Work, Energy and Power

SOLUTIONS

Exercise-I (Conceptual Questions)

1. $W = \vec{F}.\vec{d}$

$= (4\hat{i} - 4\hat{j} - 2\hat{k}) \cdot (3\hat{i} + 2\hat{j} - 2\hat{k})$

$= 12 - 8 + 4 = 8$ J

2. $\vec{F} = (3\hat{i} + 2\hat{j}) \cdot (4\hat{i} - \hat{j} + 3\hat{k})$

$= 12 - 2 = 10$ J

3. $W = \vec{F} \cdot \vec{S}$

$\vec{S} = \vec{r}_2 - \vec{r}_1 = (4\hat{i} + 3\hat{j} - \hat{k}) - (2\hat{i} + \hat{j} - 2\hat{k})$

$\vec{S} = 2\hat{i} + 2\hat{j} + \hat{k}$

$W = (3\hat{i} + 2\hat{j} + 2\hat{k}) \cdot (2\hat{i} + 2\hat{j} + \hat{k})$

$= 6 + 4 + 2 = 12$ J

4. $\vec{d} = \vec{r}_2 - \vec{r}_1$

$= (\hat{i} + 2\hat{j} + \hat{k}) - (3\hat{i} + \hat{j} + 3\hat{k})$

$= (-2\hat{i} + \hat{j} - 2\hat{k})$

$W = \vec{F}.\vec{d}$

$= (5\hat{i} + 2\hat{j} - 4\hat{k}) \cdot (-2\hat{i} + \hat{j} - 2\hat{k})$

$= -10 + 2 + 8 = 0$

5. $W_N = F d\cos 90°$

$= 0$

6. $W_F = FS\cos\theta$

$= (5g) \times 2 \times \cos 0°$

$= 5 \times 9.8 \times 2 \times 1$

$= 98$ J

7. Work will be zero as angle between force & displacement is 90°

8. Angle between Force and displacement is 90°

$\therefore \quad W = 0$

9. $W = mgH$

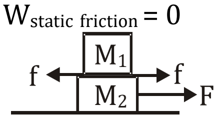
independent of time

10. 

(Body at rest)

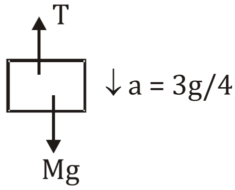
$F = f$

$W_{\text{static friction}} = 0$



If blocks move together then work done by static friction between blocks on upper block = +ve & lower block = –ve.

11. Block B will accelerate due to friction and gain speed therefore work by friction on block B will be positive.

12. 

$Mg - T = M \times \frac{3g}{4}$

$Mg - \frac{3Mg}{4} = T$

$\frac{Mg}{4} = T$

$W = T \times h\cos 180° = -\frac{Mgh}{4}$

13. Work done by T on M = – Work done by T on m

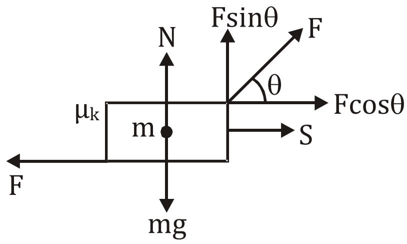
$\therefore$ net work done by T = 0

14. $W = F\Delta S\cos\theta$

$= \mu R \times 2\pi r \times \cos 180$

$= -0.5 \times 5 \times 2\pi \times \frac{1}{\pi}$

$= -5$ J

15. 

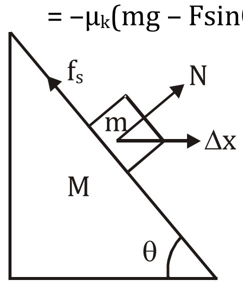
$N = mg - F\sin\theta$

$f = \mu_k N$

$f = \mu_k(mg - F\sin\theta)$

$W_f = f \times S\cos 180°$

$= -\mu_k(mg - F\sin\theta)S$

16. 

angle between N & Δx is not 90°

$\therefore W_N \neq 0$

17. Work in each direction = 100 J

$F\Delta S = 100$

$\Delta S = 2m$

displacement in each direction = x = y = z = 2m

Final coordinates = (2, 2, 2)m

18. Work done by external agent $= -(W_{friction} + W_{mg})$

$= -(-mgh - mgh)$

$= 2mgh$

19. $$\int_0^3 (x^2+3x-5)dx = \left[\frac{x^3}{3}+\frac{3x^2}{2}-5x\right]_0^3$$

$$=\frac{27}{3}+\frac{3\times 9}{2}-5\times 3$$

$$=9+\frac{27}{2}-15$$

$$=\frac{18+27-30}{2}=7.5\text{ J}$$

20. $$W=\int_{x_1}^{x_2} F dx \cos 60°$$

$$=\int_{x_1}^{x_2} kx^3 \cos 60° dx$$

$$=\left[\frac{kx^4}{4}\right]_{x_1}^{x_2}\times\frac{1}{2}$$

$$=\frac{k}{8}(x_2^4-x_1^4)$$

21. Work done = Area under F-x curve

$W = \frac{1}{2}(6 + 3) \times 6$

W = 27 J

22. Work done is the area under F-x curve

W = m[area under a-x curve]

(i) $W=4\left[\frac{1}{2}(4+3)\times 3\right]$

W = 42 J

(ii) $W=4\left[\frac{1}{2}(5+3)\times 3\right]-4\left[\frac{1}{2}(2+1)\times 3\right]$

W = 48 – 18 = 30 J

23. Area under the graph

24. $KE \propto P^2$

$$\frac{P_1}{P_2}=\sqrt{\frac{K_1}{K_2}}$$

$\therefore\ P_2 = 3P_1$

25. $K \propto P^2$

So if P becomes 'n' times then K becomes n^2 times.

26. $KE \propto P^2$

$$\frac{P_1}{P_2}=\sqrt{\frac{K_1}{K_2}}$$

$P_2 = 2P_1$

27. $$\frac{P_1^2}{2m_1}=\frac{P_2^2}{2m_2}$$

$$\frac{P_1^2}{P_2^2}=\frac{m_1}{m_2}=\frac{4}{9}\Rightarrow\frac{P_1}{P_2}=\frac{2}{3}$$

28. P = constant

So $K \propto \frac{1}{m}$

$K_1 : K_2 \Rightarrow m_2 : m_1$

= 5 : 3

29. $P \propto \sqrt{K}$

$$\frac{P_1}{P_2}=\sqrt{\frac{K_1}{K_2}}$$

$P_2 = 2P_1$

$\therefore$ momentum is increased by 100%

30. $$\frac{P_1}{P_2}=\sqrt{\frac{K_1}{K_2}}$$

$P_2 = 3P_1$

$\therefore$ Momentum increased by 200%

31. $P \propto K^{1/2}$

% change in P = $\frac{1}{2}$ {% change in K}

% change in P = $\left(\frac{1}{2}\times 3\right)$% = 1.5%

32. $\because K \propto P^2$

% change in K = 2 (% change in P)

% change in K = (2 × 2) % = 4%

33. $$E_k=\frac{p^2}{2m}$$

$\sqrt{E_K}\times\frac{1}{p}$ = constant

$\therefore$ graph is rectangular hyperbola

34. $E_K = \frac{1}{2}mv^2 \quad \therefore$ Graph is parabola

35. W = ΔKE

$= \frac{1}{2}m[v^2 - u^2]$

36. $s = \frac{t^3}{4}$

$v = \frac{3t^2}{4}$

at t = 0, v = 0

at t = 2sec, $v = \frac{3(2)^2}{4}$ = 3 m/s

By W.E.T.

W = ΔKE

$W = \frac{1}{2} \times 6 \times 3^2 - \frac{1}{2} \times 6 \times 0^2$

W = 27 J

37. $x = 2t - 3t^2 + 2t^3$

$v = 2 - 6t + 6t^2$

W = ΔKE

$= \frac{1}{2}m(v_2^2 - v_1^2)$

t = 0 sec $\Rightarrow$ $v_1 = 2$

t = 3 sec $\Rightarrow$ $v_2 = 38$

$W = \frac{1}{2} \times \frac{20}{1000}[1444 - 4]$

$= \frac{1440}{100} = 14.40\,J$

38. $\frac{KE_1}{KE_2} = \frac{\frac{1}{2}m_1v^2}{\frac{1}{2}m_2v^2} = \frac{m_1}{m_2} = \frac{1}{3}$

39. $E = \frac{1}{2}mv^2 - mgh$

$= \frac{1}{2} \times 2 \times 256 - 2 \times 10 \times 10$

= 256 – 200 = 56 J

40. $W_{all} = \Delta KE$

$mgH = \frac{1}{2}m(v^2 - u^2)$

$2gH = v^2 - u^2$

u $\rightarrow$ same and H $\rightarrow$ same $\Rightarrow$ v $\rightarrow$ same

41. W = ΔKE

$= \frac{1}{2}m[0^2 - 10^2]$

$= \frac{1}{2} \times 2[-100] = -100$ J

42. Work done by a conservative force is independent from the path

$W_C = -\Delta U = U_i - U_f$

43. Work done is independent from the path for conservative forces.

44. Gravitation is conservative force, work done is path independent

45. Viscous force (fluid friction) $\Rightarrow$ non conservative force

47. Here gravitation force of earth is centripetal force $\theta = 90°$, Work done = 0

48. $W_{PQ} + W_{QR} + W_{RP} = 0$

$15 + 5 + W_{RP} = 0$

$W_{RP} = -20$ J

$W_{PR} = 20$ J

49. Since force is constant so work done is path independent. Hence $W_1 = W_2$

50. W = –ΔU

W = mgh

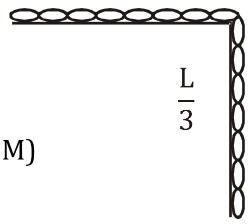
= 3 × 10 × 20 = 600 J

51. $W = m_{avg}gh$

$= \left(\frac{13+9}{2}\right) \times 10 \times 10$

= 22 × 50 = 1100 J

52. W = mgh



$m = \frac{M}{L} \times \left(\frac{L}{3}\right) = \frac{M}{3}$

$h = \left(\frac{L}{3}\right) \times \frac{1}{2} = \frac{L}{6}$ (By COM)

$WD = \frac{M}{3} \times \frac{L}{6} \times g = \frac{MgL}{18}$

53. $W = \Delta U = U_{max} - U_{min} = mg\left(\frac{a}{2} - \frac{c}{2}\right)$

54. T = Kx for spring

$\text{Energy} = \frac{1}{2}Kx^2 = \frac{1}{2}K\frac{T^2}{K^2} = \frac{T^2}{2K}$

55. $W=\frac{1}{2}k\left(x_2^2-x_1^2\right)=\frac{1}{2}\times\frac{1000}{10^4}\left(25^2-15^2\right)$

$=\frac{1}{2}\times\frac{1}{10}[625-225]=\frac{1}{2}\times\frac{1}{10}\times400=20\ J$

56. $\frac{1}{2}K(5)^2=U$

$\frac{1}{2}K(10)^2=U'$

$\frac{U}{U'}=\frac{5^2}{10^2}=\frac{25}{100}=\frac{1}{4}\Rightarrow U'=4U$

57. $W_1=\frac{1}{2}Kx_1^2$ ...(1)

$W_2=\frac{1}{2}Kx_2^2$ ...(2)

$\frac{W_2}{W_1}=\left(\frac{x_2}{x_1}\right)^2=\left(\frac{10}{5}\right)^2$

$W_2=4W_1$

Extra work done = $W_2 - W_1$

= $4W_1 - W_1 = 3W_1$

= 3 × 5 = 15 J

58. $U=\frac{1}{2}mv^2$

$\therefore\ m=\frac{2U}{v^2}$

59. By COME

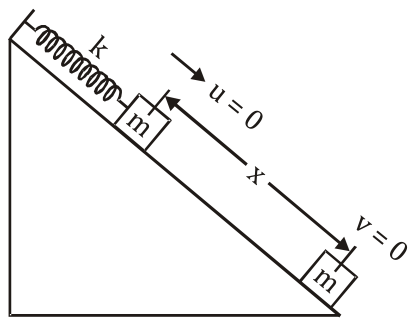
$\frac{1}{2}mv^2=\frac{1}{2}kx^2$

$4 \times (2)^2 = 100 \times x^2$

$\frac{4\times4}{100}=x^2\Rightarrow\frac{16}{100}=x^2$

$x=0.4\ m$

60.



$W_{all} = \Delta KE$

$W_{mg} + W_{sp} = 0$

$mgx\sin\theta - \frac{1}{2}Kx^2 = 0$

$x=\frac{2mg\sin\theta}{K}$

61. W = mgh = 2 × 9.8 × 10 = 196 J

62. At $H=\frac{h}{5}$

$PE=\frac{mgh}{5}$

$\therefore\ KE=\frac{4mgh}{5}$

KE : PE = 4 : 1

63. To reach point C it have to reach at point B

By COME

$\frac{1}{2}mv^2+0=mgH+0$

$v=\sqrt{2gH}$

$=\sqrt{2\times10\times320}=80\ m/s$

64. In projectile motion, there is no change in kinetic energy of projectile while landing to the ground and projected from ground. Because speed is same at the time of projection and striking.

65. By COME

$-\frac{Mg}{2}\frac{L}{4}+0=-\frac{MgL}{2}+\frac{1}{2}Mv^2$

$\frac{1}{2}Mv^2=\frac{MgL}{2}-\frac{MgL}{8}$

$\frac{v^2}{2}=\frac{gL}{2}\left(\frac{3}{4}\right)$

$v=\sqrt{\frac{3gL}{4}}$

66. For equilibrium $\frac{dU}{dx}=0$, point a, b, c, d

For stable equilibrium $\frac{d^2U}{dx^2}>0$, point a, c

For unstable equilibrium $\frac{d^2U}{dx^2}<0$, point b, d

67. For stable equilibrium

$F = 0, \frac{dU}{dx}=0$

$\frac{d^2U}{dx^2}>0$

68. $F = -\frac{dU}{dx}$

For equilibrium $\frac{dU}{dx} = 0$

$4x - 2 = 0$

$x = \frac{2}{4} = 0.5\text{m}$

69. $\because F = 2x^2 - 3x - 2$

For equilibrium

$F = 0$

$2x^2 - 3x - 2 = 0$

$2x^2 - 4x + x - 2 = 0$

$2x(x - 2) + 1(x - 2) = 0$

$x = 2 \qquad x = -\frac{1}{2}$

$\frac{dF}{dx} = 4x - 3$

at $x = 2$ | at $x = -\frac{1}{2}$

$\frac{dF}{dx} = 5$ | $\frac{dF}{dx} = -5$

$\frac{dF}{dx} > 0$ unstable equil. | $\frac{dF}{dx} < 0$ stable equil.

70. $U = \frac{A}{r^{12}} - \frac{B}{r^6}$

$\frac{dU}{dr} = 0$ at equilibrium

$\therefore \quad \frac{-12A}{r^{13}} - \frac{(-6)B}{r^7} = 0 \; ; \; \frac{6}{r^7}\left[\frac{-2A}{r^6} + B\right] = 0$

$r = \left(\frac{2A}{B}\right)^{1/6}$

$\therefore$ At equilibrium U is given by

$U = \frac{A}{\left(\frac{2A}{B}\right)^2} - \frac{B}{\frac{2A}{B}} = \frac{B^2}{4A} - \frac{B^2}{2A} = -\frac{B^2}{4A}$

71. $U = \frac{2x^2y}{z^2}$

$\vec{F} = -\left[\frac{\partial U}{\partial x}\hat{i} + \frac{\partial U}{\partial y}\hat{j} + \frac{\partial U}{\partial z}\hat{k}\right]$

$\vec{F} = -\left[\frac{2y}{z^2}(2x)\hat{i} + \frac{2x^2}{z^2}\hat{j} + 2x^2y\left(\frac{-2}{z^3}\right)\hat{k}\right]$

$\vec{F} = -\frac{4xy}{z^2}\hat{i} - \frac{2x^2}{z^2}\hat{j} + \frac{4x^2y}{z^3}\hat{k}$

72. $P = \vec{F}\cdot\vec{v}$

$= 5000 \times 2 = 10$ KW

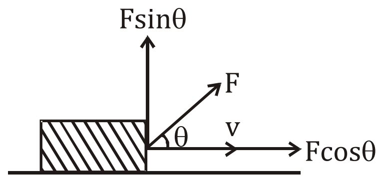
73. $F = \frac{P}{v} = \frac{50\times746}{36\times\frac{5}{18}} = 3.73\times10^3$ N

74. $P = Fv$

$7 \times 10^3 = F \times 10$

$F = 700$ Newton

75.



Power $= \vec{F}.\vec{v} = Fv\cos\theta$

76. $\overrightarrow{\Delta x} = \vec{d}_f - \vec{d}_i$

$= 8\hat{i} + 6\hat{j}$

$P = \frac{W}{t} = \frac{\vec{F}\cdot\overrightarrow{\Delta x}}{t} = \frac{(3\hat{i}+4\hat{j})\cdot(8\hat{i}+6\hat{j})}{6}$

$= \frac{24+24}{6} = 8$ Watt

77. $P_1 = \frac{WD_1}{t_1}, \quad P_2 = \frac{WD_2}{t_2}$

$\frac{P_1}{P_2} = \frac{m_1}{m_2}\times\frac{t_2}{t_1} = \frac{2}{3}\times\frac{9}{5} = \frac{6}{5}$

78. $P_{avg} = \frac{W}{t} = \frac{mgh}{t} = \frac{200\times9.8\times3}{4} = 1470$

79. $T - 4g = 4 \times g/4$

$T = 4g + g = 5g = 50$ N

$S = \frac{1}{2}\times\left(\frac{10}{4}\right)\times(2)^2$

$S = 5\text{m}$

$P = \frac{TS}{t} = \frac{50\times5}{2} = 125$ Watt

80. $P = \frac{mgh}{t}$

$= \frac{50\times9.8\times10}{10} = 490$ watt

$P = \frac{490}{746} = 0.66$ hp

81. Mass of water

$= 1492 \times 10^{-3} \times 10^{3} = 1492$ kg

Energy = mgh

$= 1492 \times 10\ (16 + 8)$

$$P = \frac{\text{Energy}}{\text{Time}}$$

$$2 \times 746 = \frac{1492 \times 10 \times 24}{t}$$

t = 240 sec = 4 minutes

82. $P = \dfrac{mgh}{t}$

$= 50 \times 10 \times 50$

$= 25$ kW

83. $a = \dfrac{F}{m}$; $s = \dfrac{1}{2}at^2$ & $v = at$

Average power (P)

$$= \frac{W}{t} = \frac{Fs}{t} = \frac{F\left(\frac{1}{2}at^2\right)}{t} = \frac{1}{2}Fv$$

84. $P_{avg} = \dfrac{F\Delta x}{t} = FV_{avg} = kmg \times \left(\dfrac{u+0}{2}\right)$

$$P_{avg} = \frac{1}{2}mukg$$

85. $P = \dfrac{dK}{dt} = 2t$

$$\int_{K_i}^{K_f} dK = \int_0^4 2t\ dt$$

$$\Delta K = \left[t^2\right]_0^4 = 16\ J$$

86. $FV = \dfrac{3t^2}{2}$

$$\int_0^v mvdv = \int_0^2 \frac{3t^2}{2}dt$$

$$\frac{mv^2}{2} = \left[\frac{t^3}{2}\right]_0^2$$

$2 \times v^2 = 8$

$v^2 = 4$

$v = 2$ m/s

87. $P = mav \Rightarrow P = m\left(v\dfrac{dv}{dx}\right).v$

$\Rightarrow mv^2dv = Pdx$

$$\Rightarrow \frac{mv^3}{3} = Px \Rightarrow x \propto v^3$$

88. $F = mg\sin\theta$

$$F = 2 \times 10 \times \frac{1}{30} = \frac{2}{3}N$$

$$\text{Efficiency} = \frac{P_{out}}{P_{in}}$$

$$\frac{40}{100} = \frac{\frac{2}{3} \times 60}{P_{in}}$$

$$P_{in} = 100\ \text{Watt}$$

89. Amount of water flowing per unit time $\dfrac{dm}{dt} = Av\rho$

v = velocity of flow, A = is area of cross–section,

ρ = density of water

To get n times water in the same time,

$$\left(\frac{dm}{dt}\right)' = n\frac{dm}{dt} \Rightarrow A v'\rho = nAv\rho \Rightarrow v' = nv$$

$$F = \frac{vdm}{dt} \text{ and } F' = v'\frac{dm'}{dt} = n^2 v\frac{dm}{dt} = n^2F$$

To get n times water, force must be increased n^2 times.

Exercise-II (Previous Year Questions)

1. $W = -\int Fdx$

$$W = -\int_{20}^{30} 0.1x\,dx$$

$$W = -0.1\left[\frac{x^2}{2}\right]_{20}^{30}$$

$$W = -0.1\left[\frac{900-400}{2}\right] = -25J$$

From work energy theorem $W = K_f - K_i$

$$-25 = K_f - \frac{1}{2} \times 10(10)^2$$

$K_f = 475$ J

2. $P = Fv = mav$

$$k = mv\frac{dv}{dt}$$

By integrating the equation

$$\int v\,dv = \int \frac{k}{m}dt$$

$$\frac{v^2}{2} = \frac{k}{m}t \Rightarrow v = \sqrt{\frac{2k}{m}t}$$

$$a = \frac{dv}{dt} = \sqrt{\frac{2k}{m}}\left(\frac{1}{2}t^{-1/2}\right) = \sqrt{\frac{k}{2m}}\,t^{-1/2}$$

$\therefore$ F = ma = $m\sqrt{\frac{k}{2m}}\,t^{-1/2}$

$\therefore$ F = $\sqrt{\frac{mk}{2}}\,t^{-1/2}$

3. $\vec{F} = 2t\hat{i} + 3t^2\hat{j} \Rightarrow m\frac{d\vec{v}}{dt} = 2t\hat{i} + 3t^2\hat{j}$ {m = 1 kg}

$\Rightarrow \int_0^{\vec{v}} d\vec{v} = \int_0^t (2t\hat{i} + 3t^2\hat{j})dt \Rightarrow \vec{v} = t^2\hat{i} + t^3\hat{j}$

Power = $\vec{F}.\vec{v}$ = $(2t^3 + 3t^5)$W

4. $\vec{s} = \vec{r}_f - \vec{r}_i = 2\hat{i} - \hat{j} + 3\hat{k}$

$W = \vec{F}.\vec{s} = (4\hat{i} + 3\hat{j}).[2\hat{i} - \hat{j} + 3\hat{k}] = 8 - 3 = 5J$

5. Work done by the gravity (W_g) = mgh

= $10^{-3} \times 10 \times 10^3$ = 10 J

By work–energy theorem :- $W_g + W_{res} = \Delta KE$

$10 + W_{res} = \frac{1}{2} \times 10^{-3} \times (50)^2$

W_{res} = –8.75 J

6. W = $\int_{y_1}^{y_2} F\,dy$

W = $\int_0^1 (20 + 10y)dy$

$W = 20[y]_0^1 + 10\left[\frac{y^2}{2}\right]_0^1$

W = 25 J

7. W = ΔKE

for x = 8, $130 = \frac{1}{2}\left(\frac{1}{2}\right)v^2$

v = $2\sqrt{130} = 22.8\ ms^{-1}$

For x=12 :-

130 – 40 – 5 + 20 = $\frac{1}{2}\left(\frac{1}{2}\right)v^2$

v = 20.6 m/s

8. U + KE = E and K.E = 3U

4U = E = mgS

4mgh = mgS

h = $\frac{S}{4}$

$V = \sqrt{2g\left(\frac{3S}{4}\right)} = \sqrt{\frac{3gS}{2}}$

9. $P_{in} = \frac{mgh}{t} = \frac{15 \times 10 \times 60}{1}$ = 9000 W

P_{out} = 90% of P_{in}

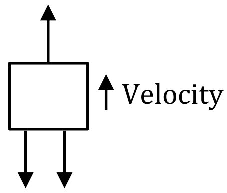
$\Rightarrow$ 8.1 kW

10. Constant velocity $\Rightarrow$ a = 0

$\Rightarrow$ T = W + f

= 20000 + 3000

= 23000 N



$\Rightarrow$ Power = Tv

= 23000 × 1.5

= 34500 watts

11. Gravitational force is a conservative force so W.D. is independent of path taken between two points.

12. $U = \frac{1}{2}kx^2$

for x = 2

$U = \frac{1}{2}k(2)^2$ ...(1)

$U' = \frac{1}{2}k(8)^2$ ...(2)

Eq. (2)/eq. (1)

$\Rightarrow \frac{U'}{U} = \left(\frac{8}{2}\right)^2$

$\Rightarrow \boxed{U' = 16U}$

13. $P = \vec{F}.\vec{V}$

$P = (10\hat{i} + 10\hat{j} + 20\hat{k}).(5\hat{i} - 3\hat{j} + 6\hat{k})$

P = 50 – 30 + 120

14. x = 2t –1

$\frac{dx}{dt} = v = 2\ m/s$

$P = \vec{F}.\vec{v} = 5(2) = 10$ watt

15. $W = K_f - K_i$

$\vec{F}.\vec{S} = K_f - K_i$

$\left(-2\hat{i}+3\hat{j}\right).3\hat{i} = K_f - 10$

$-6 = K_f - 10$

$\Rightarrow K_f = 4\text{ J}$

16. Let final t_{height} be h_f

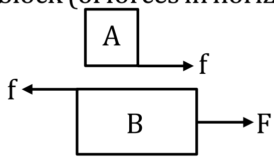
$E_f = \frac{1}{2} E_i$

$mg\, h_f = \frac{1}{2}\, mgH$

$\Rightarrow h_f = \frac{10}{2} = 5\text{m}$

Exercise-III (Analytical Questions)

3. F.B.D. of block (of forces in horizontal direction)



It can be seen that W.D. by friction (f) on block A is positive and on block B is negative.

4. Statements (a) & (b) are incorrect because according to work energy theorem, work done by all forces (Internal, External, Conservative, Non conservative) is equal to change in kinetic energy.

5. Assertion is correct because according to work energy theorem work done by all forces (Internal, External, Conservative, Non conservative) is equal to change in kinetic energy.

Therefore, kinetic energy of system may increase due to internal force only.

Reason is correct.

6. Assertion is correct, because work done is positive if angle between $\vec{F}$ & $\vec{S}$ is acute.

Reason is false:- Work done by friction may be positive, negative or zero.

8. $F = -\frac{\partial U}{\partial x}\hat{i} - \frac{\partial U}{\partial y}\hat{j} - \frac{\partial U}{\partial z}\hat{k} \Rightarrow -\left(4x\hat{i} + 9y^2\hat{j} + 2\hat{k}\right)$