Notes CH.(7): Kinetic Energy and Work(الطاقة الحركية و الشغل)

Kinetic energy (K.E) = ½ m v^2

If body is stationary → v=0 →K.E=0

The unit of energy (K.E-W) is the joule (J).
1 J = 1 kg m^2/s^2 → from K.E=(1/2) m v^2
1 J = 1 N . m → from W =F.d
1 J = 1 Watt.s → from W=P.t
1 J = 1 Watt.s (or kiloWatt.hour) → from W=P.t

kinetic energy, work and power are scalar quantities

Exp.(1): Which of the following bodies has the smallest kinetic energy?
a) Body A b) Body B c) Body C d) Body D

Body	Mass (kg)	Velocity (m/s)	kinetic energy= ½ m v^2	
A	2 m	3 V	½ (2 m) $(3 V)^2$ = (9) m V^2	The largest kinetic energy
B	1 m	4 V	½ (1 m) $(4 V)^2$ = (8) m V^2	
C	3 m	1 V	½ (3 m) $(1 V)^2$ = (1.5) m V^2	The smallest kinetic energy
D	3 m	2 V	½ (3 m) $(2 V)^2$ = (6) m V^2	

Work (W) الشغل

$W = \Delta k$

Work-kinetic energy theorem

$W = k_f - k_i$

f: final
i: Initial

$W = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$

W ➔ (+ve)	W ➔ (-ve)
Energy transfers to object	Energy transfers from object
K.E increase	K.E decrease
W increase	W decrease

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

Work done by a constant force

$W = F\, d \cos(\theta)$

Where F is Force (القوة)
d is displacement (الإزاحة)
θ is the angle between the force and displacement
الزاوية بين القوة والإزاحة

Note: $F \cdot d = F_x d_x + F_y d_y + F_z d_z$

W= No.

إذا كانت القوة على نفس مستوى الإزاحة

W= F . d = F d cos (θ)

$= F_x d_x + F_y d_y + F_z d_z$

W ➔ (+ve)	W ➔ (-ve)
1-F is in the same direction of d	1-F is in the opposite direction of d
إذا كانت القوة في نفس اتجاه الازاحة	إذا كانت القوة عكس اتجاه الازاحة
2- $0 \leq \theta < 90$	2- $90 < \theta \leq 180$

W=0

إذا كانت القوة عمودية على مستوى الإزاحة

$F \perp d \ (\theta = 90^0)$

W= F . d = 0

$W_s = \frac{1}{2} k (x_i^2 - x_f^2)$

Work done by a spring force

Note: $F_x = -k\, x$

(Hooke's Law)

Exp. (2): a) A constant force of F=(5N) in the positive x-direction acts on 4kg mass as it moves from r_1 = 3i+4j to r_2 =5i, what is the work done by force?

d= $\Delta r = r_2 - r_1$ = (5i) - (3i+4j) = (5-3)i + (0-4)j= 2i - 4j
F= 5 i
W=F.d = 5 x 2 + 0 x - 4 = 10 J

b) If a force F = 210 i - 150j (N) is applied on a box, the displacement of the box due to the force is d = 15i -12j +3k (m). Find the work done?

W= $F \cdot d = F_x d_x + F_y d_y + F_z d_z$

W= 210x15 + (-150x-12)+ (0x3) = 4950 J

Exp.(3): If the kinetic energy of a particle is initially 5 J and there is a net energy transfer of 2 J to the particle, what is the final kinetic energy?
W = $\Delta K = K_f - K_i$ (net energy transfer)
$K_f = \Delta K + K_i$
ΔK =W= +2 J (to) → K_f = + 2+ 5 → K_f = 7 J
Note: **If a net energy 2 J transfers from the particle: W = Δk = -2 J (from) → K_f = -2 + 5 = 3 J**

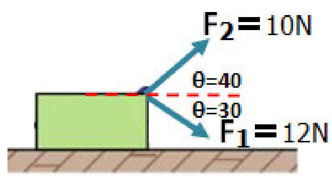
Exp.(4): Which of the following particles that moves along the x-axis has a negative work done on it?

Particle	K_i (initial K.E)	K_f (final K.E)	W= k_f - k_i	
A	4 J	4 J	4-4=0 J	W→ remains constant
B	9 J	4 J	4-9=-5 J	W→ negative value
C	Zero	5 J	5-0=+5 J	W→ positive value
D	8 J	3 J	3-8=-5 J	W→ negative value

Work net

$W_{net} = W_1 + W_2 + W_3$ $W_{net} = F_1.d + F_2.d + F_3.d$	$W_{net} = F_{net} . d$ $W_{net} = F_{net}\, d \cos(\theta)$

Exp.(5): Two forces act on a box shown in figure. The box moves 8.5m to right. What is the total work done by these forces?



$W_{net} = W_1 + W_2$

$W_{net} = F_1.d + F_2.d$

$W_1 = F_1\, d \cos(\theta_1)$

$= 12 \times 8.5 \times \cos(30) = 88.3$ J

$W_2 = F_2\, d\cos(\theta_2)$

$= 10 \times 8.5 \times \cos(40) = 65.11$J

$W_{net} = W_1 + W_2$

$= 88.33 + 65.11 = 153$ J

$W_{net} = F_{net} . d$

$W_{net} = F_{net}\, d \cos(\theta)$

$F_{net,x} = \Sigma F_x = F_{1x} + F_{2x}$

$\Sigma F_x = F_1 \cos 30 + F_2 \cos 40 = 18$

$F_{net,y} = \Sigma F_y = F_{1y} + F_{2y}$

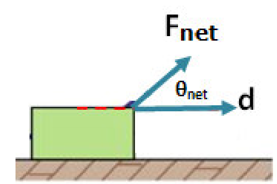
$\Sigma F_y = F_1 \sin 30 + F_2 \sin 40 = 12.4$

$F_{net} = \sqrt{F_x^2 + F_y^2} = 21.86$

$\theta_{net} = \tan^{-1}\frac{F_y}{F_x} = 35^0$

$\theta = \theta_{net}$

$W_{net} = 21.86 \times 8.5 \cos 35 = 153$J



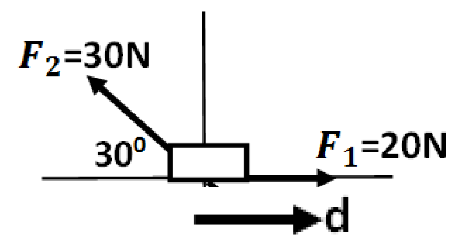
F_{net} is in part I

➔ θ_{net} with +x-axis

d is in +x-axis

➔ $\theta = \theta_{net}$

Exp.(6): There are two forces on the 2 kg box shown in the figure. If the box moves to right 6m. Find the work done by F_1 (W_1) and F_2 (W_2)?



$W_1 = F_1 . d \cos(\theta_1)$

$= 20 \times 6 \times \cos(0) = 120$ J

$W_2 = F_2 . d \cos(\theta_2)$

$= F_2 . d \cos(150)$

$= 30 \times 6 \times \cos(150) = -155.88$J

Exp.(7): Two men sliding a box of mass **m** a displacement **d** along x-axis, if the work done by the first man was W_1 =70 J, and the net work done on the box was W=120 J. What is the work W_2 done by the second man?

W_1 =70 J, W_{net} =120 J, W_2 = ??
$W_{net} = W_1 + W_2$
$W_2 = W_{net} - W_1 = 120-70=50$ J

Exp. (8): A car of mass 1000 kg accelerates at 2 m/s^2 for 10 s from an initial speed of 5 m/s. a) What is the final kinetic energy? b)Determine the work done by the car.

To find v_f :
$v_f = v_i + a\,t$ ➔ $v_f = 5 + 2\,(10) = 25$ m/s

$K_f = ½\, m\, (v_f)^2 = ½\, (1000)\, (25)^2 = 312500$ J

b) $K_i = ½\, m\, (v_i)^2 = ½\, (1000)\, (5)^2 = 12500$ J

$W = K_f - K_i = 312500 - 12500 = 3 \times 10^5$ J

أنواع الشغل

الشغل الناتج عن قوة ثابته

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

1) شغل قوة الدفع

$W_F = Fd\cos(\theta)$
$= F_x d_x + F_y d_y + F_z d_z$

2) شغل قوة الجذب (الوزن Weight)

$F_g = m\,g$

حركة أفقية

$W_{F_g} = 0$

حركة رأسيه

لأعلى ـ صعود
(rising- *moving up-above-ascent)*

$W_{F_g} = -mg\,d$

لأسفل ـ نزول
(falling- *moving down-descent*)

$W_{F_g} = mg\,d$

3) شغل القوة العمودية

$W_{F_N} = 0$

4) شغل قوة الاحتكاك

$W_f = -f\,d$

الشغل الناتج عن قوة الزنبرك المتغيرة

$F_x = -kx$
(Hooke's Law)
Where k is spring constant
(N/m)

5) شغل قوة الزنبرك

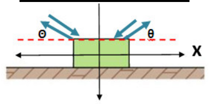
$W_s = \frac{1}{2}\,k\,(x_i^2 - x_f^2)$

أنواع الشغل

قوة ثابته

$$W = F\,d\cos(\theta)$$

قوة الدفع



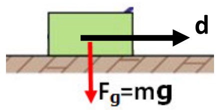
$W_F = F\,d\cos(\theta)$

شغل قوة الجذب (الوزن Weight) (gravitational force)

$F_g = m\,g$

*اتجاهها دائما لأسفل

حركة أفقية



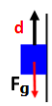
$W_{F_g} = F_g\,d\cos(\theta)$

$\theta = 90^0$

$W_{F_g} = 0$

حركة عموديه

صعود rising



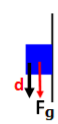
$W_{F_g} = F_g\,d\cos(\theta)$

$\theta = 180^0$

$W_{F_g} = -F_g\,d$

$W_{F_g} = -mg\,d$

نزول falling



$W_{F_g} = F_g\,d\cos(\theta)$

$\theta = 0^0$

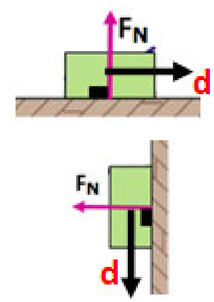
$W_{F_g} = F_g\,d$

$W_{F_g} = mg\,d$

شغل القوة العمودية (Normal force)

F_N

اتجاهها عمودية على السطح



$W_{F_N} = F_N\,d\cos(\theta)$

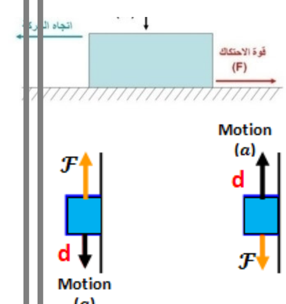
$\theta = 90^0$

$W_{F_N} = 0$

شغل قوة الاحتكاك (Friction)

$\mathcal{F} = \mu F_N$,

اتجاهها عكس اتجاه الحركة



$W_f = f\,d\cos(\theta)$

$\theta = 180^0$

$W_f = -f\,d$

قوة متغيرة (F is variable)

شغل قوة شد الزنبرك (Spring)

$F = -kx$ (Hooke's Law)

$W_s = \frac{1}{2}k(x_i^2 - x_f^2)$

Exp. (9): A 5.0-kg box is raised a distance of 2.5 m from rest by a vertical applied force of 90 N. Find (a) the work done on the box by the applied force, and (b) the work done on the box by gravity? (c) What is the final velocity for box at the end of 2.5 m?

a) $W_F = F\ d = 90 \times 2.5 = 225$ J

b) For rising object: $W_{Fg} = -\ mg\ d = -\ 5 \times 9.8 \times 2.5 = -122.5$ J

c) $v_i = 0$ (raised from rest) ➔ $K_i = 0$

$W_{net} = W_F + W_{Fg} = 225 - 122.5 = 102.5$ J

$W_{net} = K_f - K_i = ½\ m\ (v_f)^2 - ½\ m\ (v_i)^2$

$102.5 = ½\ (5)\ (v_f)^2$ ➔ $(v_f)^2 = (2*102.5)/5 = 41$ ➔ $v_f = 6.4$ m/s

Exp. (10): A 40 kg box is pulled 30 m on a horizontal floor by applying a force (F) of magnitude 100 N directed by an angle of 60° above the horizontal. If the floor exerts a friction force (f) of magnitude 20 N, calculate the work done by each one of these forces. Calculate the work done by the weight (F_g) and the normal force(F_N). Calculate also the total work done on the box.

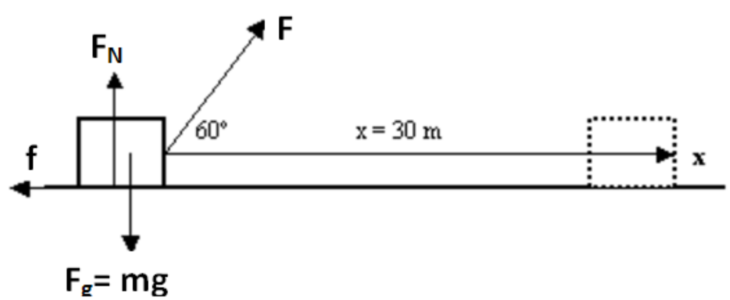
$W_F = F\ d \cos\theta = 100 \times 30 \cos(60) = 1500$J

$W_f = f\ d \cos(180) = -f\ d = -20 \times 30 = -600$ J

$W_{Fg} = F_g\ d \cos(90) = 0$

$W_{FN} = F_N\ d \cos(90) = 0$

$W_{net} = W_F + W_f + W_{Fg} + W_{FN} = 1500 - 600 + 0 + 0 = 900$J



Exp. (11): A 1-kg box slides along an +x-axis on the rough floor. The box is moving from 6 m/s to 2 m/s. Find the work done by friction

$W_{net} = W_f = K_f - K_i = ½\ m\ (v_f)^2 - ½\ m\ (v_i)^2 = ½\ (1)\ [2^2 - 6^2] = -16$ J

بقية الأمثلة في المرفق الثاني باستثناء مثال رقم 11

Power (P): the rate of work
القدرة

average power

$$P = \frac{W}{t}$$

$$P_{net} = P_1 + P_2 + P_3$$

The unit of power is the Watt (W)
1 Watt= J/s ➔ from P= w/t
1 Watt= kg.m^2/s^3 (where J = kg m^2/s^2)

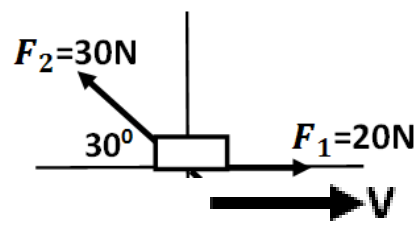
Instantaneous power

$$P = \frac{dW}{dt}$$

$$P = \vec{F}.\vec{v} = F\, v\, cos(\theta)$$

Where F is Force (القوة)
v is velocity (السرعة)
θ is the angle between the force and velocity (الزاوية بين القوة والسرعة)

Exp.(12): There are two forces on the 2 kg box shown in the figure. If the box moves to right with constant velocity 4m/s. What is the power due to F_1) and F_2 then find the net power?



$P_1 = F_1 . v\, cos\, (\theta_1) =$ 20 x 4 x cos (0)= 80 J

$P_2 = F_2 . v\, cos\, (\theta_2) = F_2 . d\, cos\, (150) =$ 30x4 x cos(150)= -103.9J

$P_{net} = P_1 + P_2 =$ 80 -103.9 =-23.9 J

Exp.(13): **A person lifts a 100 N weight 2 m above the ground during 2 s. What is the power required?**

Rising ➔ W=-mgd= -100x2= -200 J

P=-200/2= - 100 W

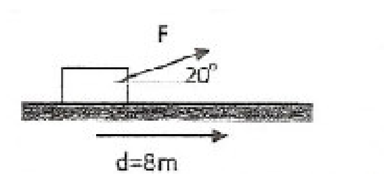
Exp. (14): In which of the following situation the net power = 5 W?

Situation	**P_1**	**P_2**	**P_3**	**$P_{net} = P_1 + P_2 + P_3$**
A	**12**	**5**	**-7**	**12 + 5 -7 =10 Watt**
B	**-13**	**3**	**-2**	**-13 + 3 – 2= -12 Watt**
C	**15**	**-12**	**-3**	**15 – 12 -3 = 0**
D	**10**	**2**	**-7**	**10 + 2 -7 = 5 Watt**

Exp. (15): A man uses a force of 200 N, which is 20^0 above the horizontal, (as in the diagram) to push a box a distance of 8m. What is the power if the man takes 12 s to push the box?

F= 200 N, $\theta=20^0$, d=8m, t= 12 s

$P = \frac{W}{t} = \frac{F\, d \cos(\theta)}{t} = \frac{(200)(8)\cos(20)}{12}$= 125 Watt



هنـــاء فرحان

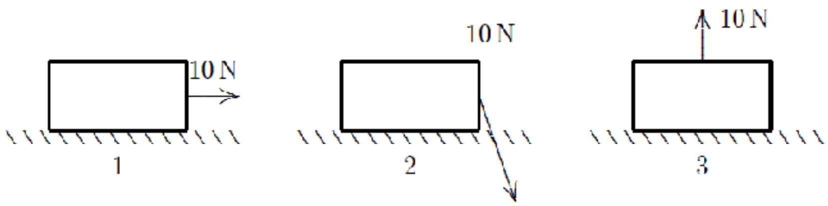
Problems:

1- Which of the following groups does NOT contain a scalar quantity?

A. velocity, force, power
B. displacement, acceleration, force
C. acceleration, speed, work
D. energy, work, distance
E. pressure, weight, time

ans: B

2- A crate moves 10 m to the right on a horizontal surface as a woman pulls on it with a 10-N force. Rank the situations shown below according to the work done by her force, least to greatest.



A. 1, 2, 3
B. 2, 1, 3
C. 2, 3, 1
D. 1, 3, 2
E. 3, 2, 1

ans: E

3- An object moves in a circle at constant speed. The work done by the centripetal force is zero because:

A. the displacement for each revolution is zero
B. the average force for each revolution is zero
C. there is no friction
D. the magnitude of the acceleration is zero
E. the centripetal force is perpendicular to the velocity

ans: E

4- The work done by gravity during the descent of a projectile:

A. is positive
B. is negative
C. is zero
D. depends for its sign on the direction of the y axis
E. depends for its sign on the direction of both the x and y axes

ans: A