Physics 1028A: Physics for the Life Sciences | Academic Year 2013/2014
Date: December 14, 2013, 14:00 – 17:00 | Location: tba

FINAL PHYSICS 1028A

Your Exam consists of two components: this exam booklet and a scantron sheet. We can only credit you with a mark for this exam if *your Scantron sheet and this exam booklet* are retrieved by an exam proctor.

Last Name (Print legibly) | **Student Number**

As stated consistently throughout the course, note that + 2 < + 5, but – 2 > – 5.

In the space below on this page and its back, indicate any queries you have about this test; in particular, indicate any questions where you are convinced that either no, or more than one answer is correct.

Part I — Multiple Choice Exam

Part I contains 30 questions, numbered 1 through 30, each worth 1 mark (right answer) or 0 marks (wrong answers).

Question 1:
Enter (C) to confirm that you have encoded your student number correctly on the scantron sheet. This mark will be withheld if we have to retrieve your scantron sheet to identify you; it is the easiest mark to get, so please don't miss it. Note that two fonts are used for the Greek letter phi: $\varphi = \Phi$.

Question 2:
Fig. 1 shows an object attached to a string. Only its weight, **W**, and the tension in the string, **T**, act on the object; neglect air resistance if the object moves. Choose $\theta = 35^0$. What do we know about the magnitude of the two forces?

(A) W > T
(B) W = T
(C) W < T
(D) The figure and question text do not provide enough information to choose one of answer choices (A) to (C)

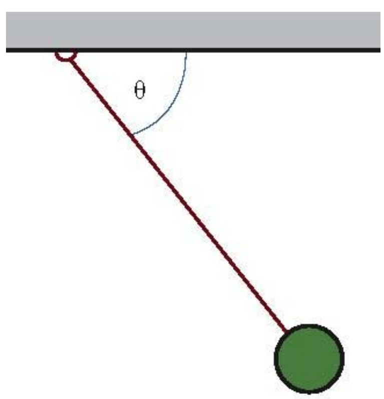


Fig. 1

Question 3:
Fig.2 shows the free–body diagram of an object of interest. What do we know about the motion of the object?

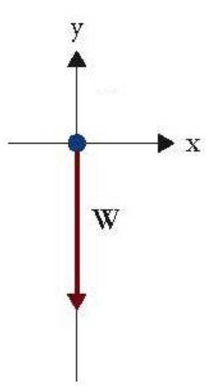


Fig. 2

(A) The object moves upwards
(B) The object moves downwards
(C) The object is at rest
(D) The object moves sideways
(E) The figure and question text do not provide enough information to choose one of answer choices (A) to (D)

Question 4:
Fig. 3 shows a diver accelerating horizontally along a straight line. What causes the forward acceleration of the diver?

(A) No forward–directed force acts on the diver, thus we cannot identify a cause for this acceleration
(B) The Earth through gravity
(C) The diver's flippers
(D) The seawater
(E) A cause other than those listed in choices (B) to (D)

Fig. 3

Question 5:

The following story is reported in the incredible adventures of Freiherr Karl Friedrich Hieronymus von Münchhausen (1720 – 1797). Von Münchhausen participated in a hunting party of the king of Lithuania. As guest of honour, he had been given the fastest horse in the royal stables, and so he arrived first at a local river in pursuit of a stately elk. Under-estimating the depth of the water, von Münchhausen made the horse run straight into it. He noticed the mistake too late, already sinking with the poor animal toward an untimely death. With no other hope for rescue, he decided to take things into his own hands – literally indeed, by grabbing his long hair and pulling himself and the horse straight up out of the water. Von Münchhausen's effort is illustrated in Fig. 4.

Fig. 4

While you may not believe this story, let's assume that Fig. 4 were a snapshot from a movie (not easy to make, letting a horse and rider fall into water might be considered animal cruelty; showing the film sequence then in reverse though would give the impression of events as von Münchhausen claimed). In Fig. 4, how many forces acting on the head of the person (as a single part identified within the system) contribute to the net force acting on the system of interest, which is horse and rider? We neglect the role of the surrounding air; any water still attached to the horse and rider are considered part of the respective part of the system of interest.

(A) zero forces
(B) one force
(C) two forces
(D) three forces or more

Question 6:

Fig. 5 shows the free–body diagram a student developed for a particular problem. When he/she writes Newton's laws in the usual component form next, how many terms will be included that are negative (carry a negative sign)?

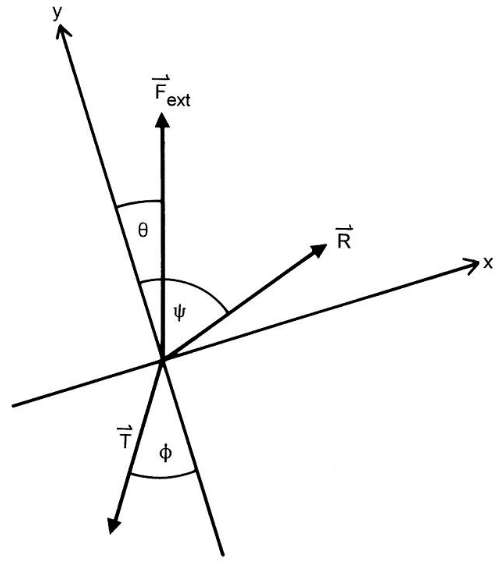


Fig. 5

(A) none (no negative terms)
(B) one negative term
(C) two negative terms
(D) three negative terms
(E) four or more negative terms

Question 7:
Fig. 6 shows two athletes competing in a pair skating event. Assume that the female weighs $|\mathbf{W}| = 540$ N, how much work does the male athlete do to carry her a distance 10 m in the posture shown (that is, holding her with his vertical right arm in an overhead position)? Neglect air resistance and assume that the ice is frictionless, which allows the pair to move the 10 m distance at constant speed without forward thrust once the motion started.

Fig. 6

(A) $W > +5500$ J
(B) $+5500 \text{ J} \geq W > +5300$ J
(C) $+5300 \text{ J} \geq W > -5300$ J
(D) $-5300 \text{ J} \geq W > -5500$ J
(E) $-5500 \text{ J} \geq W$

Question 8:
Fig. 7 shows two experiments we do with the same object on the same firctionless incline. In both cases, a massless string is attached to the object (round dot), and a person pulls the string such that the object slides down the incline at a constant speed. (Colloquially, we would refer to the person slowing the object as it slides down the incline.) Part (a) shows the first experiment, in which the person pulls in a direction parallel to the incline, part (b) shows the second experiment, in which the string and the incline form an angle of 45^0. If the object slides down the incline by a distance of 1.5 m in both cases, in which case does the object more work on the person?

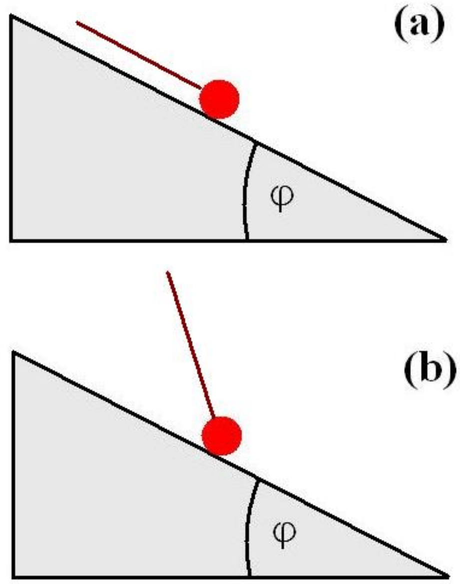


Fig. 7

(A) The object does more work in the experiment shown in part (a)
(B) The object does the same work in the experiments shown in part (a) and part (b)
(C) The object does more work in the experiment shown in part (b)
(D) Not enough information is given in the text and Fig. 7 to choose one of answers (A) to (C).

Question 9:
Studying once more the case shown in Fig. 7(b), if I double the distance the object slides downhill at constant speed while the person pulls to the upper left with constant force, by what factor changes the work (due to the doubling of the distance)?

(A) by a factor – 4
(B) by a factor – 2
(C) by a factor + 2
(D) by a factor + 4
(E) The work has not changed, or has changed by a factor different from those listed in choices (A) to (D)

Question 10:

☞ For this question, please refer to the sheet of graphs attached to this exam.

You are pushing a crate along the circumference of a circle of radius r at constant speed. As a vector, the force you apply continuously changes direction, but its magnitude is constant. If you push the object through 180^0, how does the work you have done on the crate depend on the radius of the circle, i.e., which plot shows properly the dependence of (the absolute value of) the work W as a function of radius r? **Note that the axes of each graph intersect at the value 0 on each axis, except in graphs I and III, in which zero–values on both axes are separately labelled.**

(A) I
(B) V
(C) VI
(D) VII
(E) VIII

Question 11:

Considering again the effort described in the previous question (pushing a crate along a semi–circle), what is the sign of the work *if you identify with yourself as the object for which the work is stated*?

(A) negative (non–zero)
(B) positive (non–zero)
(C) the work is zero, thus neither answer (A) or (B) can be chosen

Question 12:

You observe a child at a birthday party releasing a helium–filled balloon, which then floats to the ceiling. Which parameter must differ from a second balloon, filled with air, that does not take off when released? Treat helium and air as ideal gases.

(A) balloon's volume
(B) gas pressure in the balloon
(C) temperature of the gas in the balloon
(D) number of mol of gas (gas amount) in the balloon
(E) none of answer choices (A) to (D) is correct

Question 13:

You mix helium gas at 100^0C with oxygen gas at 0^0C. After thermal equilibrium is reached (almost instantaneously), which of the two gas components in the mixture has the higher root–mean–square speed? Treat helium as an ideal gas of molar mass M = 4 g/mol and oxygen as an ideal gas of molar mass M = 0.016 kg/mol.

(A) Both gas components have the same root–mean–square speed because the system is in equilibrium
(B) The oxygen component
(C) The helium component
(D) Not enough information is given in the question to select one of the answers (A) to (C)

Question 14:

☞ For this question, please refer to the sheet of graphs attached to this exam.

In Eq. (1), we rewrite the formula for the root–mean–square speed of one mol of an ideal gas of molar mass M using the ideal gas law:

$$v_{rms} = \sqrt{\frac{3\,R\,T}{M}} = \sqrt{\frac{3\,p\,V}{M}} \qquad \textbf{(1)}$$

Based on Eq. (1) which graph shows the dependence of the root–mean–square speed of this ideal gas (plotted on the ordinate or vertical axis) on the pressure (plotted on the abscissa or horizontal axis) in an experiment in which I vary the pressure isothermally?

(A) II
(B) V
(C) IX
(D) XIII
(E) none of the graphs listed in answers (A) to (D) is the correct choice

Question 15:
In a particular industrial process, the following steps are performed:
① Isothermal expansion of the processing gas to twice its original volume
② Adiabatic compression of the processing gas back to the original volume
③ Isochoric cooling of the processing gas to the initial temperature
Once this industrial process is complete, the pressure of the processing gas has doubled. Which of the following five statements can you make about this process?

(A) The process may consist of just the three steps labelled ①, ② and ③
(B) The process *must* include a fourth step that returns the pressure to its original value
(C) In an industrial plant, the process as described by steps ① to ③ can only be done with an ideal gas
(D) The process must include at least one more step in which some of the gas is released from the processing vessel
(E) None of the statements (A) to (D) is correct

Question 16:
☞ For this question, please refer to the sheet of graphs attached to this exam.
1.0 mol of an ideal gas is adiabatically expanded to twice its volume. We plot this process in a V–T diagram (i.e., the volume is plotted along the ordinate and the temperature is plotted along the abscissa; if you are not sure about the used terms, compare with Question 14). Which of the following choices resembles this plot best?

(A) III
(B) V
(C) VIII
(D) XII
(E) None of the choices (A) to (D) is consistent with the correct graph

Question 17:
☞ For this question, please refer to the sheet of graphs attached to this exam.
In an isothermal process, the pressure is doubled for 1.0 mol of an ideal gas. We plot this process in a U–p diagram (i.e., the internal energy is plotted along the ordinate and the pressure is plotted along the abscissa; if you are not sure about the used terms, compare with Question 14). Which of the following choices resembles this plot best?

(A) II
(B) IV
(C) V
(D) VIII
(E) None of the choices (A) to (D) is consistent with the correct graph

Question 18:
Fig. 8 shows the p–V diagrams of two cyclic processes that each consist of two isochoric and two isobaric steps. In process I, the respective changes in pressure and volume in each step are all larger than in process II.

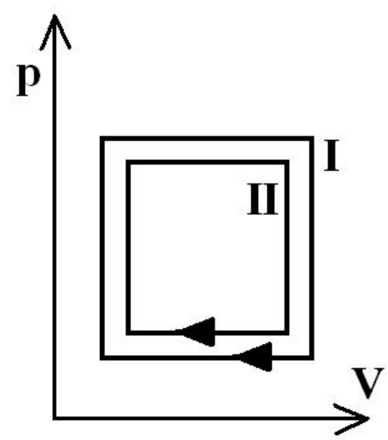


Fig. 8

How do the values for the heat exchange with the system's environment per cycle relate for the two processes?

(A) $Q_I = Q_{II}$
(B) $Q_I < Q_{II}$
(C) $Q_I > Q_{II}$
(D) Not enough information is given in the question text and Fig. 8 to choose one of choices (A) to (C). Note also the comment regarding relative values of numbers on the cover page of this exam.

Question 19:
We consider again the two processes shown in Fig. 8 and described in the question text of Question 18. How do the values for change in internal energy of the system per cycle relate for the two processes?

(A) $\Delta U_I = \Delta U_{II}$
(B) $\Delta U_I < \Delta U_{II}$
(C) $\Delta U_I > \Delta U_{II}$
(D) Not enough information is given in the question text and Fig. 8 to choose one of choices (A) to (C). Note also the comment regarding relative values of numbers on the cover page of this exam.

Question 20:
We consider the specific heat capacity c* and the molar heat capacity C, both in SI units, for the same chemical compound. Which of the following statements is true?

(A) For *all* chemical compounds, the numerical value of c* is larger than the numerical value for C
(B) The numerical value of c* may be larger or smaller than the value of C, depending on the particular chemical compound under consideration
(C) For *all* chemical compounds, the numerical value of c* is smaller than the numerical value for C

Question 21:
☞ For this question, please refer to the sheet of graphs attached to this exam.
You set up a laboratory experiment to measure the molar heat capacity for a particular chemical compound. Then, you plot the amount of heat required to raise the temperature for a given amount of the chemical compound as a function of the observed temperature change of the compound. Such a plot will be a straight line – will you obtain the sought molar heat capacity as the slope in this graph?

(A) yes
(B) no, I have to invert the slope
(C) no, I have to do one further calculation step with the slope (multiply or divide by a measurable value)
(D) no, I have to invert the slope and then do one further calculation step (multiply or divide by a measurable value)

Question 22:
In Fourier's law, the thermal conductivity is a materials constant. Therefore, you expect it to depend on the following parameter (recall that we discussed this in class):

(A) The length of the thermal bridge between the two fixed–temperature heat reservoirs in the experiment
(B) The cross–sectional area of the thermal bridge between the two fixed–temperature heat reservoirs in the experiment
(C) The environmental temperature in the laboratory on the day the experiment is conducted
(D) The temperature of the higher temperature heat reservoir
(E) None of the parameters listed in choices (A) to (D)

Question 23:
We consider a diffusion system impurity/matrix that adheres to Fick's law. In this diffusion experiment, we vary only one independent parameter at a time (i.e., in each case the parameter listed in the respective choice below). Which of these changes leads to *no change* in the rate of material diffusing through a diffusion barrier?

(A) Increasing the concentration of the diffusing species on the higher concentration side of the barrier
(B) Increasing the concentration of the diffusing species on the lower concentration side of the barrier
(C) Increasing the thickness of the diffusion barrier
(D) Shifting the fixed concentration difference to a higher value on the lower concentration side of the barrier
(E) All four choices (A) to (D) lead to a change in the rate of transport of matter through the barrier

Question 24:
☞ For this question, please refer to the sheet of graphs attached to this exam.
For demonstration purposes, you set up several experiments that are run in parallel, each such that the same diffusion length is reached when the experiment is terminated. If you enter the obtained data in a plot of time each experiments runs (ordinate) versus the diffusion coefficient for the respective system impurity/matrix (abscissa), which of the following plots resembles the best fit through these data?

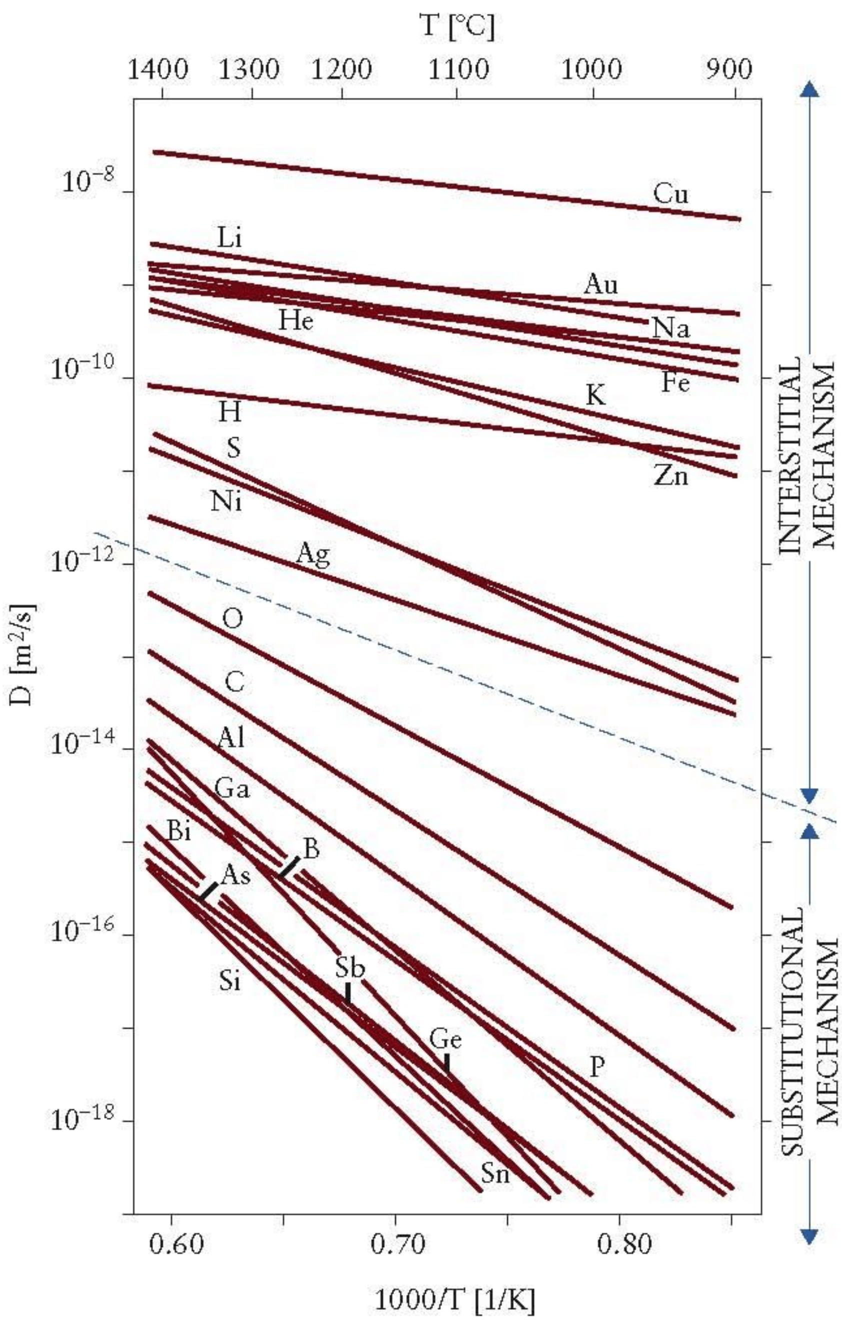
(A) II
(B) V
(C) IX
(D) XIII
(E) None of the choices (A) to (D) is suitable as an answer to this question

<u>Question 25:</u>

Fig. 9 shows the Arrhenius plot of a large number of diffusing species (labelled with the respective chemical symbol) in crystalline silicon. Which of the following impurities has the smallest activation energy among the five listed in choices (A) to (E)?

(A) Gold (Au)
(B) Aluminium (Al)
(C) Carbon (C)
(D) Germanium (Ge)
(E) Silicon (Si) in a self–diffusion experiment

Fig. 9



Question 26:

Fig. 10 shows the photograph of a young lady on the subway in Vienna, Austria. What you see is her reflection in the window while the train is travelling through a tunnel. The fact that her reflection looks at me (while taking the picture) should give me a tantalizing chill down the spine (which it didn't because she is my friend and we staged the picture). Where did my friend actually look when I took the picture?

(A) at my face
(B) at the reflection of my face
(C) at a random object outside the window
(D) at a random object inside the subway car
(E) we cannot select one of the choices (A) to (D) based on the question text and Fig. 10.

Fig. 10

Question 27:

Where must an object be located in front of a convex mirror for its image to be as large as possible?

(A) anywhere along the optical axis
(B) at a distance greater than the focal length
(C) at a distance equal to the focal length
(D) as close as possible to the mirror
(E) not enough information is given in the question text to select one of the choices (A) to (D)

Question 28:

The image of an object is both upright and diminished in size ($M < 1$) when using a converging lens. Where did we place the object?

(A) in front of the lens, and farther from the lens than the focal point
(B) in front of the lens at the focal point
(C) in front of the lens, and closer to the lens than the focal point
(D) behind the lens
(E) none of the choices (A) to (D) is correct in this case

Question 29:

☞ For this question, please refer to the sheet of graphs attached to this exam.
You want to select an objective lens for a microscope from a large set of lenses in the laboratory. For this, you combine each objective lens you consider with the same, given eyepiece such that the assembled microscope meets a specification of total angular magnification $m_{total} = 1000$ (absolute value). You prepare a graph of the microscope's barrel length as a function of the focal length of the objective lens to cut correctly each barrel from a long plastic tube. Which graph resembles best the graph you draw?

(A) II
(B) V
(C) VIII
(D) XII
(E) XVI

Question 30:

If a person cannot see clearly objects that are farther than 2.0 metres from his/her eyes, the person will be prescribed corrective lenses with what value of refractive power $\mathfrak{R}$?

(A) prescription glasses with negative $\mathfrak{R}$
(B) prescription glasses with $\mathfrak{R} = 0$ dpt
(C) prescription glasses with positive $\mathfrak{R}$
(D) not enough information is given in the question text to select one of the answer choices (A) to (D)

Part II — Problem Solving Short Answer

There are 20 problems (numbered 31 through 50), each worth 1 mark (right answer) or 0 marks (wrong answers).

Problem 31:
Fig. 11 shows an object of mass m = 3.5 kg that has just been released on an inclined plane, which forms an angle φ with the horizontal. What is the magnitude of the normal force, N, on the object of mass m **if $\varphi = 0^0$**?

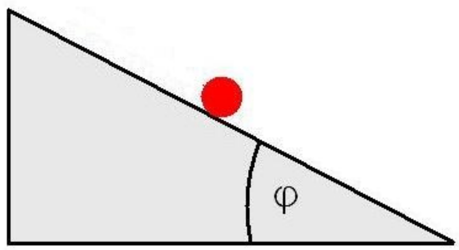


Fig. 11

(A) $0 \leq N < 10$ N
(B) 10 N $\leq N < 20$ N
(C) 20 N $\leq N < 30$ N
(D) 30 N $\leq N < 40$ N
(E) 40 N $\leq N$

Problem 32:
We consider again the object shown in Fig. 11. Again, its mass is m = 3.5 kg, but this time the angle φ of the incline is $\varphi = 35^0$. What is the magnitude N of the normal force on the object in this case?

(A) $0 \leq N < 10$ N
(B) 10 N $\leq N < 20$ N
(C) 20 N $\leq N < 30$ N
(D) 30 N $\leq N < 40$ N
(E) 40 N $\leq N$

Problem 33:
We consider again the object shown in Fig. 11. Again, its mass is m = 3.5 kg, and the angle φ of the incline is $\varphi = 35^0$, like in Question 32. What is the magnitude of the acceleration a of the object?

(A) 0 m/s² $\leq a <$ 3.5 m/s²
(B) 3.5 m/s² $\leq a <$ 7.0 m/s²
(C) 7.0 m/s² $\leq a <$ 10.5 m/s²
(D) 10.5 m/s² $\leq a <$ 14 m/s²
(E) 14 m/s² $\leq a$

Problem 34:
Fig. 12 shows an inclined surface on which a big sphere of mass M rests. The angle of the incline with the horizontal is $\theta = 40^0$, and the angle between the horizontal and the massless rope holding the sphere in place is $\varphi = 20^0$.

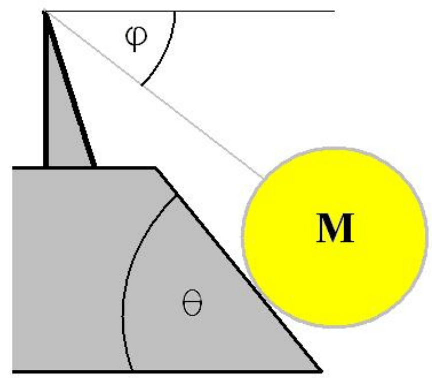


Fig. 12

What is the mass M of the sphere if the tension in the rope is 500 N?

(A) $0 \leq M <$ 100 kg
(B) 100 kg $\leq M <$ 200 kg
(C) 200 kg $\leq M <$ 300 kg
(D) 300 kg $\leq M <$ 400 kg
(E) 400 kg $\leq M$

Problem 35:
In Fig. 13 you see an African leopard carrying its impala prey up a tree. Let's assume the impala weighs 55 kg. The branch to which the leopard carries its prey is 6.5 m above the ground. How much work does the leopard do during the lift (absolute value)?

Fig. 13

(A) $0 \leq W < 10$ J
(B) 10 J $\leq W < 100$ J
(C) 100 J $\leq W < 1.0$ kJ
(D) 1.0 kJ $\leq W < 10$ kJ
(E) 10 kJ $\leq W$

Problem 36:
A cheetah, as shown in Fig. 14, may run as fast as 120 km/h. Assume that we are dealing with an adult cheetah, what is the magnitude of its weight if its kinetic energy is 30.5 kJ at top speed?

Fig. 14

(A) $0 \leq W < 150$ N
(B) 150 N $\leq W < 300$ N
(C) 300 N $\leq W < 450$ N
(D) 450 N $\leq W < 600$ N
(E) 600 N $\leq W$

Problem 37:
Back to the leopard in Problem 35 (and Fig. 13). If it decides to jump from the branch where it brought the impala back to the ground, what impact speed v would the cat's knees and shoulders have to absorb? Assume that the cat starts from rest and does not jump upwards when leaving the branch.

(A) $0 \leq v < 15$ km/h
(B) 15 km/h $\leq v < 25$ km/h
(C) 25 km/h $\leq v < 35$ km/h
(D) 35 km/h $\leq v < 45$ km/h
(E) 45 km/h $\leq v$

Problem 38:
If the cheetah in Problem 36 decides to launch at top speed upwards at an angle of 20^0 above the horizontal, what is the greatest height h_{max} it will reach before it falls back down to the ground? Note: based on the result, try to figure out why a cheetah would ever do this, then you know why you never saw it on Discovery Channel; however, it also demonstrates what wide range of impact options the cheetah has as it closes in on its prey.

(A) $h_{max} < 1.0$ m
(B) 1.0 m $\leq h_{max} < 4.0$ m
(C) 4.0 m $\leq h_{max} < 8.0$ m
(D) 8.0 m $\leq h_{max} < 12.0$ m
(E) 12.0 m $\leq h_{max}$

Problem 39:

The root–mean–square speed of an ideal gas at 0^0C is given as v_{rms} = 350 m/s. What is the molar mass of this gas?

(A) 0 ≤ M < 40 g/mol
(B) 40 g/mol ≤ M < 80 g/mol
(C) 80 g/mol ≤ M < 120 g/mol
(D) 120 g/mol ≤ M < 160 g/mol
(E) 160 g/mol ≤ M

Problem 40:

1.0 mol of an ideal at 20^0C has a pressure of 1.0×10^5 Pa. If we now double its volume at constant pressure, what is its final temperature T_{final}?

(A) $T_{final} < -50^0$C
(B) $-50^0\text{C} \le T_{final} < +50^0$C
(C) $+50^0\text{C} \le T_{final} < +150^0$C
(D) $+150^0\text{C} \le T_{final} < +250^0$C
(E) $+250^0\text{C} \le T_{final}$

Problem 41:

We start with 1.0 mol of an ideal in a 15.0 L container at a pressure of 4.0×10^5 Pa. Next we decrease its internal energy *to* 75%. What is the final temperature T_{final} of the ideal gas?

(A) $T_{final} < -100^0$C
(B) $-100^0\text{C} \le T_{final} < +100^0$C
(C) $+100^0\text{C} \le T_{final} < +300^0$C
(D) $+300^0\text{C} \le T_{final} < +500^0$C
(E) $+500^0\text{C} \le T_{final}$

Problem 42:

1.0 mol of an ideal gas is *isothermally compressed* from inital volume V_i = 5.0 L to final volume V_f = 2.0 L.Its initial pressure is 3.0 atm. Calculate the work for this process. Hint: the gas, as always, is the system of interest.

(A) W < –10 kJ
(B) –10 kJ ≤ W < –100 J
(C) –100 J ≤ W < + 100 J
(D) + 100 J ≤ W < +10 kJ
(E) +10 kJ ≤ W

Problem 43:

Fig. 15 shows a cyclic process conducted with an ideal gas (which again is our system of interest). We use this process twice, in the current problem to calculate the work for one particular step, then in the next problem to calculate the work for a full cycle.

For this problem, calculate the work for the step from gas state p_2 and V_1 to gas state p_3 and V_2. Use p_2 = 1.0 atm, p_3 = 1.5 p_2, and V_1 = 8.0 L, V_2 = 2 V_1.

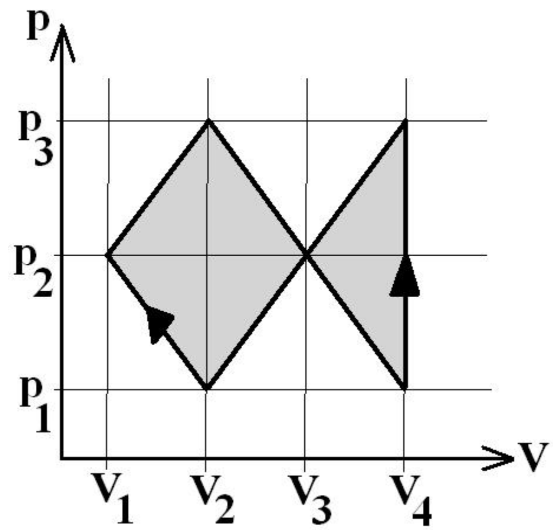


Fig. 15

(A) W < –750 J
(B) –750 J ≤ W < –250 J
(C) –250 J ≤ W < +250 J
(D) + 250 J ≤ W < +750 J
(E) +750 J ≤ W

Problem 44:

Fig. 15 shows a cyclic process conducted with an ideal gas (which again is our system of interest). We use this process twice, in the previous problem to calculate the work for one particular step, and now in this problem to calculate the work for a full cycle.

For this problem, calculate the work for the system going through one full cycle. Use p_1 = 0.5 atm, p_2 = 2 p_1, p_3 = 3 p_1. Also use V_1 = 8.0 L, V_2 = 2 V_1, V_3 = 3 V_1, and V_4 = 4 V_1.

(A) W < –750 J
(B) –750 J ≤ W < –250 J
(C) –250 J ≤ W < +250 J
(D) + 250 J ≤ W < +750 J
(E) +750 J ≤ W

Problem 45:
We study for a particular system the impurity diffusion in a matrix. It is observed that a diffusion length of 8 mm is reached after the experiment runs for 12 minutes (that is, the sample is held at the temperature at which the diffusion occurs for this time). For practical applications, the diffusion length is supposed to be 23 mm. If the practical applications are performed at the same temperature as our initial experiment, how long will the system need to reach the intended diffusion length? Hint: the unit [h] means [hours].

(A) $t < 1.0$ min
(B) 1.0 min $\leq t <$ 10.0 min
(C) 10.0 min $\leq t <$ 1.0 h
(D) 1.0 h $\leq t <$ 3.0 h
(E) 3.0 h $\leq t$

Problem 46:
We study for a given system that follows Arrhenius' model of diffusion the diffusion of the impurity in the solid. The activation energy for this system is 4.0×10^{-19} J. The diffusion coefficient is $D = 2.0 \times 10^{-13}$ m²/s at 1100^0C. What is the diffusion coefficient at 700^0C?

(A) $D < 1.0 \times 10^{-22}$ m²/s
(B) 1.0×10^{-22} m²/s $\leq D < 1.0 \times 10^{-19}$ m²/s
(C) 1.0×10^{-19} m²/s $\leq D < 1.0 \times 10^{-16}$ m²/s
(D) 1.0×10^{-16} m²/s $\leq D < 1.0 \times 10^{-13}$ m²/s
(E) 1.0×10^{-13} m²/s $\leq D$

Problem 47:
We study a slab of transparent material that is immersed in an unknown, transparent fluid. A light ray travels at an angle of $\beta = 22^0$ with the vertical to the slab's surface in the slab. If light travels 10% faster in the slab than in the fluid, what angle α does the light ray form with the vertical while travelling through the fluid?

(A) $\alpha < 13^0$
(B) $13^0 \leq \alpha < 17^0$
(C) $17^0 \leq \alpha < 21^0$
(D) $21^0 \leq \alpha < 25^0$
(E) $25^0 \leq \alpha$

Problem 48:
The near point of a person is 70 cm. What refractive power $\Re$ must the prescription glasses for this person have so that he/she can see clearly objects at the standard man's near point?

(A) $\Re < -3.0$ dpt
(B) -3.0 dpt $\leq \Re < -1.0$ dpt
(C) -1.0 dpt $\leq \Re < +1.0$ dpt
(D) $+1.0$ dpt $\leq \Re < +3.0$ dpt
(E) $+3.0$ dpt $\leq \Re$

Problem 49:
A person at 8.0 cm from a bathroom mirror sees his/her face upright and twice the actual size. When the person steps back from this mirror, he/she sees an inverted image which is located 18 cm in front of the mirror. When the person makes this observation, at what distance d from the mirror is he/she located?

(A) $d < 8.0$ cm
(B) 8.0 cm $\leq d <$ 50 cm
(C) 50 cm $\leq d <$ 90 cm
(D) 90 cm $\leq d <$ 130 cm
(E) 130 cm $\leq d$

Problem 50:

Fig. 16 shows a diverging lens (vertical line) and an object O that is placed on the optical axis. F denotes the focal points of the lens. Use ray tracing to find the image, then measure the image distance. Report it with the correct sign.

(A) $q < -5$ cm; (B) $-5 \text{ cm} \leq q < -1$ cm; (C) $-1 \text{ cm} \leq q < +1$ cm; (D) $+1 \text{ cm} \leq q < +5$ cm; (E) $+5 \text{ cm} \leq q$

Fig. 16