time taken by A to overtake B and x m be distance traveled by B at time t
$\therefore$ distance traveled by $A = 600 + x$
For B: $u = 10\ m/s, a = 0$ and $s = x$
$s = u\ t + \frac{1}{2}a\ t^2$
$\therefore x = 10\ t$
For A: $u = 0, a = 10\ m/s^2$ and $s = 600 + x$
$s = u\ t + \frac{1}{2}a\ t^2$
$\therefore 600 + x = 5\ t^2$
$\therefore 600 + 10\ t = 5\ t^2$
We get $5t^2 - 10t - 600 = 0$
$\therefore t^2 - 2t - 120 = 0$
$\therefore t^2 - 12t + 10t - 120 = 0$
$\therefore t(t - 12) + 10(t - 12) = 0$
$\therefore (t - 12)\ \ (t + 10) = 0$
Discarding negative value for time, we get $t = 12$ sec
Ans: 12