Physical Science 126: 2nd Exam NAME:
2005 March 11 Friday

Instructions: There are 60 multiple choice questions each worth 1 mark for a total of 60 marks altogether. Choose the **BEST** answer, completion, etc., and darken fully the appropriate circle on the table provided below. Read all responses carefully. **NOTE** long detailed responses won't depend on hidden keywords: keywords in such responses are bold-faced capitalized.

This is a **CLOSED-BOOK** exam. **NO** cheat sheets allowed. An equation sheet is provided. Calculators are permitted.

This an 75 minute test. Just hand in your answer table. Remember your name (and write it down on the exam too).

Answer Table

Name:

	a	b	c	d	e
1.	O	O	O	O	O
2.	O	O	O	O	O
3.	O	O	O	O	O
4.	O	O	O	O	O
5.	O	O	O	O	O
6.	O	O	O	O	O
7.	O	O	O	O	O
8.	O	O	O	O	O
9.	O	O	O	O	O
10.	O	O	O	O	O
11.	O	O	O	O	O
12.	O	O	O	O	O
13.	O	O	O	O	O
14.	O	O	O	O	O
15.	O	O	O	O	O
16.	O	O	O	O	O
17.	O	O	O	O	O
18.	O	O	O	O	O
19.	O	O	O	O	O
20.	O	O	O	O	O
21.	O	O	O	O	O
22.	O	O	O	O	O
23.	O	O	O	O	O
24.	O	O	O	O	O
25.	O	O	O	O	O
26.	O	O	O	O	O
27.	O	O	O	O	O
28.	O	O	O	O	O
29.	O	O	O	O	O
30.	O	O	O	O	O

	a	b	c	d	e
31.	O	O	O	O	O
32.	O	O	O	O	O
33.	O	O	O	O	O
34.	O	O	O	O	O
35.	O	O	O	O	O
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37.	O	O	O	O	O
38.	O	O	O	O	O
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42.	O	O	O	O	O
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44.	O	O	O	O	O
45.	O	O	O	O	O
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47.	O	O	O	O	O
48.	O	O	O	O	O
49.	O	O	O	O	O
50.	O	O	O	O	O
51.	O	O	O	O	O
52.	O	O	O	O	O
53.	O	O	O	O	O
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58.	O	O	O	O	O
59.	O	O	O	O	O
60.	O	O	O	O	O

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008 qmult 00100 1 1 4 easy memory: conservation of energy
Extra keywords: physci

1. In the physics, the conservation of energy means energy:

   a) shouldn't be wasted on cars. b) is never destroyed. c) is never created. d) is never created or destroyed. e) is perpetually created.

   SUGGESTED ANSWER: (d)

   Wrong answers:
   e) Well no.

   Redaction: Jeffery, 2001jan01

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008 qmult 00110 1 1 2 easy memory: universe and conservation of energy
Extra keywords: physci KB-92-5

2. If the universe as a whole is a closed system, then current physical law tells us that its total energy is:

   a) 30 J. b) conserved. c) not conserved. d) only kinetic energy. e) sometimes conserved.

   SUGGESTED ANSWER: (b) A closed system is one in which nothing goes in or out.

   Wrong answers:
   e) All things are wrong.

   Redaction: Jeffery, 2001jan01

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008 qmult 00200 1 1 2 easy memory: potential energy definition
Extra keywords: physci

3. Potential energy is:

   a) the energy of position: it exists for nonconservative forces.
   b) the energy of position: it exists for conservative forces.
   c) the energy of motion: its formula is PE= $(1/2)mv^2$.
   d) the energy of position: its formula is PE= $(1/2)mv^2$.
   e) heat energy.

   SUGGESTED ANSWER: (b) There are plenty of clues.

   Wrong answers:
   e) Nah.

   Redaction: Jeffery, 2001jan01

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008 qmult 00400 2 5 2 moderate thinking: mountain climber power output
Extra keywords: physci KB-95-7

4. A 100 kg mountain climber climbs 4000 m in 10 hours. What is his power output going into gravitational potential energy? What is his total power output?

a) 3.92×10^6 W and 3.92×10^6 W.
b) The power going into gravitational potential energy is 109 W. His total power output cannot be accurately calculated since a lot of power must go into waste heat due to frictional forces and also his body constantly radiates heat. All one can easily say is that 109 W is a **LOWER BOUND** on the total power output.
c) The power going into gravitational potential energy is 3.92×10^6 W. His total power output cannot be accurately calculated since a lot of power must go into waste heat due to frictional forces and also his body constantly radiates heat. All one can easily say is that 3.92×10^6 W is a **LOWER BOUND** on the total power output.
d) The power going into gravitational potential energy is 3.92×10^6 W. His total power output cannot be accurately calculated since a lot of power must go into waste heat due to frictional forces and also his body constantly radiates heat. All one can easily say is that 3.92×10^6 W is an **UPPER BOUND** on the total power output.
e) The power going into gravitational potential energy is 109 W. His total power output cannot be accurately calculated since a lot of power must go into waste heat due to frictional forces and also his body constantly radiates heat. All one can easily say is that 109 W is an **UPPER BOUND** on the total power output.

SUGGESTED ANSWER: (b)

Fortran Code

```
        print*
        xmass=100.
        gg=9.8
        hh=4.e+3
        tt=3600.*10.
        energy=xmass*gg*hh
        power=xmass*gg*hh/tt
        print*,'energy,power'
        print*,energy,power
*            3920000.       108.8889
```

Wrong answers:
e) All things are wrong.

Redaction: Jeffery, 2001jan01

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008 qmult 00500 1 1 4 easy memory: mechanical energy conservation
Extra keywords: physci

5. Mechanical energy is the sum of kinetic energy and potential energy. It is a conserved quantity:

a) always.
b) whenever it has both kinetic and potential energy components.
c) if all the forces that do net work are **NONCONSERVATIVE**.
d) if all the forces that do net work are **CONSERVATIVE**.
e) whenever it is positive.

SUGGESTED ANSWER: (d) I'm trying to be careful in my right answer. Magnetism and static friction are have no potential energy associated, and so I don't think they are ever called conservative forces, and yet they don't dissipate energy to heat, and so arn't dissipative forces in the usual sense either. (Actually a magnetic dipole in magnetic field does have potential energy, but that's a special case.) Someone will have to straighten me out on the terminology someday. Note: As long as there is no slip, friction doesn't cause dissipation. A charge moving in a magnetic field doesn't dissipate energy: it just goes into circular motion. Heat may not be quite the only form of dissipation: dissipation to sound energy may count too: but were trying to be briefly correct in the main, not precisely correct in detail. Anyway sound energy usually ends up as heat energy pretty quickly.

Wrong answers:

a) Nah.

Redaction: Jeffery, 2001jan01

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008 qmult 00600 1 3 5 easy math: dog drops brick mech. energy conserved

Extra keywords: physci

6. A brick has mass 1 kg. A dog (from a joke that I'll tell you someday) drops the brick (which it was holding in its mouth) 1 m. What is the kinetic energy of the brick just before it hits the ground? **HINT:** The calculator is superfluous.

   a) 9.8 watts. b) 9.8 gems. c) 9.8 newtons. d) 9.8 jowls. e) 9.8 joules.

SUGGESTED ANSWER: (e) The potential energy at 1 meter of a 1 kilogram brick is 9.8 joules. If it drops 1 meter its potential energy becomes zero and its kinetic energy 9.8 joules by the conservation of mechanical energy.

Wrong answers:

d) James Prescott Joule (1818–1889) British physicist and brewer proved that mechanical, heat, and chemical energies were all different forms of the same thing within experimental uncertainty. He was one of the last of the great gentleman scientists. He actually pronounced his name jowl (rhymes with bowel), but in the interests of euphony we usually pronounce the unit named after him jool (rhymes with drool).

Redaction: Jeffery, 2001jan01

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008 qmult 00700 2 5 5 moderate thinking: girl on a swing KE/PE

Extra keywords: physci KB-95-19

7. A girl on a swing oscillates between being 2 m off the ground where she is ________ and 1 m off the ground where her speed is a ____________. No non-conservative forces act. What is her maximum speed?

   a) moving; minimum; 0 m/s. b) at rest; minimum; 0 m/s. c) at rest; maximum; 1 m/s. d) at rest; maximum; 2.4 m/s. e) at rest; maximum; 4.4 m/s.

SUGGESTED ANSWER: (e)

Because non-conservative forces do not do any net work, mechcanical energy (KE plus PE) is conserved. In this system the energy will oscillate back and forth between KE and PE perpetually.

At the highest point of the cycle the swing is momentarily at rest and all the mechanical energy PE. At the lowest point of the cycle the PE is at minimum and KE must be at a maximum by conservation of energy. Let us take the lowest point as the zero point of PE for convenience and let the height coordinate be y. Recall we are always free to choose the zero point of PE since only changes in PE affect any other quantity. The lowest point is then zero PE.

In general,

$$\Delta E_{\text{mechanical}} = W_{\text{nonconservative}} \ .$$

In this case, $W_{\text{nonconservative}} = 0$, and so

$$0 = \Delta E_{\text{mechanical}} = \left(\frac{1}{2}mv_f^2 + mgy_f\right) - \left(\frac{1}{2}mv_i^2 + mgy_i\right) = \frac{1}{2}mv_f^2 - mgy_i$$

since the initial KE is zero and the final PE is zero. Algebra then gives

$$mgy_{\text{i}} = \frac{1}{2}mv_{\text{f}}^2$$

which leads to

$$v = \sqrt{2gy_i} = \sqrt{2 \times 9.8 \times 1} = 4.43\,\text{m/s} \ .$$

Note that we did not have to solve for the motion with Newton's laws. We found the solution more easily using energy. But on the other hand we do not know everything. We do not know the position of the girl as a function of time. Do do that we do have to solve for the whole motion. That is a harder calculation, but it can be done.

The situation is typical: energy methods give some information easily, but not complete information.

Fortran Code

```
print*
gg=9.80
hh=1.
vmax=sqrt(2.*gg*hh)
print*,'vmax=',vmax    ! 4.42719
```

Wrong answers:

a) There is an instant of rest at the highest point of the oscillation as you well know from all those days in the playground.

Redaction: Jeffery, 2001jan01

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008 qmult 00800 1 4 2 easy deducto-memory: energy and heat

Extra keywords: physci KB-73

8. British American Benjamin Thompson (ennobled as Graf Rumford) (1753–1814), while employed as director of the Bavarian arsenal, noticed that in boring cannon

(but not causing cannon ennui) that the boring motion and friction seemed to produce unlimited amounts of heat. He concluded:

a) heat was a substance of which there could only be so much of in any object.
b) that heat was somehow generated by motion and friction. This conclusion eventually led to the recognition of heat as another form of energy that could be converted from or converted into mechanical or chemical energy.
c) that heat had no relation to motion and friction and was somehow spontaneously generated by cannon.
d) that cannon could be the plural of cannon.
e) that the biergartens in Munich were much better than the taverns in Boston and that Sam Adams, patriot-founding-father notwithstanding, could have learnt a thing or two about brewing beer.

SUGGESTED ANSWER: (b) Putting a thing or two together the answer should be obvious. This question exemplifies my belief that some questions should be easy, but should drive in an idea like a spike. Anyway I used to stroll by Thompson-Rumford's statue in the Englischer Gartens sometimes in my Munich days. Hm—should they be called the Amerikaner Gartens if they were named after Graf Rumford as I vaguely seem to recall. There's a very pleasant biergarten, Der Chinisien??? Turm in the Englischer Gartens.

Wrong answers:
a) In the 18th century, one theory of heat held that it was a substance that was conserved independently of anything else: a subtle fluid perhaps.
d) Probably English speakers (or as we call them in Canada Anglophones or Anglos or darned Anglos) already knew this in the 18th century and it's even relevant either.
e) Personal experience suggests this was true in the late 20th century, but for the 18th century I'm just guessing. It certainly isn't the best answer in the context of the question.

Redaction: Jeffery, 2001jan01

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009 qmult 00300 1 1 5 easy memory: definition of 1-d momentum
Extra keywords: physci

9. Linear momentum, or just momentum for short, for a one-dimensional system is given by:

a) $p = m/v$. b) $p = v/m$. c) $p = (1/2)mv^2$. d) $p = (1/2)mv$. e) $p = mv$.

SUGGESTED ANSWER: (e) No vector signs are needed if one is restricting the defintion to one dimension.

Wrong answers:
c) The right-hand side is kinetic energy.

Redaction: Jeffery, 2001jan01

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009 qmult 00310 1 1 3 easy memory: momentum is not energy
Extra keywords: physci KB-93-15

10. Linear momentum is **NOT**:

a) a physical quantity. b) dependent on velocity. c) a kind of energy. d) dependent on mass. e) given by $p = mv$ for one-dimensional cases.

SUGGESTED ANSWER: (c) Momentum is closely related to kinetic enery. The two both calculated from mass and velocity, but momentum is not energy. For one thing, momentum is a vector and energy is a scaler.

Wrong answers:
e) But it is so given.

Redaction: Jeffery, 2001jan01

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009 qmult 00320 2 5 1 moderate thinking: KE change and momentum change
Extra keywords: physci KB-94-13

11. If the kinetic energy of an object is doubled, the linear momentum changes by a factor of:

a) $\sqrt{2}$. b) 2. c) 1/2. d) $1/\sqrt{2}$. e) 1.

SUGGESTED ANSWER: (a) Momentum depends linearly on the magnitude of velocity $\vec{v}$. Now $KE = mv^2/2$, and thus $v = \sqrt{2KE/m}$. Thus, momentum increases as the square root of KE.

Wrong answers:
b) Not a good guess, but better than some others anyway.

Redaction: Jeffery, 2001jan01

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009 qmult 00500 1 1 2 easy memory: conservation of momentum
Extra keywords: physci

12. For system on which no net external force acts, momentum is:

a) not conserved. b) conserved. c) zero. d) never zero. e) always negative.

SUGGESTED ANSWER: (b)

Wrong answers:
c) Sometimes, but not always.
e) A negative momentum really only makes sense in 1-dimensional problems where one dispenses with vector notation and makes one sense positive and one sense negative.

Redaction: Jeffery, 2001jan01

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009 qmult 00520 2 4 1 mod. deducto-memory: collision, explosion, momentum
Extra keywords: physci

13. A collision or explosion is an event in which relatively strong forces act between objects for a relatively short time. If one considers all the objects involved in the collision or explosion as constituting one system, then frequently in calculations it is useful to use the ____________ principle provided the external forces acting on the system can be considered negligible compared to the internal forces of the system.

    a) conservation of momentum b) conservation of mechanical energy c) cosmological d) anthropic e) Peter

    SUGGESTED ANSWER: (a)

    Wrong answers:
    b) Mechanical energy is not necessarily conserved. It can be dissipated to heat or generated from explosion energy.
    c) Not this time.
    d) I fail to see how the fact of the existence humankind can lead to any useful information.
    e) Back in the 1970s there was this guy named Peter who discovered/invented his own principle: "people tend to rise in life to their level of incompetence." It's probably as true as it is false.

    Redaction: Jeffery, 2001jan01

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009 qmult 00530 1 1 1 easy memory: operation of rocket
Extra keywords: physci KB-92-9

14. The operation of a rocket in space is based on:

    a) conservation of linear momentum. b) conservation of angular momentum. c) jet fuel pushing on the vacuum. d) starlight pressure. e) running an internal treadmill.

    SUGGESTED ANSWER: (a)

    Wrong answers:
    d) It has been suggested by some, like Arthur C. Clarke, that light pressure could be used for sailing in space. But this is probably only possible within solar systems.

    Redaction: Jeffery, 2001jan01

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009 qmult 00550 1 1 2 easy memory: conservation of momentum, Thor
Extra keywords: physci

15. The mighty Thor is trapped in the eternal vacuum of gravity-free space with nothing to push on. But he sees Asgard glittering **YONDER**. Having taken introductory physics in his young Viking days, he realizes that he will soar straight to Asgard if, with awesome strength, he throws his hammer:

    a) yonder. b) anti-yonder. c) any which way. d) left. e) in a parabolic arc.

SUGGESTED ANSWER: (b)

Wrong answers:
e) Not in gravity-free space.

Redaction: Jeffery, 2001jan01

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009 qmult 00560 1 3 4 easy math: diver from boat, momentum conserved
Extra keywords: physci KB-96-25

16. A 50 kg girl dives horizontally at 2.0 m/s in the **POSITIVE** direction from a 200 kg boat that initially is at rest. What is the recoil **VELOCITY** of the boat?

a) 0.25 m/s. b) 0.70 m/s. c) −0.70 m/s. d) −0.50 m/s. e) infinite.

SUGGESTED ANSWER: (d) The total momentum was zero before the explosion and must be so after by conservation of momentum provided we idealize the problem as we should by implication. Thus

$$0 = m_{\rm girl} v_{\rm girl} + m_{\rm boat} v_{\rm boat}$$

from which it immediately follows that

$$v_{\rm boat} = -\frac{m_{\rm girl}}{m_{\rm boat}} v_{\rm girl} = -0.5\,{\rm m/s}\ .$$

Wrong answers:
a) It looks like you forgot to multiply by velocity.
b) Wrong sign. Wrong absolute value.
e) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001jan01

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038 qmult 00200 1 1 1 easy memory: discovery special relativity
Extra keywords: physci

17. Einstein first published his theory of special relativity in:

a) 1905. b) 1879. c) 1955. d) 1776. e) 1066.

SUGGESTED ANSWER: (a)

Wrong answers:
b) Year of Einstein’s birth.
c) Year of Einstein’s death.
d) Year of the American Revolution.
e) The year of the Norman conquest of England and the Battle of Hastings: 1066 and all that.

Redaction: Jeffery, 2001jan01

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038 qmult 00300 1 1 2 easy memory: 2 special relativity postulates
Extra keywords: physci KB-94-19

18. Einstein developed special relativity starting from ____________ basic postulates.

    a) zero b) two c) three d) four e) infinite

    SUGGESTED ANSWER: (b) The relativity postulate and the vacuum speed of light postulate

    Wrong answers:
    e) As Lurch would say: "Aaaarh."

    Redaction: Jeffery, 2001jan01

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038 qmult 00310 1 1 3 easy memory: relativity postulate 1
Extra keywords: physci KB-92-11, KB-94-19

19. According to the principle (or postulate) of relativity, the laws of physics or, more exactly, the expressions of physical law are the same in:

    a) all frames of reference.
    b) most frames of reference.
    c) all inertial frames (i.e., fundamentally unaccelerated frames) of reference.
    d) all non-inertial frames (i.e., fundamentally accelerated frames) of reference.
    e) no frames of reference

    SUGGESTED ANSWER: (c) The answer without the "more exactly" phrase is the way the relativity principle is usually expressed in elementary books (KB-81; HRW-921). And as a shorthand so I guess it is adequate. But it makes me a bit squimish in that it implies the laws of physics are different in non-inertial frames which is not true. One should say that physical law expressions should be the same in all inertial frames (La-5). Non-inertial frames can be treated too by making appropriate adjustments. But that is longwinded and, perhaps, obscuring for elementary students.

    Wrong answers:
    e) All things are wrong.

    Redaction: Jeffery, 2001jan01

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038 qmult 01220 1 3 1 easy math: E=mc**2 applied to electron
Extra keywords: physci KB-93-33

20. The mass of an electron is 9.1×10^{-31} kg. The energy equivalent of this mass is approximately:

    a) 10^{-13} J. b) 10^{-47} J. c) 3×10^{-22} J. d) 3×10^{-38} J. e) 1 J.

    SUGGESTED ANSWER: (a) Behold

$$E = mc^2 \approx 10^{-30} \times (3 \times 10^8) \approx 10^{-30} \times 10^{17} = 10^{-13}\,\mathrm{J} .$$

    Wrong answers:
    b) You probably have the wrong sign on the exponent of the c^2 value.

Redaction: Jeffery, 2001jan01

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038 qmult 00330 1 1 4 easy memory: light speed postulate

Extra keywords: physci KB-94-19

21. The speed of light in vacuum has the same value, labeled by c, in all directions and in:

a) some inertial frames. b) frames moving with the Earth only. c) no frames. d) all inertial frames. e) no inertial frames.

SUGGESTED ANSWER: (d) La-7 says the vacuum speed of light is the same in all inertial frames. But this is too fine a point for the students and me too.

Wrong answers:

e) Exactly wrong.

Redaction: Jeffery, 2001jan01

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038 qmult 00400 1 4 2 easy deducto-memory: revising Newtonian mechanics

Extra keywords: physci

22. Einstein's two special relativity postulates implied that classical Newtonian physics:

a) needed no revision. b) needed revision. c) was wildly wrong in all cases of interest. d) was not correct now, but would be in the future. e) was completely useless.

SUGGESTED ANSWER: (b)

Wrong answers:

a) It sure did need revision. New transformations (i.e., the Lorentz transformations), new rules for kinetic energy, momentum, and force, a 4-vector formulation, and other things. Of course, for much of the human realm the revisions are of negligible.

c) C'mon. It works fine for all low velocity, macroscopic cases outside of strong gravitational fields.

d) Huh?

e) No way. Classical Newtonian mechanics has a vast realm relevant to human and natural activities in which it is entirely adequate or almost so. Relativistic and quantum corrections in this realm are negligible. This realm includes macroscopic engineering and most celestial mechanics.

Redaction: Jeffery, 2001jan01

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038 qmult 00700 1 4 4 easy deducto-memory: relativistic mass increase

Extra keywords: physci KB-92-12

23. As an object's velocity increases relative to some observer, the mass of the object as measured by that observer:

a) goes to zero. b) decreases. c) stays constant. d) increases and approaches infinity as the speed approaches the vacuum light speed. e) is infinite.

SUGGESTED ANSWER: (d)

Wrong answers:

e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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038 qmult 00800 1 1 2 easy memory: time dilation mnemonic

Extra keywords: physci

24. The mnemonic for the time dilation effect is "moving clocks:

a) run fast." b) run slow." c) are stopped." d) are wrong.
e) run backward.

SUGGESTED ANSWER: (b)

Wrong answers:

e) You can make a mechanical clock run backwards, of course, but you can't really make time run backward. Entropy always increases in a closed system and time hurrying chariot doesn't step into the same stream twice.

Redaction: Jeffery, 2001jan01

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038 qmult 00900 1 4 3 easy deducto-memory: twins paradox

Extra keywords: physci

25. In the twins paradox, the twin who ages least is the one who is:

a) not accelerated. b) not Fitzgerald contracted. c) accelerated.
d) Fitzgerald contracted. e) hermetically sealed in a time capsule.

SUGGESTED ANSWER: (c)

Wrong answers:

a) Exactly wrong.
b) Either twin can see the other as Fitzgerald contracted. And both are compared to observers in any other inertial frame.
e) Hermetically means air-tight. Either twin could be sealed in a time capsule for all the good it would do.

Redaction: Jeffery, 2001jan01

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038 qmult 01200 1 1 5 easy memory: Einstein's equation presented

Extra keywords: physci

26. Einstein's equation (or mass-energy equivalence equation) is

a) $E = mc^3$. b) $E = m/c^3$. c) $E = m/c^2$. d) $E = mc^4$.
e) $E = mc^2$.

SUGGESTED ANSWER: (e)

Wrong answers:

a) C'mon.

Redaction: Jeffery, 2001jan01

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038 qmult 01230 1 3 3 easy math: E=mc**2 applied to dynamite
Extra keywords: physci KB-96-31

27. About 5.4×10^6 J of chemical energy is released as explosion energy when 1 kg of dynamite explodes. What fraction of the total rest mass energy of the dynamite is this?

 a) 9.0×10^{16}. b) 4.8×10^{23}. c) 6.0×10^{-11}. d) 0. e) infinite.

SUGGESTED ANSWER: (c)

Fortran Code

```
          print*
          clight=2.99792458e+8
          ex=5.4e6
          xmcsq=1.*clight**2
          frac=ex/xmcsq
          xmult=ex*clight**2
          print*,'xmcsq,xmult,frac'
          print*,xmcsq,xmult,frac
 *     8.9875515E+16  4.8532778E+23  6.0083105E-11
```

Wrong answers:
 a) This is the energy equivalent of 1 kg. A useful number to know, but since one can always recreate it, not worth memorizing.
 b) Aaah! You've multiplied the two energies.
 e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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015 qmult 00100 1 1 1 easy memory: density defined
Extra keywords: physci

28. Density (with standard physics symbol the Greek rho ρ) unqualified is conventionally take to be the ratio of:

 a) mass over volume. b) volume over mass. c) weight over volume. d) weight over mass. e) mass over weight.

SUGGESTED ANSWER: (a)

Wrong answers:
 e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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015 qmult 00110 1 3 3 easy math: g/cm**3 to kg/m**3
Extra keywords: physci

29. The MKS unit of density is the kg/m^3, but this unit is often inconveniently small for many ordinary terrestrial densities: these densities in kg/m^3 are inconveniently and unmemorably large. Thus, the CGS unit of density is often used for convenience:

g/cm^3 (grams per cubic centimeter). Many common terrestrial substances are of order a few g/cm^3. Now 1 g/cm^3 equals:

a) 1 kg/m^3. b) 0.001 kg/m^3. c) 1000 kg/m^3. d) 10^6 kg/m^3. e) 0.5 kg/m^3

SUGGESTED ANSWER: (c) The conversion calculation is

$$1\,\mathrm{g/cm^3} = 1\,\mathrm{g/cm^3}\left(\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}}\right)\left(\frac{10^2\,\mathrm{g}}{1\,\mathrm{m}}\right)^3 = 1000\,\mathrm{cm/m^3}\ .$$

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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015 qmult 00120 1 3 5 easy math: volume of gold
Extra keywords: physci

30. The density of gold (which as Marshal Saxe said is the father of armies) is 19.3 g/cm^3 under ordinary terrestrial conditions. What volume does 30.0 g of gold occupy?

a) infinite. b) 0 cm^3. c) 579 cm^3. d) 0.643 cm^3. e) 1.55 cm^3.

SUGGESTED ANSWER: (e) The calculation is

$$V = \frac{m}{\rho} = \frac{30}{19.3} = 1.55\,\mathrm{cm}^3\ .$$

It's not a lot.

I think it was Marshal Saxe who said that thing about father of armies. Still true too.

Fortran Code

```
          print*
          rho=19.3   ! density of gold, ordinary terrestrial
conditions.
          xm=30.
          vol=xm/rho
          print*,'rho/xm,rho*xm,vol'
          print*,rho/xm,rho*xm,vol
    *    0.6433333       579.0000       1.554404
```

Wrong answers:
a) I don't think so.
b) The answer sure seems awfully close to that.
c) You've multiplied the numbers.
d) You've done the division wrong way around.

Redaction: Jeffery, 2001jan01

---

015 qmult 00130 1 3 1 easy math: air mass in a room
Extra keywords: physci KB-132-9

31. The density of air at 20° and 1 atm pressure is $1.21\,\mathrm{kg/m^3}$. (For comparison, water density under the same conditions is $998\,\mathrm{kg/m^3}$ which is nearly the frequently quoted $1000\,\mathrm{kg/m^3}$.) There is a room 5 m long, 4 m wide, and 3 m high filled with air. What is the mass of air in the room?

a) 72.6 kg. b) 1.21 kg. c) 998 kg. d) 0 kg. e) −998 kg.

SUGGESTED ANSWER: (a) See HRW-323 for the densities.

Behold

$$m = \rho V = 1.21 \times 60 = 72.6\,\mathrm{kg} ,$$

which is about the mass of a typical male person.

Wrong answers:

e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

---

015 qmult 00200 1 4 4 easy deducto-memory: particle density
Extra keywords: physci

32. "Let's play *Jeopardy*! For $100, the answer is: The number of particles per unit volume."

What is ____________, Alex?

a) volume b) specific heat c) mass density d) particle density e) surface density

SUGGESTED ANSWER: (d)

Wrong answers:

c) This is what we customarily call density unqualified.

Redaction: Jeffery, 2001jan01

---

015 qmult 00300 1 1 2 easy memory: pressure defined
Extra keywords: physci

33. Pressure is:

a) force per unit mass. b) force per unit area. c) force by another name. d) density by another name. e) coercive influence.

SUGGESTED ANSWER: (b)

Wrong answers:

e) Not the best answer in this context.

Redaction: Jeffery, 2001jan01

---

015 qmult 00310 1 4 1 easy deducto-memory: Earth atmosphere pressure
Extra keywords: physci KB-129-3

34. The pressure of the Earth's atmosphere at any level is caused by:

    a) the weight of the overlying air mass. b) respiration by living things. c) evaporation of sea water. d) glaciers. e) squid.

    SUGGESTED ANSWER: (a)

    Wrong answers:
    e) As Lurch would say: "Aaaarh."

    Redaction: Jeffery, 2001jan01

---

015 qmult 00320 1 4 2 easy deducto-memory: pressure in straw
Extra keywords: physci KB-131-5

35. "Let's play *Jeopardy*! For $100, the answer is: This causes water to rise in a sucked on straw."

    What is ____________, Alex?

    a) higher than room air pressure inside the straw b) lower than room air pressure inside the straw c) the electric force d) the magnetic force e) the speed of light

    SUGGESTED ANSWER: (b) This is not really a case of Pascal's principle (HRW-328) since there must be a non-gravitational pressure gradient in the water.

    Wrong answers:
    a) Exactly wrong.

    Redaction: Jeffery, 2001jan01

---

015 qmult 00350 1 5 5 easy thinking: 2001: A Space Odyssey
Extra keywords: physci

36. In *2001: A Space Odyssey*, astronaut David Bowman finds himself trapped without his helmet in a space pod. The computer Hal has locked the direct pod-to-space-ship airlock. Bowman decides to "breathe vacuum"—to go sans helmet through space to an outside airlock—and then deal with Hal. Why doesn't Bowman explode due to his internal body pressure in the nearly zero pressure of space?

    a) He is too quick to explode.
    b) He holds his breath.
    c) Hal has not anticipated Bowman's maneuver or at least has no contingency plan.
    d) Sheer plot requirement.
    e) Most of the body's internal pressure is supplied by nearly incompressible (and therefore nearly non-expandible) fluid and solid: these parts won't explode under decompression. At least according to Kubrick and Arthur C. Clarke, the body can contain the air pressure that Bowman must have inside his lungs and other air vessels. It's only 15 psi (pounds per square inch) or so. But I always think his ears must have cracked like crazy.

    SUGGESTED ANSWER: (e) I hope Arthur C. Clarke and Stanley Kubrick were right about this. The aerospace majors at MTSU in 1999–2000 confirmed that this is at least roughly correct. Clarke is/was a diver as well as a space guru: so supposedly he knows all about it. But Bowman can't stay out too long because some nasty bubbles must form in his blood, or so I seem to recall. Apparently, the situation is more dangerous if you try to return to ordinary air pressure with your lungs full of high pressure air: see Haliday & Resnick, p. 526. Even about a 1 psi difference between between lungs and body is dangerous then—say when a diver surfaces without exhaling.

I think the resolution of the two cases is this. In the space case, the whole membrane (skin) of the body resists decompression from normal air pressure (about 15 psi) to nearly zero pressure, and thus the lung-body pressure difference stays tolerable. In the diver case, the body, blood and tissue, can relax from a slightly higher than air pressure state to an air pressure state quickly: the body is designed to hold itself at air pressure. But if the diver doesn't exhale an intolerable pressure difference between lungs and body develops. Maybe I'm talking through my hat.

This may be one of those many cases where physicists get it wrong because they insist on arguing from first principles.

Wrong answers:
a) Oh, c'mon.
b) True, but not an answer.
c) True, but not an answer.
d) The screenwriters could have got him out of that pod some other way.

Redaction: Jeffery, 2001jan01

---

038 qmult 01210 2 1 5 moderate memory: Einstein's equation in general
Extra keywords: physci

37. Einstein's equation $E = mc^2$:

a) applies only to rest mass.
b) applies only to electromagnetic radiation.
c) applies only to nuclear reactions.
d) is only valid in non-inertial frames.
e) is general. All forms of energy have inertial mass and a gravitational effect. Rest mass is itself a special form of energy like electromagnetic field, thermal, or kinetic energies.

SUGGESTED ANSWER: (e) La46 confirms this general formulation. Some elementary books like HRW avoid stating it clearly leaving the impression that only rest mass energy has inertial mass.

Wrong answers:
a) No although it is often used in rest mass calculations.
d) C'mon. Special relativity goes on endlessly about inertial frames

Redaction: Jeffery, 2001jan01

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015 qmult 00410 2 3 5 moderate math: pressure at depth 25 m

Extra keywords: physci

38. The expression for the pressure of an incompressible fluid with depth is

$$P = P_{\text{surface}} + \rho g y ,$$

where is P_{surface} is surface pressure, ρ is fluid density, $g = 9.8\text{N/kg}$ is the force per unit mass due to gravity near the Earth's surface, and y is depth measured downward from the surface. Air pressure and water density near the Earth's surface are to good approximation, respectively, 10^5 Pa (almost 1 atm) and $1000\,\text{kg/m}^3$. The pressure in atmospheres at 25 m in depth is about:

a) 3.5×10^5 atm. b) 10^5 atm. c) 1 atm. d) 2.5 atm. e) 3.5 atm.

SUGGESTED ANSWER: (e) Behold

$$P = P_{\text{surface}} + \rho g y \approx 10^5 + 10^3 \times 10 \times 25 = 3.5 \times 10^5\,\text{Pa} \approx 3.5\,\text{atm} .$$

Wrong answers:

a) You forgot to convert to atmospheres.

Redaction: Jeffery, 2001jan01

---

015 qmult 00510 1 3 3 easy math: buoyant force on 1 cubic meter object

Extra keywords: physci

39. What is the buoyant force on a completely submerged object of volume $1\,\text{m}^3$. **HINT:** The density of water is $1000\,\text{kg/m}^3$.

a) 1000 N. b) 10^{-3} N. c) 9800 N. d) 4900 N. e) 9.8 N.

SUGGESTED ANSWER: (c)

Wrong answers:

Redaction: Jeffery, 2001jan01

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015 qmult 00600 1 1 4 easy memory: Archimedes' principle

Extra keywords: physci

40. According to Archimedes' principle, the buoyant force is equal to the:

a) weight of the object.
b) weight of the object submerged beneath the surface of the fluid.
c) weight of the fluid inside the object.
d) weight of the fluid displaced by the object.
e) ratio of the density of the fluid to that of the object.

SUGGESTED ANSWER: (d)

Wrong answers:

e) A ratio has no units and cannot be a force.

Redaction: Jeffery, 2001jan01

---

015 qmult 00610 1 5 5 easy thinking: ship in mercury
Extra keywords: physci KB-129-5

41. Freshwater density is about $1.00\,\mathrm{g/cm^3}$, seawater density, $1.03\,\mathrm{g/cm^3}$, and mercury density, $14\,\mathrm{g/cm^3}$. A toy boat floats higher in:

a) all of them. b) none of them. c) seawater. d) freshwater. e) mercury.

SUGGESTED ANSWER: (e)

Wrong answers:
a) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

---

015 qmult 00620 2 5 1 moderate thinking: ice in full cup
Extra keywords: physci KB-131-11

42. The basic floating equation when only one fluid needs to be considered is

$$m = \rho_{\mathrm{fluid}} V_{\mathrm{dis}} ,$$

where m is the mass of the floating object, ρ_{fluid} is the density of the fluid, and V_{dis} is the amount of fluid displaced by the floating object. Say that you have a cup of water filled to the brim with water and an ice sample of volume V and mass m floating in the water. The volume displaced by the ice is V_{dis}. After the sample melts its mass is unchanged, of course, and its density is that of water. So after melting, sample has volume:

a) V_{dis} and the cup is filled to the brim still. b) V and the cup overflows. c) V and the cup is completely unfilled. d) zero and the cup is completely unfilled. e) zero and the cup overflows.

SUGGESTED ANSWER: (a)

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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019 qmult 00110 1 1 1 easy memory: temperature a ratio
Extra keywords: physci I've finally concluded intensive quantities are ratios

43. Absolute or Kelvin temperature in modern physical understanding is, in fact, a ratio of quantities: these quantities can be determined by addition. There are a variety of ratios that can be used to determine temperature. The simplest ratio to understand is set by the ideal gas law. Because temperature is a ratio, a sample of any size above the microscopic level can have

a) any temperature at all, except absolute zero (or so it seems) and infinite temperature. b) only negative temperatures. c) only temperatures proportional to its volume. d) only temperatures proportional to its mass. e) only infinite temperatures.

SUGGESTED ANSWER: (a)

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

---

019 qmult 00120 1 4 4 easy deducto-memory: absolute zero defined
Extra keywords: physci KB-129-9

44. "Let's play *Jeopardy*! For $100, the answer is: At this absolute temperature, the microscopic kinetic energy of a substance is as low as quantum mechanics allows."

What is ____________, Alex?

a) zero celsius b) the boiling point of water c) the freezing temperature of water d) absolute zero e) relative zero

SUGGESTED ANSWER: (d)

Wrong answers:
a) C'mon.

Redaction: Jeffery, 2001jan01

---

019 qmult 00210 1 1 1 easy memory: 3 temperature scales
Extra keywords: physci

45. The three common temperature scales are:

a) Fahrenheit, Celsius, and Kelvin. b) Fahrenheit, Celsius, and Newton. c) Fahrenheit, Vesuvius, and Kelvin. d) Fahrenheit, Celsius, and Calvin. e) Gesundheit, Vesuvius, and Calvin.

SUGGESTED ANSWER: (a)

Wrong answers:
e) Everyone one remembers *Calvin and Hobbes*: that great old comic strip.

Redaction: Jeffery, 2001jan01

---

019 qmult 00220 1 4 2 easy deducto-memory: kelvin/absolute temperature
Extra keywords: physci

46. "Let's play *Jeopardy*! For $100, the answer is: This temperature scale is considered to be the absolute temperature scale and its zero-point is absolute zero."

What is the ____________ scale, Alex?

a) Fahrenheit b) Kelvin c) Celsius d) thermometer e) Hobbes

SUGGESTED ANSWER: (b)

Wrong answers:
a) Contact force: no way.

Redaction: Jeffery, 2001jan01

---

019 qmult 00300 1 3 2 easy math: temperature conversion

Extra keywords: physci

47. What are 10° C, 20° C, and 30° C in Fahrenheit? **HINT:** I always multiply a Celsius temperature by 1.8 and add 32° to get Fahrenheit. Going the other way subtract 32° and divide by 1.8.

a) −273.15° F, 273.15° F, 373.15° F. b) 50° F, 68° F, 86° F. c) 40° F, 48° F, 56° F. d) 48° F, 68° F, 90° F. e) 0° F, 100° F, 212° F.

SUGGESTED ANSWER: (b) An easy math question. Super easy with the hint, but I think they really need that rule. Personally I think we all ought to use Kelvin all the time. It's real absolute temperature. Now it's awkward to say 288 K and the like for ordinary human uses. So as a convention for human activities make the leading 2 understood. Thus '88 K, etc where the apostrophe isn't spoken ust understood and written. But along with exponents of rational calendrical reform and Esperanto, I'll just have to live with perpetually dashed hopes. There is some deep-seated fixation on clunky systems in human nature.

Wrong answers:

e) Not likely.

Redaction: Jeffery, 2001jan01

---

019 qmult 00310 1 3 1 easy math: boiling ethyl alcohol

Extra keywords: physci KB-130-23

48. Ethyl alcohol boils at about 172°F (at 1 atmosphere pressure one assumes). The conversion formula from Fahrenheit to Celsius is

$$T_{\rm C} = \frac{T_{\rm F} - 32}{9/5} \ .$$

The boiling point on the Celsius scale is:

a) 77.8°C. b) 32°C. c) 0°C. d) 100°C. e) 172°C.

SUGGESTED ANSWER: (a) Behold:

$$T_{\rm C} = \frac{T_{\rm F} - 32}{9/5} = \frac{140}{9/5} = \frac{700}{9} \approx 77.8^\circ{\rm C} \ .$$

Fortran Code

```
          print*
          tf=172.
          tc=(tf-32)/1.8
          print*,'tc'
          print*,tc
*           77.77778
```

Wrong answers:

e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

---

019 qmult 00700 1 5 1 easy thinking: spontaneous heat flow 1
Extra keywords: physci

49. In the macroscopic world, heat spontaneously always flows from:

a) hot to cold. b) cold to hot. c) hot to hotter. d) hot to hottest. e) objects at 0 K.

SUGGESTED ANSWER: (a) We can make heat go the other way, but that takes work: it doesn't happen spontaneously.

Wrong answers:
b) Exactly wrong.

Redaction: Jeffery, 2001jan01

---

019 qmult 01100 1 1 1 easy memory: specific heat
Extra keywords: physci

50. Specific heat of a material is its:

a) rate of change of heat energy content (sometimes called internal energy) per unit mass per unit temperature.
b) rate of change of temperature per unit mass per unit heat energy content (sometimes called internal energy).
c) temperture in a pressure of 1 atmosphere.
d) temperture at its melting point.
e) heat energy content (usually called internal energy) at its melting point.

SUGGESTED ANSWER: (a)

Wrong answers:
b) Temperature per unit mass!!

Redaction: Jeffery, 2001jan01

---

019 qmult 01300 1 4 3 easy deducto-memory: 3 modes of heat transfer I
Extra keywords: physci

51. The three common heat transfer processes are:

a) conduction, invection, and radiative transfer. b) induction, convection, and radiative equilibrium. c) conduction, convection, and radiative transfer. d) conduction, invection, and radiative equilibrium. e) introduction, insurrection, and radiative hibernation.

SUGGESTED ANSWER: (c)

Wrong answers:
e) Oh, c'mon.

Redaction: Jeffery, 2001jan01

---

021 qmult 00100 1 4 5 easy deducto-memory: heat engine definition
Extra keywords: physci

52. "Let's play *Jeopardy*! For $100, the answer is: A device that operates in a cycle. It extracts heat from a hot reservoir and converts some fraction of this heat into macroscopic work and rejects the rest of the heat to a cold reservoir."

What is a ____________, Alex?

a) working fluid b) piston c) cylinder d) refrigerator e) heat engine

SUGGESTED ANSWER: (e)

Wrong answers:

a) A heat engine needs a working fluid.
d) Sort of the opposite of engine or an engine in reverse. Either way not the best answer.

Redaction: Jeffery, 2001jan01

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021 qmult 00110 1 4 2 easy deducto-memory: example heat engine 1

53. An example of a heat engine is a/an:

a) fire. b) internal combustion engine. c) electric motor. d) common household refrigerator. e) bicycle.

SUGGESTED ANSWER: (b)

Wrong answers:

e) It is an engine, but it converts mechanical energy to mechanical energy, or at another level human chemical energy to mechanical energy.

Redaction: Jeffery, 2001jan01

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021 qmult 00210 1 1 2 easy memory: refrigerator gives off more heat
Extra keywords: physci KB-130-20

54. The heat a refrigerator absorbs from its cold bath (or cold reservoir) is:

a) more than the heat is reject to its hot bath. b) less than the heat it rejects to its hot bath. c) zero. d) infinite. e) the same as it rejects to its hot bath.

SUGGESTED ANSWER: (b)

Wrong answers:

d) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

---

021 qmult 00430 1 1 4 easy memory: limit on engine efficiency
Extra keywords: physci KB-130-17

55. The **UPPER LIMIT** on the efficiency of a heat engine:

a) depends on the amount of friction present.
b) is 100 %.
c) is 10 % always.
d) depends on the intake and exhaust temperatures (or hot and cold bath temperatures) of the engine.
e) is zero.

SUGGESTED ANSWER: (d)

Wrong answers:
a) The upper limit does not depend on friction at all. Friction can certainly cause an engine to perform below this limit.
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

---

021 qmult 00440 1 3 2 easy math: maximum efficiency calculation 1
Extra keywords: physci KB-133-33

56. An engine operates between baths of 2000 K and 700 K. Its actual efficiency is 40 %. What is its ideal maximum efficiency?

a) 35 %. b) 65 %. c) 100 %. d) 40 %. e) 0 %.

SUGGESTED ANSWER: (b) Behold

$$\varepsilon_{\rm max} = 1 - \frac{T_{\rm cold}}{T_{\rm hot}} = 1 - \frac{700}{2000} = 1. - 0.35 = 0.65 = 65\,\% \ .$$

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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021 qmult 00450 2 3 1 moderate math: maximum efficiency calculation 2
Extra keywords: physci KB-133-31

57. An enterprising designer plans an engine which will operate between baths at 200°C and 50°C with an efficiency of 50 %. Will the engine reach its specified efficiency and what is the theoretical upper limit on the efficiency of an engine working between the two baths?

a) No and 32 %. b) No and 25 %. c) Yes and 68 %. d) Maybe and 68 %. e) Maybe and 75 %.

SUGGESTED ANSWER: (a) Behold

$$\varepsilon = 1 - \frac{T_{\rm cold}}{T_{\rm hot}} = 1 - \frac{323.15}{473.15} = 0.317 \approx 32\,\% \ .$$

Fortran Code

```
print*
```

```
          th=200.
          thk=th+273.15
          tc=50.
          tck=tc+273.15
          eff=1.-tck/thk
          effwrong=1.-tc/th
          print*,'tc/th,tck/thk,effwrong,eff'
          print*,tc/th,tck/thk,effwrong,eff
*     0.2500000       0.6829758       0.7500000       0.3170242
```

Wrong answers:

b) You have done a wrong maximum efficiency calculation.
c) You have done a wrong maximum efficiency calculation and you cannot be sure the engine will reach its specified efficiency.
d) You have done a wrong maximum efficiency calculation
e) You have used Celsius temperature rather than absolute temperature in the efficiency calculation.

Redaction: Jeffery, 2001jan01

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021 qmult 00520 1 4 3 easy deducto-memory: entropy law emergent principle
Extra keywords: physci

58. The 2nd law of thermodynamics (which the instructor at least calls the entropy law) say that the entropy of a closed, macroscopic system will increase until it reaches a maximum at which point the system will be in thermodynamic equilibrium and will be unchanging at the macroscopic level. Entropy in thermodynamics is a well-defined measure of microscopic disorder. The essential reason for the entropy law is that random processes will continue to make a closed system more disorderly until a maximum disorder has been reached. The entropy law is called the "arrow of time" because it dictates that certain sequences of events will never happen in reverse in practice: one never in practice sees the entropy of a closed, macroscopic system decrease noticeably even though that is energetically possible and must happen sometimes after immensely long time periods.

Physicists, in fact, believe that the entropy law would apply in worlds with different laws of motion than our own because it is based on the concept of randomizing processes which is more general than any particular law of motion. It is also reasonable to say that a generalized and perhaps not quantifiable version of the entropy law applies in realms other than that of microscopic particles. For example, a household will tend to some maximum of disorder by random dropping, kicking around, and dog processes unless someone (e.g., Mom) picks things up and re-orders them.

The entropy law can be regarded as an example of:

a) intelligent design. b) negligent design. c) an emergent principle. d) a submergent principle. e) an unprinciple.

SUGGESTED ANSWER: (c) The instructor has spoken ex cathedra on this issue and right or wrong will accept no other answers.

Wrong answers:

a) I suppose so.
b) In some cases probably.

Redaction: Jeffery, 2001jan01

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021 qmult 00620 1 5 1 easy thinking: entropy and spontaneous heat flow 2
Extra keywords: physci

59. In the macroscopic world (i.e., on scales much larger than atomic), heat energy flows spontaneously (i.e., without any outside cause) from **COLD** bodies to **HOT** bodies:

a) never.
b) whenever the temperature is greater than 300 K.
c) whenever the temperature is greater than 27°C.
d) always.
e) whenever the two bodies are both in the gas state.

SUGGESTED ANSWER: (a)

An easy thinking problem, but the longest-answer-is-right-rule fails. This result is one of common everyday experience. In classical thermodynamics, we understand it as consequence of the second law of thermodynamics: entropy always increases or stays constant for an closed system: entropy is state function of the thermal state like temperature and pressure, but it is not in everyday use: it's rather abstract and has no very simple direct way of being measured: in fact classically only entropy changes can be measured: in quantum mechanical statistical physics absolute entropy can be defined. In statistical mechanics, we understand entropy to a measure of the disorder of the microstate of matter. An closed system tends toward maximum disorder: macroscopically we see this as thermodynamic equilibrium. The 2nd law is the fundamental physical reason for the direction of time. There is one thermodynamic direction for an closed system: toward maximum entropy: once there it is in a timeless state. The universe is not in thermodynamic equilibrium as one easily see and so there is secular (i.e., non-periodic) change overall.

Our physiological changes in relatively closed parts of our bodies occur in accordance with increasing entropy, but human beings are open systems and so we don't proceed to thermodynamic equilibrium so long as we live. We arn't completely steady-state though. We age and acquire more memory. One could imagine a biological system that always repaired itself exactly and had to no increase in memory (which in some sense requires exact repair since memory is sort of the scar tissue of life). Such a being would be internally timeless even though it was not a closed system and the surroundings experienced secular change. It's probably a good thing that we are mortal or at least metamorphosical.

At a microscopic level, a simple example shows why heat flows from hot to cold. Say two atoms collide: a fast atom (a hot atom) and a slow atom (a cold atom). Depending on conditions, collision could result in one of the atoms becoming colder than cold atom was before the collision and one becoming hotter than the hot atom was before the collision. But this is an improbable result. The most probable outcome is for the atoms to become closer in kinetic energy (in thermal energy content). Thus at the microscopic level heat usually flows from hot to cold. Averaging over a large number of micro-events, one gets the average behavior: heat always flows from hot to cold. The macroscopic world is this average of the microscopic world.

Wrong answers:

d) Exactly wrong.

Redaction: Jeffery, 2001jan01

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021 qmult 00710 1 1 1 easy memory: Santa Claus the fate of the universe
Extra keywords: physci

60. Santa Claus musing correctly on the physics of the universe says to himself "if the universe is a closed system and the 2nd law of thermodyamics is universally valid, then the universe as a whole will ultimately approach a state of:

a) timeless, lifeless thermodynamic equilibrium."
b) thermodynamic disequilibrium."
c) varying, life-sustaining thermodynamic equilibrium."
d) elves in charge."
e) peace on Earth and goodwill to humankind."

SUGGESTED ANSWER: (a)

Wrong answers:

b) Wrong! That's where it is now—and a good thing for us too.
c) No thermodynamic equilibrium is unvarying and, as far as we know, lifeless
d) As likely as not.
e) Ah, well . . . .

Redaction: Jeffery, 2001jan01

Equation Sheet for Physical Sciences Courses

The equations are mnemonic. Students are expected to understand how to interpret and use them. Usually, non-vector forms have been presented: i.e., forms suitable for one-dimensional calculations.

1 Geometry

$$C_{\text{cir}} = 2\pi r \qquad A_{\text{cir}} = \pi r^2 \qquad A_{\text{sph}} = 4\pi r^2 \qquad V_{\text{sph}} = \frac{4}{3}\pi r^3$$

$$c^2 = a^2 + b^2 \quad \text{Pyth.Thm.}$$

2 Kinematics

$$d = vt \qquad v_{\text{ave}} = \frac{d_{\text{final}} - d_{\text{initial}}}{t} \qquad v = at \qquad a_{\text{ave}} = \frac{v_{\text{final}} - v_{\text{initial}}}{t}$$

$$\text{Amount} = \text{Constant Rate} \times \text{time} \qquad \text{time} = \frac{\text{Amount}}{\text{Constant Rate}} \qquad a_{\text{centripetal}} = \frac{v^2}{r}$$

3 Dynamics

$$F_{\text{net}} = ma \qquad 1\,\text{N} \approx 0.225\,\text{lb} \qquad F_{\text{centripetal}} = \frac{mv^2}{r} \qquad p = mv$$

4 Gravity

$$F = \frac{Gm_1m_2}{r^2} \qquad F_g = mg \qquad v_{\text{circular}} = \sqrt{\frac{GM}{r}} \qquad v_{\text{escape}} = \sqrt{\frac{2GM}{r}}$$

$$G = 6.6742 \times 10^{-11}\,\text{MKS units (circa 2002)}$$

$$g = 9.80\,\text{m/s}^2 \quad (\text{latitude range} \sim 9.78030\text{–}9.8322\,\text{m/s}^2\ \text{[CAC-72]})$$

5 Energy and Work

$$W = Fd \qquad 1\,\text{J} = 1\,\text{N}\cdot\text{m} \qquad P = \frac{W}{t} \qquad KE = \frac{1}{2}mv^2 \qquad PE_{\text{gravity}} = mgy$$

$$c = 2.99792458 \times 10^8\,\text{m/s} \approx 2.998 \times 10^8\,\text{m/s} \approx 3 \times 10^8\,\text{m/s}$$

$$E = mc^2 \qquad E_{\text{rest}} = m_{\text{rest}}c^2 \qquad \Delta t_{\text{proper}} = \Delta t\sqrt{1 - (v/c)^2}$$

6 Thermodynamics and Buoyancy

$$T_{\text{absolute}} = T_{\text{Celsius}} + 273.15 \qquad T_{\text{Fahrenheit}} = \frac{9}{5}T_{\text{Celsius}} + 32 \qquad \Delta Q = C_{\text{specific}}m\Delta T$$

$$\rho = \frac{m}{V} \qquad n = \frac{N}{V} \qquad p = \frac{F}{A} \qquad p = p_{\text{surface}} + \rho g y \qquad F_{\text{buoyant}} = m_{\text{dis}} g = \rho_{\text{fluid}} V_{\text{dis}} g$$

$$\rho_{\text{fluid}} V_{\text{dis}} = m_{\text{floating}} \qquad PV = NkT \qquad k = 1.3806505 \times 10^{-23}\,\text{J/K}$$

$$\varepsilon = \frac{W_{\text{done}}}{Q_{\text{absorbed}}} \qquad \varepsilon_{\text{upperlimit}} = 1 - \frac{T_{\text{cold}}}{T_{\text{hot}}}$$

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7 Electricity and Magnetism

$$F = \frac{kQ_1Q_2}{r_{12}} \qquad k = 8.99 \times 10^9\,\text{N}\,\text{m}^2/\text{C}^2 \qquad e = 1.60217733 \times 10^{-19}\,\text{C}$$

$$1 \text{ ampere (A)} = 1\,\frac{\text{coulomb (C)}}{\text{second (s)}}$$

$$1 \text{ volt (V)} = 1\,\frac{\text{joule (J)}}{\text{coulomb (C)}} \qquad 1 \text{ ohm } (\Omega) = 1\,\frac{\text{volt (V)}}{\text{ampere (A)}}$$

$$\sum \Delta V_{\text{rise}} = \sum \Delta V_{\text{drop}} \qquad V = IR \qquad P = VI$$

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8 Waves

$$v = f\lambda \qquad p = 1/f \qquad n\frac{\lambda_n}{2} = L \qquad \lambda_n = \frac{2L}{n} \qquad f_n = \frac{v}{2L}n$$

$$v_{\text{sound } 20^\circ\text{C } 1\,\text{atm}} = 343\,\text{m/s} \qquad v_{\text{sound } 0^\circ\text{C } 1\,\text{atm}} = 331\,\text{m/s}$$

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9 Nuclear Physics

$$^{A}_{Z}X \qquad n(t) = \frac{N_0}{2^{t/t_{1/2}}} \qquad 1\,\text{amu} = 931.494043\,\text{MeV}$$

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10 Quantum Mechanics

$$h = 6.6260693 \times 10^{-34}\,\text{J}\,\text{s} \qquad m_e = 9.1093826 \times 10^{-31}\,\text{kg} \qquad E = hf \qquad \lambda = \frac{h}{p} = \frac{h}{mv}$$

$$KE_{\text{photoelectron}} = hf - w \qquad H\Psi = \frac{ih}{2\pi}\frac{\partial \Psi}{\partial t}$$

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11 Astronomy

$$v = Hd \qquad H = 71^{+4}_{-3}\,\frac{\text{km/s}}{\text{Mpc}} \quad \text{(circa 2004)}$$