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**EXAM IN HMET4101, JANUARY 16, 2026:
SUGGESTED SOLUTIONS AND COMMENTS**

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INTRODUCTION

The exam was arranged digitally on the Inspera platform and consisted of 10 questions. The first two questions were multiple-choice questions in which the candidates should choose one of several alternative answers. The remaining questions were in an "essay" format and the answers had to be written as text.

The multiple-choice questions were automatically assessed, while the "essay" questions were manually assessed. The maximum scores per question ranged from 10 to 15 points. In total, the maximum score was 120 points.

The following relation between grades (A-F) and points [0-120] was used: A: [107–120], B: [91–106], C: [73–90], D: [56–72], E: [45–55], F: [0–44].

Explanation of grades. After the grades are published, the candidates will have access to their individual scores by logging into Inspera. The suggested solution presented here, which will be distributed to the candidates, explains the general principles for how the scores and grades were awarded. A candidate's detailed scores on the exam questions and the general suggested solution constitute the formal explanation of the grade, and no further formal explanations will be given.

Appeal against grades. Appeals against grades must be submitted following the procedure described on the course website (that is, not submitted to the course coordinator).

Informal feedback. A candidate who wishes to receive additional feedback can ask the course coordinator for an informal talk (say by phone or Zoom). The candidate must then email the course coordinator 2-3 suggested times with at least two workdays notice. The suggested times should be within normal office hours (09:00-17:00) in the period between February 9 and February 15, 2026.

QUESTION 1 (10P)

$$\begin{aligned} P(3 < X < 6) &= P\left(\frac{3 - 4.8}{1.6} < \frac{X - 4.8}{1.6} < \frac{6 - 4.8}{1.6}\right) \\ &= P(-1.13 < Z < 0.75) = P(Z < 0.75) - P(Z < -1.13) \\ &= 0.7734 - 0.1292 \approx 0.644. \end{aligned}$$

QUESTION 2 (10P)

$$\begin{aligned}
 P(X \geq 3) &= P(X = 3) + P(X = 4) + \dots = 1 - P(X \leq 2) \\
 &= 1 - 0.6767 \approx 0.323.
 \end{aligned}$$

QUESTION 3 (10P)

Let X denote the number of patients who do not attend their appointment. We use a binomial distribution with $n = 15$ and $p = 0.3$.

a)

$$P(X = 5) = 0.2061. \quad (\text{table of individual probabilities})$$

b)

$$\begin{aligned}
 P(X \geq 4) &= P(X = 4) + P(X = 5) + \dots + P(X = 15) = 1 - P(X \leq 3) \\
 &= 1 - 0.297 = 0.703. \quad (\text{table of cumulative probabilities})
 \end{aligned}$$

QUESTION 4 (10P)

We use the formula

$$\bar{x} \pm t_{\alpha/2, n-1} \cdot \frac{s}{\sqrt{n}},$$

and insert

$$1350 \pm 2.064 \cdot \frac{420}{\sqrt{25}} \Rightarrow 1350 \pm 173.4.$$

This gives the interval (1176.6; 1523.4).

It is assumed that the costs in the population are normally distributed and that the standard deviation is unknown. In addition, it is assumed that it is a simple random sample, where the observations are independent of each other. *A priori*, that is, before collecting the data, there is a 95% probability that the confidence interval procedure will produce an interval that contains the population mean. We cannot say anything about the probability that the specific, interval estimate contains the population mean. The interval is fairly wide because there are few observations in the sample.

QUESTION 5 (10P)

Let μ denote the mean satisfaction score in the population after the reorganisation. Before the reorganisation, the population mean was $\mu_0 = 72$.

We test $H_0 : \mu = 72$ versus $H_1 : \mu > 72$.

We assume that satisfaction scores are approximately normally distributed in the population, and that the population standard deviation is unknown and is estimated by the sample standard deviation.

$$T_{\text{obs}} = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{75 - 72}{12/\sqrt{36}} = 1.50.$$

We will reject H_0 and accept H_1 if T_{obs} is sufficiently large. Under H_0 , the test statistic follows a Student t -distribution with $n - 1 = 36 - 1 = 35$ degrees of freedom. Since the available table does not include this value, we use 40 degrees of freedom as an approximation, that is $t_{0.05;40} = 1.684$.

Observing that T_{obs} is lower than the critical value, we decide to keep the null hypothesis at the 5% significance level. We conclude that the data do not provide sufficient evidence that the mean satisfaction score has increased after the reorganisation.¹

QUESTION 6 (10P)

(More than one solution is possible.) Let μ_A and μ_B be the true mean waiting times at Clinic A and Clinic B, respectively. We want to calculate a 95% confidence interval for the difference $\mu_A - \mu_B$.

We assume that the two samples are independent. The populations of waiting times are expected to be normally distributed for each clinic, and we assume that the unknown population variances are equal.

Compute the pooled variance:

$$s_p^2 = \frac{(n_A - 1)s_A^2 + (n_B - 1)s_B^2}{n_A + n_B - 2} = \frac{(20 - 1)1.8^2 + (18 - 1)2.0^2}{20 + 18 - 2} = 3.599.$$

The confidence interval is given by

$$\bar{x}_A - \bar{x}_B \pm t_{\alpha/2; n_A + n_B - 2} \cdot SE,$$

where

$$SE = \sqrt{\frac{s_p^2}{n_A} + \frac{s_p^2}{n_B}} = \sqrt{\frac{3.599}{20} + \frac{3.599}{18}} = 0.616.$$

We use $t_{0.025; 20+18-2} = t_{0.025; 36} \approx t_{0.025; 40} = 2.021$ as an approximation, since the textbook table does not report the value for 36 degrees of freedom. Inserting the remaining sample values into the formula gives the interval

$$5.1 - 6.0 \pm 2.021 \cdot 0.616,$$

that is, $(-2.15, 0.35)$.

The interval for the difference between the means contains zero. Therefore, at the 95% confidence level, the data do not provide sufficient support for concluding that the mean waiting times differ between the two clinics.

QUESTION 7 (15P)

You can see from the Pearson correlation that the relationship is increasing, since the sign of the R coefficient is positive (3p). The effect of age is significant, the p-value is < 0.001 from the regression output (3p). The Multiple R-Squared of 0.162 means that age explains 16.2% of the variation in pain level (3p). If age increases by 10 years, the pain increases by $10 \cdot 0.546 = 5.46$ units (3p). In the scatter plot, you should look for signs of a non-linear relationship between pain and age, but it looks ok (3p).

¹At the 10% significance level, the critical value is $t_{0.90; 40} = 1.303$, and since $1.50 > 1.303$, H_0 would be rejected.

QUESTION 8 (15P)

Null hypothesis: $\beta_{gender} = 0$ Alternative: $\beta_{gender} \neq 0$ (2p). Test statistic: $3.09/2.76 = 1.12$ (3p). From a standard normal distribution, the critical values are ± 1.96 (1p). Hence, we cannot reject the null hypothesis since the value of the test statistic is within those limits (3p). The pain level for a male is given by the constant as 51.74 (3p), and the pain level for a female is $51.74 + 3.09 = 54.93$ (3p).

QUESTION 9 (15P)

Pain reliever A, which is included in the constant, gives the lowest pain level respectively 5.23 and 22.38 points lower than Pain relievers B and C (3p). The difference between pain relievers B and C is $22.38 - 5.23 = 17.15$, where pain reliever C has the highest pain score (3p). If I wanted a p-value for this difference, I could have chosen B as the baseline or reference category and made dummy variables for A and C instead (3p). The prediction for pain reliever A becomes $Pain = 11.96 + 0.57 \cdot 62 + 1.86 \cdot 1 + 5.24 \cdot 0 + 22.39 \cdot 0 = 49.16$ (3p). If she used pain reliever B, the difference can be read directly from the table, by the coefficient 5.24 as this gives the difference between pain relievers A and B. The pain level would be $49.16 + 5.24 = 54.4$ (3p).

QUESTION 10 (15P)

The predicted pain level for the 28 year-old woman using pain reliever A in this model becomes: $Pain = 41.89 + 0.002 \cdot 28 + 1.19 \cdot 1 - 53.50 \cdot 0 - 8.65 \cdot 0 + 1.11 \cdot 0 \cdot 28 + 0.60 \cdot 0 \cdot 28 = 43.14$.

If she used pain reliever B, it becomes: $Pain = 41.89 + 0.002 \cdot 28 + 1.19 \cdot 1 - 53.50 \cdot 1 - 8.65 \cdot 0 + 1.11 \cdot 1 \cdot 28 + 0.60 \cdot 0 \cdot 28 = 20.71$. I.e. a difference of about 23 in pain level in favor of pain reliever B (5p).

If she was 62 years old, the calculation for A becomes: $Pain = 41.89 + 0.002 \cdot 62 + 1.19 \cdot 1 - 53.50 \cdot 0 - 8.65 \cdot 0 + 1.11 \cdot 0 \cdot 62 + 0.60 \cdot 0 \cdot 62 = 43.20$. If she used pain reliever B, it becomes: $Pain = 41.89 + 0.002 \cdot 62 + 1.19 \cdot 1 - 53.50 \cdot 1 - 8.65 \cdot 0 + 1.11 \cdot 1 \cdot 62 + 0.60 \cdot 0 \cdot 62 = 58.52$. I.e. a difference of about 15 in pain level in favor of pain reliever A (5p)! Hence we see the interaction effect: The difference between pain relievers A and B depends on the age of the woman.

We see that originally, pain reliever A seemed to be the most effective, but actually there is an interaction between the pain relievers and age, meaning that pain reliever B is more effective than A for younger patients. For older patients, it seems like pain reliever A is the most effective. Hence, both have to be recommended (5p).