Second Semester Examination
2022/2023 Academic Session

July / August 2023

EME 442 – Biomechanics
(Biomekanik)

Duration: 2 hours
(Masa: 2 Jam)

Please check that this examination paper consists of ELEVEN (11) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEBELAS (11) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer ALL **FOUR (4)** questions.

*[**Arahan**: Jawab SEMUA **EMPAT (4)** soalan]*

1. Figure 1 shows a basic structure used in the Wilmington Robotic Exoskeleton. The structure consists of links OA, AB and BC where the links are pin jointed. Point O and C are anchored to the wheelchair. To compensate the weight W=3 kg at point A, a spring of stiffness k N/mm with unstretched length of 200 mm is used to connect point O and B. The links are considered massless:

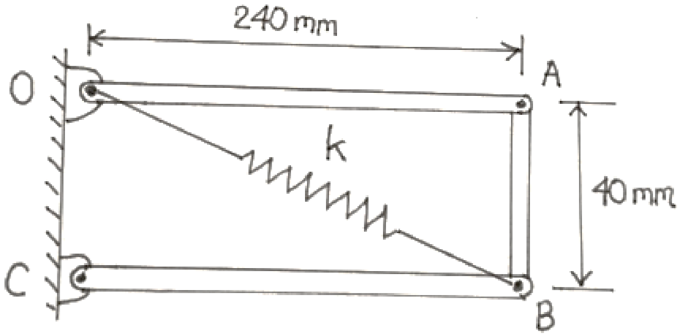

Figure 1

(a) Determine the stiffness of the spring k in order to fully compensate the weight W= 3 kg at the neutral position.

(40 marks)

(b) If the link OA is now pushed to rotate 30 degrees downward (i.e. clockwise about point O) determine the new righting moment

(30 marks)

(c) A young mechanical engineer suggested that a damper unit should be installed parallel with the spring. Comment on this suggestion

(30 marks)

2. You have developed a new upper limb orthosis named **NEWHand** that can be used to help children with neuromuscular weakness of the upper limb. In order to prove that **NEWHand** is better than the **WREX** orthosis you have to plan the clinical trial. For the clinical trial the statistical parameters that are accepted are ($p < 0.05$), Power=0.8. The data from the pilot study (N=10) is listed in Table 1 below. The population standard deviation can be taken as 8.4 seconds.

The clinically important difference that we want to detect is 5 seconds.

(a) Determine the standardized difference and the sample size required to achieve the above power value

(40 marks)

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(b) Comment on the power value P=0.8 used. Is this sufficient? Would you advise the study to go for P=0.95?

(20 marks)

(c) What is the implication when P=0.95 is used in terms of costs and time needed to complete the study?

(20 marks)

(d) Most study requires the analysis to include the confidence interval on top of the p-value. Do you agree with this requirement and explain the reason for it?

(20 marks)

Table 1 – Data from pilot study

Task	USMHand	WREX	Control
Mean time to complete the task (in seconds)	21.2	25.6	28.8
Standard deviation of the time to complete the task (in seconds)	4.5	7.6	8.4

Table 2 – List of Z values that can be used in the calculation for Question 2

$Z_{0.975}$ = 1.96
$Z_{0.95}$ = 1.64
$Z_{0.90}$ = 1.29
$Z_{0.80}$ = 0.84

3. (a) Work-related Musculoskeletal Disorders (WMSDs) refer to injuries and disorders that affect the movement and musculoskeletal system of individuals in a work setting. These disorders can be caused by various factors, including poor ergonomics, repetitive motions, awkward postures, and physical strain.

The Ovako Working-posture Assessment System (OWAS) is a commonly employed approach used to assess and categorize working postures with the aim of promoting occupational health and preventing WMSDs. It provides a systematic approach to evaluating the ergonomic aspects of work and identifying high-risk postures that can contribute to the development of WMSDs. By using OWAS, organizations can analyze work postures, identify potential risk factors, and implement preventive measures to minimize the occurrence of WMSDs among workers.

Referring to the guidelines in **Appendix 1**, determine the OWAS scores for the postures of the workers shown in Figure 3 (a).

State the <u>assumptions</u> you made for this calculation.

(a) A worker is cutting a tree using a heavy-duty chainsaw that weighs 10 kg.

(b) An oil palm worker is lifting and loading hundreds of fresh fruit bunches (FFBs) per hour above his shoulder. The average weight of each FFB is approximately 25 kg.

(c) A ground-handling staff member transfers hundreds of pieces of luggage to a conveyor belt connected to a passenger aircraft at KL International Airport. The average weight of each piece of luggage is approximately 20 kg.

(d) A caregiver is lifting an old aunty from a wheelchair into a car. The weight of aunty is 50 kg

(e) Two emergency medical service personnel are lifting a person who weighs 130 kg and has fallen to the floor.

Determine the OWAS score for the posture of the worker indicated with an arrow.

Figure 3 (a) – Typical awkward postures in working activities

(50 marks)

(b) A worker positions himself midway between the hand truck and the mixing hopper, as depicted in Figure 3 (b). Without moving his feet, he twists to the right and picks up a bag from the hand truck. In one continuous motion, he then twists to his left to place the bag on the rim of the hopper. The angle formed during this movement is asymmetric, with a 45-degree angle at the starting point and a 45-degree angle at the endpoint of the lift. Inside the hopper, there is a sharp-edged blade that cuts open the bag, allowing the contents to fall into the hopper.

The overall task is performed at a rate of less than 0.2 lifts per minute and lasts for less than one hour.

(a) Determine the recommended weight limit (RWL) and lifting index (LI) for this task according to the National Institute of Occupational and Health (NIOSH) revised lifting equation.

Equations and tables for multipliers are available in Appendix 2.

(30 marks)

(b) Discuss whether the task is safe. Provide a detailed suggestions or recommendation on how to improve the LI, thus reducing the risk of injury.

(20 marks)

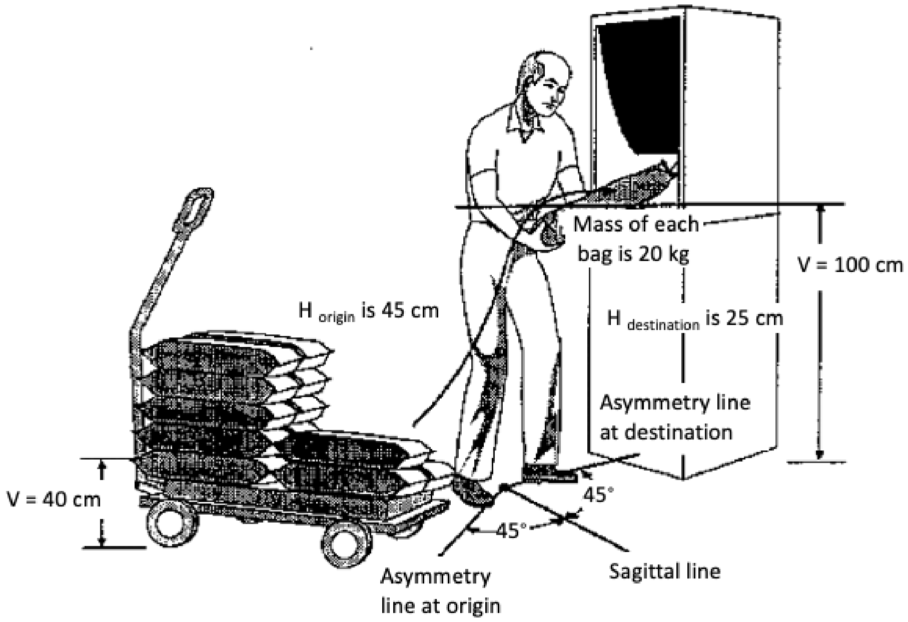

Figure 3 (b) – Loading bags into a hopper

4. (a) Aunt Rokiah, aged 65, is leaning forward as she lifts an object with a weight of 100 N [Figure 4 (a)]. Her head, arms, and trunk have a combined weight of 450 N. Determine the followings,

(a) The erector spinae muscle force, F_M.

(10 marks)

(b) The compressive and shear components of joint reaction force (F_{JC} and F_{JS} respectively) at the L5/S1 lumbar disc vertebral joint (grey square), point O.

(10 marks)

(c) How does the force joint compression (F_{JC}) compare to the recommended value of 3,400 N, which serves as a guideline set by NIOSH to determine a safe threshold for the amount of force that can be applied to the joints while performing tasks? Based on your answer, what suggestions can you provide to Aunt Rokiah to ensure that she minimizes the risk of injury and helps her perform the task safely?

(20 marks)

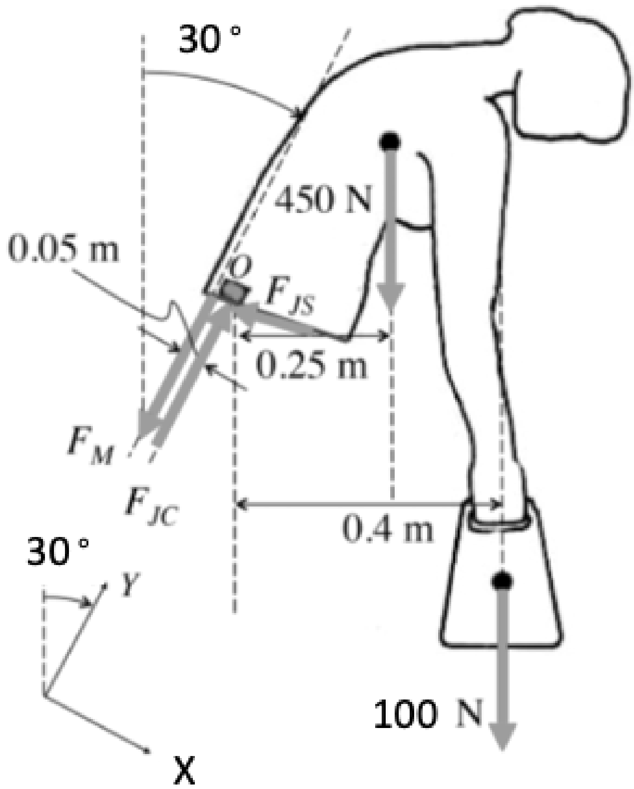

Figure 4 (a) – Aunt Rokiah is lifting 100 N object.

b) A team of final-year engineering students from Universiti Sains Malaysia (USM), who are studying biomechanics, has successfully designed a functional prototype of an exoskeleton. The exoskeleton is specifically intended to assist in improving upper-limb coordination and muscle strength in post-stroke patients.

To evaluate the effectiveness of the design, the team has decided to conduct clinical trials at the Hospital Universiti Sains Malaysia (HUSM), involving 24 post-stroke patients. The patients will be randomly assigned to two intervention groups: the manual physical therapy group (control group) and the exoskeleton-aided therapy group (the exoskeleton group).

The primary objective of the study is to investigate whether the treatment utilizing the assistive exoskeleton can potentially lead to superior recovery outcomes compared to manual physical therapy.

(a) Suggest the appropriate inclusion and exclusion criteria for selection of participants.

(20 marks)

(b) List the rights of the participants before, during and after participating the study.

(20 marks)

(c) What are the types of research data that could be collected by the students from this clinical study?

(20 marks)

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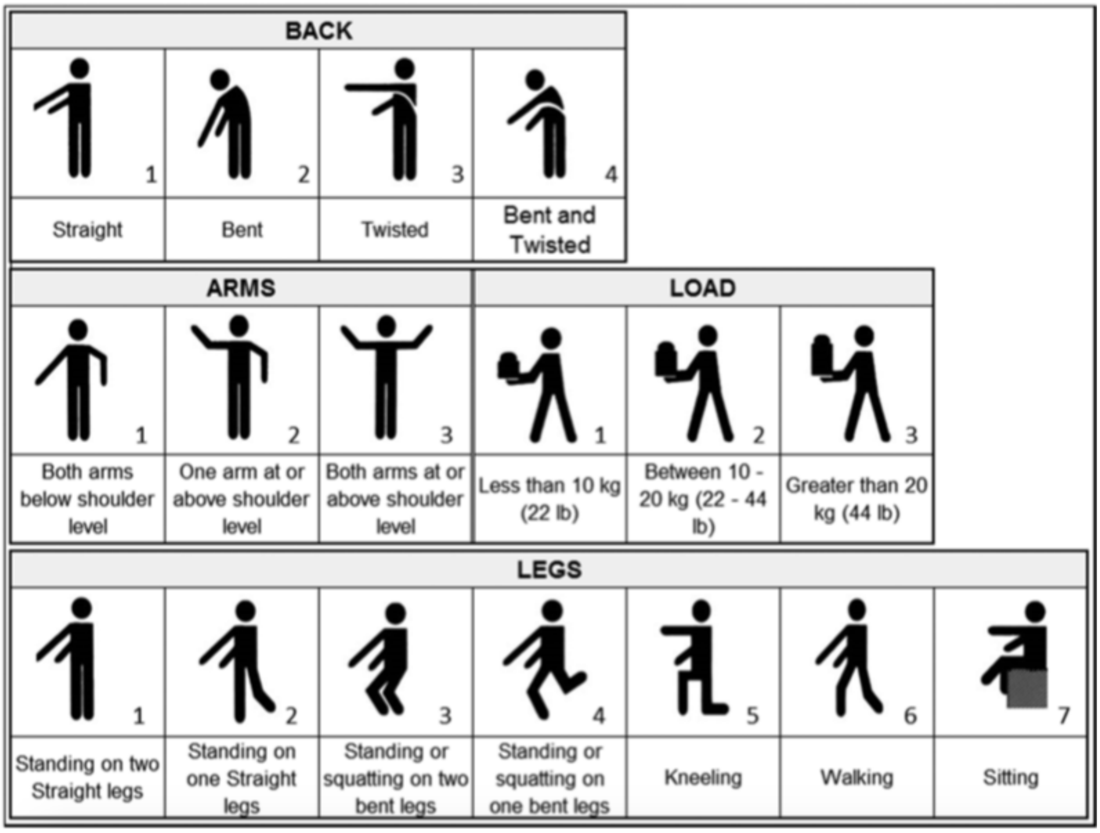
APPENDIX 1

OWAS method postures chart



Postures classification by the combination of variables

Back	Arms	1			2			3			4			5			6			7			Legs
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Loads
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2	
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3	
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4	
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1	
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1	
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1	
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4	
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	

APPENDIX 2

		METRIC	US CUSTOMARY
Load Constant	LC	23 kg	51 LB
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1-(.003 [V-75])	1-(.0075 [V-30])
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1-(.0032A)	1-(.0032A)
Frequency Multiplier	FM	From Table	From Table
Coupling Multiplier	CM	From Table	From Table

Frequency Multiplier table (FM)

Frequency Lifts/min (F):	Work Duration					
	<= 1 Hour		>1 but <=2 Hours		>2 but <=8 Hours	
	V<30+	V>=30	V<30	V>=30	V<30	V>=30
<=0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

\+ Values of V are in inches

: For lifting less frequently than once per 5 minutes, set F = 0.2 lifts/minute.

Coupling Multiplier table (CM)

Coupling Type	Coupling Multiplier: V < 30 inches (75 cm)	Coupling Multiplier: V >= 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Hand-to-Container Coupling Classification

GOOD	FAIR	POOR
For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object	For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees	Lifting non-rigid bags (i.e., bags that sag in the middle).